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GEOLOGICAL, CLIMATIC AND HYDROLOGICAL CONTROLS ON SOILS AND FORESTS IN GEOAGIU

Casiana MIHUȚ, Anișoara DUMA COPCEA, Adalbert OKROS, Ramona ȘTEF, Marius Silviu STROIA, Nelu Daniel POPA, Sorin Tiberiu BUNGESCU, Vlad Dragoslav MIRCOV, Attila BLENEȘI-DIMA, Daniela SCEDEI

[1]University of Life Sciences "King Mihai I" from Timișoara, România
Corresponding author: anisoaradumacopcea@usvt.ro

ABSTRACT: This study provides an integrated analysis of the geological, climatic, and hydrological conditions in the Geoagiu area (Hunedoara County, Romania), highlighting their role in soil formation and the distribution of forest vegetation. The study area is characterized by a complex geographical setting, located at the intersection of the Western Carpathians, the Transylvanian Depression, and the Southern Carpathians, which results in a high diversity of natural conditions.

From a geological perspective, the lithological substrate is highly diverse, including volcanic, sedimentary, and metamorphic rocks, as well as alluvial deposits, leading to significant variations in soil properties. The climate is temperate continental, with an average annual temperature of approximately 10.1°C and average annual precipitation of about 578 mm (Deva meteorological station), characterized by pronounced seasonal variability. The hydrological regime is influenced by the Mureș River basin and a dense hydrographic network, with a nival–pluvial and percolative regime.

The analysis indicates that Cambisols are the dominant soil type (approximately 79%), followed by Luvisols and other soil types in smaller proportions. Pedogenetic relationships reveal a direct correlation between parent material, climatic conditions, and vegetation types: basic substrates favor the development of fertile soils and productive forest stands, whereas acidic rocks lead to less fertile soils and lower vegetation productivity.

The results emphasize the importance of the interaction between natural factors in shaping forest ecosystems and highlight the need for sustainable management practices to preserve soil resources and maintain ecological stability in the studied area.

• Introduction

The soil represents a complex natural system, the result of the interaction between fundamental pedogenetic factors such as the bedrock, climate, relief, hydrological regime and vegetation (BRADY & WEIL, 2016; MIRCOV ET AL., 2025). These factors control both soil formation and evolution processes and vegetation distribution, especially in forest ecosystems, where soil–climate–rock relationships are particularly close (BUOL ET AL., 2011).

Globally, studies show that geological and lithological variability determine the differentiation of the physicochemical properties of soils, directly influencing the fertility and support capacity of vegetation (FAO, 2015; WRB, 2015). Basic rocks (basalts, marls) generate more fertile soils, while acidic or metamorphic rocks lead to poorer and more acidic soils (BRADY & WEIL, 2016)

.Climate is a major determinant of pedogenetic processes, influencing the rate of rock alteration, organic matter decomposition, and soil water regime (LAL & STEWART, 2010; MHUT & NIȚĂ, 2014). Temperatures and precipitation control the distribution of forest and grassland vegetation, as well as the dynamics of biochemical processes in the soil (BONAN, 2008; MIRCV ET AL., 2025). In continental temperate zones, characterized by accentuated seasonal variations, these processes are strongly influenced by thermal amplitudes and rainfall (PEEL ET AL., 2007).

The hydrological regime plays an essential role in the transport of substances, in the processes of eluviation and alluvial accumulation and in the development of soil horizons (HILLEL, 2004). Water availability also determines vegetation types and the productivity of forest ecosystems (WARDLE, 2002).

• Material and method

The study was carried out in the Geoagiu area, located in the central-western part of Romania, in Hunedoara County, in a complex geographical context characterized by the interference between major geomorphological units. This positioning determines a high variability of natural conditions, which provides an appropriate framework for the integrated analysis of the relationships between pedogenetic factors.

The natural setting of the studied area is dominated by a hilly and mountainous relief, with variable altitudes, which influences the distribution of temperature, precipitation and water regime. The geological substrate is characterized by a high lithological diversity, including volcanic, sedimentary, metamorphic rocks and alluvial deposits, each of which specifically contributes to the formation of soils.

The data used in the study were obtained through a combination of field methods and laboratory analyses, complemented by the processing of climatic and hydrological data. The investigation of the soils was carried out through pedological mapping, which involved the identification and description of the soil profiles in the field, as well as the collection of samples for further analysis. The profiles were described from a morphological point of view, following the characteristics of the horizons, texture, structure and other relevant elements for the interpretation of pedogenetic processes.

The laboratory analyses aimed to determine the main physicochemical indicators of the soil, such as soil reaction, organic matter content and nutrients, using standardised methods specific to pedology. These analyzes allowed the evaluation of soil fertility and its correlation with natural factors.

The climatic data were processed based on the records from the Deva meteorological station, the average monthly and annual temperatures and precipitation being analyzed. These data were used to characterize the climate regime and to assess its influence on pedogenetic processes and vegetation.

• Results and discussions

Geological structure and pedogenetic implications

The Geoagiu area is distinguished by a high lithological complexity, determined by the overlapping of several geological formations belonging to different tectonic units. This diversity is directly reflected in the variability of soils and, implicitly, in the distribution of forest vegetation. To highlight these relationships, the main types of rocks and their pedogenetic role are summarized in Table 1.

