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SOILS, PROPERTIES AND LIMITATIONS IN RELATION TO LAND USE IN GEOAGIU

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Abstract. *This study provides an integrated analysis of the pedological characteristics of soils in the Geoagiu area (Hunedoara County, Romania), with a focus on soil types, physico-chemical properties, limiting factors, and their land use implications. The study area is characterized by a high diversity of pedogenetic conditions, resulting from the interaction of major geomorphological units and the variability of lithological substrate, climate, and hydrological regime. The results highlight the predominance of Cambisols (approximately 79%), followed by Luvisols and other soil types occurring in smaller proportions. Cambisols exhibit favorable properties, including high humus content and well-developed structure, being associated with moderate to high fertility. In contrast, Luvisols are characterized by clay accumulation in subsurface horizons, leading to hydrophysical constraints, while Dystric Cambisols are affected by high acidity and low nutrient status. The main limiting factors identified include soil acidity, high skeletal content, clay-rich texture, erosion, and the influence of altitude on climatic conditions. The analysis of pedological relationships reveals direct links between parent material, soil properties, and vegetation types, confirming the key role of lithological substrate and climatic conditions in soil formation and evolution. The findings emphasize the importance of site-specific land use according to soil properties and limitations, as well as the need for sustainable management practices aimed at maintaining soil fertility and preventing soil degradation in the studied area.*

Keywords: *soils; pedological properties; fertility; limiting factors; land use*

INTRODUCTION

Soil is one of the most important natural resources, playing an essential role in supporting agricultural production, ecosystems and global biogeochemical cycles (BRADY & WEIL, 2016; LAL, 2004). The formation and evolution of soils are the result of the complex interaction between pedogenetic factors, namely the bedrock, climate, relief, organisms and time (BUOL ET AL., 2011; MIRCOV ET AL., 2025).

At the international level, numerous studies highlight the role of soil in regulating the carbon cycle and mitigating climate change, through its ability to store organic carbon (LAL, 2004; SIX ET AL., 2002). Also, the physical and chemical properties of the soil, such as texture, structure, pH, and humus content, are decisive for fertility and productivity (HILLEL, 2004; WARDLE, 2002; MIHUȚ ET AL., 2024).

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In Europe, the diversity of climatic and geological conditions leads to a wide variety of soils, of which cambisols and luvisols are the most widespread in hilly and mountainous areas (FAO, 2015; IUSS WORKING GROUP WRB, 2015). These soils are characterized by specific properties, but also by limitations related to acidity, texture or drainage.

At the national level, soil studies highlight the fact that the soils in Romania are strongly influenced by natural conditions, especially by the lithological and relief substrate (FLOREA & MUNTEANU, 2012; MUNTEANU ET AL., 2014; MIHUȚ & NIȚĂ, 2014). In mountainous and hilly areas, such as Hunedoara County, cambisols and luvisols predominate, characterized by moderate fertility and limitations determined by acidity, clay or skeleton content (CANARACHE, 1990; SPÂRCHEZ & TĂUT, 2013).

In the western part of Romania, the interaction between geological, climatic and hydrological factors determines a high variability of soils, which directly influences their use and the productivity of forest and agricultural ecosystems. In this context, the analysis of soil properties and their limitations is essential for sustainable land use.

MATERIAL AND METHODS

1. Location and geographical classification of the studied area

The studied area is located in the Geoagiu area, located in the central-western part of Romania, in Hunedoara County, within the hydrographic basin of the Mureș River. Geographically, this region is at the interference of major relief units, namely the Apuseni Mountains, belonging to the Western Carpathians, the Transylvanian Depression and the Șureanu Massif, part of the Southern Carpathians. This positioning gives the area a high complexity from a geomorphological and geological point of view, which is directly reflected in the variability of pedogenetic factors and, implicitly, in the diversity of soil types.

The interaction between these geographical units determines a marked heterogeneity of soil formation conditions, through the combined influence of relief, lithological substrate and climatic regime. Thus, the area is characterized by a high diversity of pedogenetic processes, which lead to the formation of a complex and spatially differentiated soil cover.

The exact location of the studied area is illustrated in Figure 1, where its position is highlighted both within Romania and at the level of Hunedoara County, providing visual support for understanding the geographical and pedological context of the study.

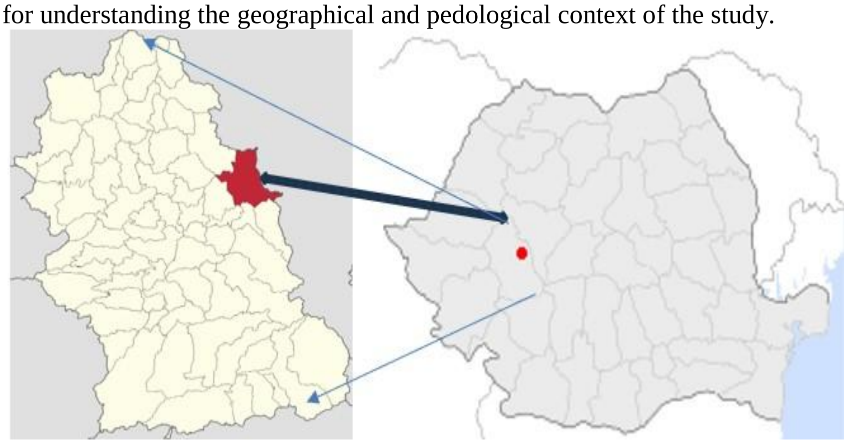

Figure 1. Location of the study area (Geoagiu, Hunedoara County, Romania).

This geographical positioning is of major importance in the interpretation of pedogenetic conditions, as it reflects the location within the hydrographic basin of the Mureș River, the influence of the temperate-continental climate and the contact between distinct geomorphological units, respectively hilly and mountainous areas. At the same time, this localization explains the variability of the lithological substrate and, implicitly, the diversity of the pedogenetic processes that led to the formation of the soil cover.

The geographical position of the studied area determines a series of essential soil characteristics, being located at the interface of major geomorphological units, where continental and mountain climatic influences are simultaneously manifested. This combination of factors leads to a high diversity of soil types, a marked variability of soil properties and a differentiated distribution of forest vegetation. Directly, this positioning explains the predominance of cambisols in hilly areas, the appearance of luvisols on clay substrates in conditions of sufficient precipitation and the presence of skeletal soils (regosols), in areas with fragmented relief and hard lithological substrate.

From a geomorphological point of view, the area is characterized by a hilly-submontane relief, which directly influences the erosion and accumulation processes, as well as the distribution of soils on slopes and interfluviums.

The hydrological conditions are marked by the proximity of the Mureș River and by the existence of a dense hydrographic network, with a density of approximately 0.7–0.8 km/km², which determines a predominantly percolative water regime and significantly influences soil moisture. The variable flows of the watercourses, between 2 and 9 m³/s, contribute to the diversification of water conditions and to the emergence of specific pedogenetic processes, such as gleisation or podzolire.

The climatic conditions of the area fall into the temperate-continental type, with topoclimatic variations determined by altitude and relief fragmentation. The average annual temperature is about 10.1°C, and the average annual amount of precipitation is about 578 mm.

The vegetation period lasts for 160–190 days, ensuring favorable conditions for biological and pedogenetic processes.

The distribution of precipitation is uneven, with a maximum in June–July and a minimum in the winter period, which favors the eluviation and alluvial processes and leads to the differentiation of Bt horizons in the soil profile.

The geological and lithological substrate is characterized by high variability, including rocks such as basalts, marls, sandstones, limestones, micaschists, and gneisses. This lithological diversity directly controls soil reaction, nutrient content, texture, and structure, thus determining a wide range of soil types with distinct properties.

Soils developed on basalts tend to be more fertile, while those formed on micaschists and gneisses show more acidic reactions, and those developed on limestone have a pronounced basic character.

From a pedological point of view, cambisols predominate in the area, occupying about 79% of the surface, followed by luvisols, with about 15%, and other types of soil, which amount to about 6%. This distribution reflects the combined influence of lithological substrate, climatic conditions, relief and vegetation on soil formation and evolution processes.

The research methodology included soil mapping, with a density of approximately one profile per 50 ha, accompanied by detailed morphological description of the profiles and sampling for laboratory analysis.

The analyzed parameters were correlated with environmental factors, in order to highlight the relationships between soil, rock, climate and vegetation.

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The data processing was carried out using descriptive and comparative statistical methods, the average values, variation intervals and general trends of the analyzed indicators being calculated. Correlations between soil and environmental factors were also made to highlight how natural conditions control soil formation and properties.

The average values of climatic and soil parameters, such as temperature, rainfall and distribution of soil types, indicate a high variability of environmental conditions, which explains the high soil diversity of the studied area.