Table 1.

Main geological formations and pedogenetic significance

Nr.crt.	Rock type	Lithological examples	Predominant location	Pedogenetic role
1	Volcanic rocks	Basalts	Almașul Mic – Poiana	Formation of fertile soils
2	Sedimentary rocks	Marls, sandstones, clays	Hilly areas	Variable fertility soils
3	Carbonate rocks	Limestones	Balșa – Ardeu	Formation of basic soils (Rendzinas)
4	Alluvial deposits	Sands, gravels	Mureș terraces	Young and productive soils
5	Metamorphic rocks	Schists, gneiss	Southern sector	Acid and low fertility soils

Altitudinal structure and control over ecosystems

The relief is an essential factor in the spatial organization of soils and vegetation, through its influence on temperature, precipitation and water circulation. The altitudinal distribution of the forest area is shown in Table 2.

Altitudinal distribution of forest area

Altitude range (m)	Area (ha)	Percentage (%)
100–200	53.02	<1
201–400	606.31	5
401–600	3324.13	25
601–800	1866.79	14
801–1000	2826.59	21
1001–1200	2599.30	20
1201–1400	1548.46	12
1401–1600	398.01	3
Total	**13222.61**	**100**

Climate regime analysis

The climatic regime of the Geoagiu area is characterized by a marked seasonal variability, specific to the temperate-continental climate. The evolution of the monthly average temperatures is illustrated in Figure 1.

Figure 2 highlights the uneven distribution of precipitation throughout the year, characterized by a maximum in the warm season and a minimum in the cold period. This distribution is specific to the temperate-continental climate and has direct implications on pedogenetic processes. High rainfall in the summer months favours eluviation and flooding processes, helping to differentiate soil horizons, while periods of low rainfall can limit the availability of water in the soil. Thus, the rainfall regime influences both the evolution of soils and the productivity of forest vegetation.

The integrated climate graph (Figure 3) provides a picture of the interaction between temperature and precipitation, highlighting the climatic regime specific to the Geoagiu area. There is a clear seasonal correlation between the increase in temperatures and the intensification of rainfall, with maximum values in the summer period, especially in June and July. This overlap of thermal and rainfall maximums is an essential factor for the development of forest vegetation, as it simultaneously provides thermal energy and water resources during the vegetation period.

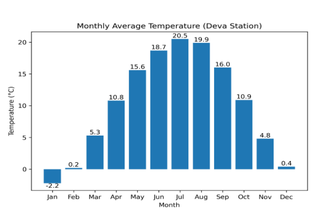

Figure 1. Monthly Average Temperature (Deva Station)

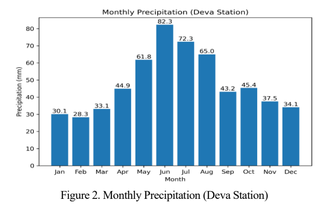

Figure 2. Monthly Precipitation (Deva Station)

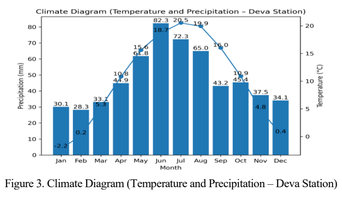

Figure 3. Climate Diagram (Temperature and Precipitation – Deva Station)

The relationship between rock, soil and vegetation

The interdependence between the lithological substrate, soil and vegetation is summarized in Table 3, which highlights the fundamental pedogenetic relationships in the studied area.

Table 3.

Rock–soil–vegetation relationships

Rock type	Soil type	Dominant vegetation
Basalts, marls	Eutric Cambisols	Beech, mixed forests
Limestones	Rendzinas	Calcicolous vegetation
Sandstones, clays	Luvisols	Beech, oak
Schists, gneiss	Distric Cambisols	Spruce, beech
Alluvial deposits	Alluvial soils	Grassland, mixed vegetation

• Conclusions

The integrated analysis of geological, climatic, and hydrological conditions in the Geoagiu area demonstrates that soil formation and forest vegetation are controlled by the interaction of multiple natural factors. Lithological diversity, including volcanic, sedimentary, and metamorphic rocks, plays a decisive role in differentiating soil properties, influencing pH, fertility, and vegetation support capacity.

The results indicate that basic substrates favor the development of more fertile soils, particularly eutric cambisols, which sustain productive forest ecosystems, whereas acidic rocks lead to less fertile soils with reduced nutrient availability. These findings confirm the primary influence of the parent material on soil characteristics and ecosystem distribution.

Climatic conditions regulate biological activity and organic matter dynamics, while the hydrological regime, dominated by percolation processes, contributes to the redistribution of substances and the differentiation of soil horizons. These combined effects explain the predominance of cambisols and the moderate stage of soil development in the study area.

The strong interdependence between rock, soil, climate, and vegetation highlights the existence of a relatively balanced ecological system, in which vegetation reflects the underlying pedoclimatic conditions.

In the context of climate change, these relationships require continuous monitoring and adaptive management strategies to maintain ecosystem resilience and soil functionality.