RESULTS AND DISCUSSIONS

1. Soil types and their distribution

The analysis of soil distribution highlights the dominance of cambisols (79%), followed by luvisols and other soil types in smaller proportions

Cambisols are considered moderately evolved soils, with favorable properties for forest vegetation, being frequently found in temperate forest ecosystems (BRADY & WEIL, 2016; BUOL ET AL., 2011). In Romania, their predominance in mountainous and submontane areas was also highlighted by FLOREA AND MUNTEANU (2012), who emphasize their important role in forestry.

Luvisols, although less extensive, are of pedological importance through clay illuvial processes, which lead to textural differentiation on the profile and hydrophysical limitations (HILLEL, 2004). These characteristics negatively influence permeability and can generate temporary stagnation of water.

Consistent with international studies, soil distribution reflects the balance between pedogenesis processes and environmental conditions (LAL AND STEWART, 2010).

Table 1.

Distribution of soil types

Soil class	Tip dominant	Area (%)
Cambisols	Eutric cambisol	79
Luvisols	Luvisol	15
Protisols	Lithosol	1
Cernisols	Rendzina	1
Spodisols	Prepodzol	4

The analysis of the distribution of soils in the Geoagiu area highlights a clear predominance of cambisols, which occupy about 79% of the surface, followed by luvisols, with about 15%, while the other types of soil, such as spodisols, protisols and chernisols, have a low share. This distribution reflects a moderate pedogenetic stage, characteristic of hilly and submontane areas, where the processes of alteration, eluviation and accumulation are manifested in a relatively stable balance.

The graphical representation of the percentage distribution of soils (Figure 2) highlights this structure, emphasizing the dominance of cambisols and the secondary role of other soil types. This pedological configuration indicates a high forest productive potential, due to the favorable properties of cambisols, which are well structured and show moderate to good fertility. At the same time, the low proportion of poorly developed soils suggests relatively high ecological stability.

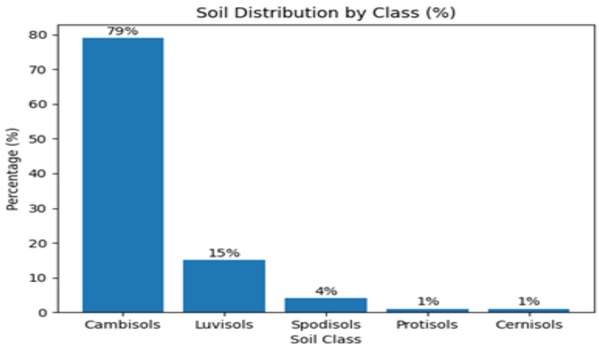

Figure 2. Soil Class Distribution (%)

The comparative analysis of soil classes (Figure 2), confirms the significant difference between cambisols and other soil types. This differentiation is determined by the combined influence of the lithological substrate and climatic conditions, which favor the processes of alteration and claying.

From the point of view of land use, cambisols are favorable for intensive forest use, while luvisols have limitations generated by the accumulation of clay in the lower horizons, and the other soil types have a restricted use.

The pedological properties of the soils in the studied area show significant variations, with direct implications on fertility.

The data presented in Table 2 highlight that eutrichabbosols are characterised by a moderate acidic pH, high humus content and medium texture, which gives them good fertility. In contrast, distrymbosols exhibit a more acidic reaction and lower levels of available nutrients, which limits biological activity and productivity.

Luvisols are distinguished by their clayey texture and the presence of the Bt horizon, which causes reduced permeability and poor drainage.

Table 2.

Soil characteristics of the analyzed soils

Soil	**pH**	**Humus**	**Fertility**	**Texture**
Eutric cambisol	moderately acidic	high	good	medium-textured
Distric camboiol	acidic	medium	moderate	light-textured
Luvosol	acidic	low	low	clayey
Rendzina	alkaline	medium	good	skeletal

The interpretation of these characteristics highlights the fact that acidic soils are affected by chemical limitations, in particular by reducing the availability of nutrients, while clay soils have physical limitations, associated with compaction and water stagnation.

Skeletal soils, such as rendzines, are characterized by volumetric limitations, generated by the high content of coarse fragments, which reduces the retention capacity of water and nutrients.

The analysis of limiting factors, summarized in Table 3 and illustrated in Figure 3, highlights the fact that acidity and erosion are the main pedological constraints, having the greatest impact on soil fertility. Acidity directly affects nutrient availability and microbiological activity, while erosion causes the loss of the humus-rich surface layer. The clayey texture and high skeletal content also contribute to limiting productivity by reducing permeability and usable soil volume.

Table 3.

Main limiting factors of the studied soils

Limiting factors	**The effect of these factors**
Acidity	reduces nutrient availability
Schelet	volum edafic redus
Clay	poor drainage
Altitudine	low temperatures
Erosion	I will lose from humus

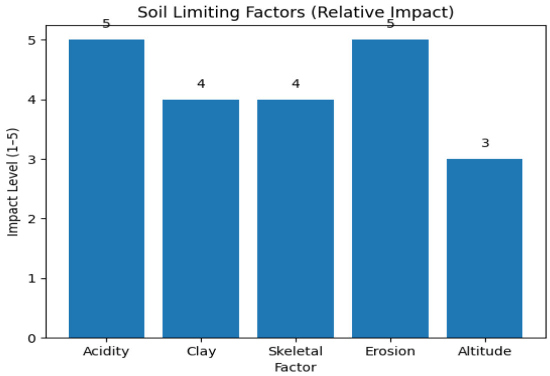

Figure 3. Soil Limiting Factors

Pedological correlations highlight a direct relationship between the lithological substrate, soil properties and vegetation type (Table 4).

Table 4.

Correlations between soils, rock and vegetation

Rock	**Soil**	**Vegetation**	**Usage**
Basalt	Eutric cambisol	fag	Forestry
Tracing	Rendzină	Chalcophilous vegetation	pastures
Gnais	Districambosol	Safflower	forestry
Clay	Luvosol	gorun	Limited

Data in Table 4. shows that basic rocks favor the formation of fertile soils, associated with beech forests, while acidic rocks lead to the development of poorly fertile soils, specific to spruces.

The clay deposits are associated with luvisols and mixed vegetation, confirming the decisive role of the mother rock in the formation of soils.

The influence of climate on pedogenetic processes is manifested by the control of temperature and precipitation on eluvieration and alluvial processes, which determines the spatial distribution of soils and vegetation. The interaction between these factors leads to the formation of a complex pedological system, in which the properties of the soil reflect the environmental conditions.

Soil use is closely correlated with their properties and limitations. Cambisols are predominantly used in forestry, due to their fertility and stability, while luvisols require careful management to compensate for physical and chemical limitations. Skeletal soils are mainly used as pastures, having a reduced capacity to support other uses.

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The analysis of the relationship between pH and fertility highlights a positive correlation, in the sense that higher pH values are associated with better fertility.

Acidic soils have important chemical limitations, including reduced phosphorus availability and the occurrence of aluminum toxicity, which affects plant development (Figure 4).

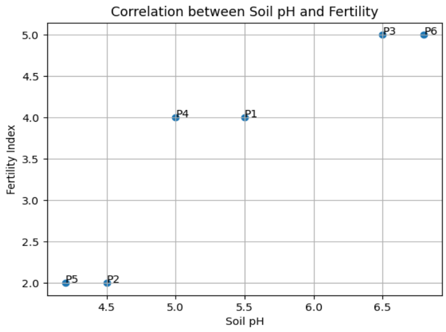

Figure 4. Correlations between soil pH and soil fertility

The results of the statistical analysis confirm the existence of correlations between pH and fertility, between altitude and soil type, as well as between climate and vegetation. These relationships highlight the complex and interdependent character of the soil system in the studied area.

CONCLUSIONS

The study highlights the fact that the Geoagiu area has a high pedological diversity, determined by the variability of the lithological substrate and climatic conditions. Cambisols are the dominant type of soil, being characterized by favorable properties and high productive potential, which makes them suitable for intensive forestry use.

Luvisols and districhbosols are limited by unfavorable physical and chemical properties, especially by clay accumulation and acid reaction, which reduce fertility and agricultural use capacity.

The main limiting factors identified are acidity, erosion, clay texture and skeleton content, which directly influence productivity and land use.

The results confirm the existence of a close relationship between the lithological substrate, climatic conditions and soil properties, which determines the spatial distribution of vegetation and land use. The pedological system in the studied area is characterized by a relative balance between pedogenetic processes, being controlled by multiple and interdependent factors.

In order to improve fertility and sustainable land use, differentiated management measures are recommended. Acidic soils require amendment with calcareous materials, to correct the reaction and increase the availability of nutrients. In the case of soils affected by erosion, anti-erosion works and maintenance of the vegetation carpet are necessary to prevent the loss of the fertile layer.

Luvisols require specific interventions to improve drainage and reduce compaction, while skeletal soils must be used properly, mainly as pastures. It is also necessary to adapt forest species and management systems to specific pedoclimatic conditions, as well as to continuously monitor soil properties.

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