Characteristics of Rendzinas in the Ludogorie Region

Vladimir Ilinkin*, Simeon Bogdanov**, Antonia Goleva**

*Institute of Biodiversity and Ecosystem Research at the Bulgarian Academy of Sciences, Sofia, Bulgaria
**University of Forestry – Sofia, Bulgaria
Corresponding Author: Vladimir Ilinkin, e-mail: ilinkin@mail.bg

Abstract

The paper presents results from an investigation on soils located in the Ludogorie region. Rendzinas (Rendzic Leptosols, FAO, 2006) have been studied. They are situated in the Lower forest vegetation zone (0–600 m a.s.l.) of the Moesian forest vegetation area. Soil samples have been taken from seven soil profiles. The study covers an area of 3000 m^2. The factors of soil formation have been characterized. Soil physical and chemical properties have been investigated. The results have been processed by a statistical programme. The arithmetic means (M) and standard deviations (±SD) have been calculated.

The studied soils are characterized by favourable physical properties, e.g. water-resistant crumb and granular structure, porosity and bulk density Their low supply of plant available water is due to the high permeability of the parent material.

The tendency of calcium to form complex insoluble compounds with humic substances (Knežević & Košanin, 2010) is a prerequisite for reduced accessibility of N and humus, although are not in low contents.

The calcium content is naturally higher given the specific features of the parent material. Antagonism between the ions of Ca and K, Ca and Mg (Jorova, 1995) is a prerequisite for reduced accessibility of K and Mg, although, soil texture with a predominant presence of silt and clay, allows for higher nutrient content than that of other primitive soils.

Key words: Rendzic Leptosols, factors of soil formation, physical properties, chemical properties.

Introduction

The sustainable development and productivity of forest plantations depend to a great extent on the silvicultural properties of the soil. Soil characteristics determine the existence and normal functioning of ecosystems. Based on studies on soil composition and properties forestry activities can be planned properly in such a way, as to ensure the effective and environmentally friendly use of forest resources.

Rendzinas were described for the first time in Bulgaria by N. Pushkarov as "Humus-Calcareous soils" (Pushkarov, 1938). Later Koynov (1968) coined the term "Humus-Calcareous soils" (Koynov, 1968), which is still used today as a synonym of Rendzinas. They

are defined as soils formed on carbonate-rich rocks under different climatic conditions (Duchaufour, 1965). Rendzinas are mostly loose soils with good permeability, regarding their shallow profile with lower water capacity they have usually less water supply (Paganová, 2007).

According to the basic classification of soils in Bulgaria (Penkov et al., 1992), Rendzinas soils belong to the Leptosol soil group. The soils belonging to this soil group are intrazonal and occur mainly in mountainous, semi-mountainous and hilly sloping terrains, where enviromental conditions favour physical weathering and intense erosion, as well as specific soil-forming rocks. The soils are characterized by a thin, dark or light humus horizon located on a solid rock or on loose weathering materials (Donov, 1993; FitzPatrick, 1986; Frisby, 1961). Rendzinas occupy about 2.7% of the country's territory (Gyurov & Artinova, 2001), and their distribution is related to the presence of limestone. In Northern Bulgaria Rendzinas are found among Chernozems (occupying 21% of the country's territory (Teoharov et al., 2015; Hristov, 2009) and Gray forest soils (occupying 16% of the country's territory (Donov, 1993), around Varna, Shumen, Pleven, Montana, Lovech, etc., and in Southern Bulgaria among Vertisols and Cinnamonic Forest soils, around Burgas, Aytos, Chirpan, etc. In the mountains they occur among Brown forest soils (Fig. 1). The main soil-forming processes that have resulted in the formation of Rendzinas are the formation and accumulation of humus in a Chernozem type of soil formation (Donov, 1993; Malinova, 2010). Humus-accumulating layer is formed out not only by means of herbaceous vegetation, but also exists in forests with no sod (Kyrylchuk, 2017; Kutrovskiy & Val'Kov, 2006). Thus it should be assumed that humus-accumulating layer of Rendzinas is formed out: a) in herbaceous cenoses, b) in forest cenoses with herbaceous cover, c) in forest cenoses with no sod (although participation of sod in the initial humus formation is impossible to deny). The biogeocenotic diversity of vegetation in different bioclimatic zones varies from boreal to tropical with various humidity conditions (Kutrovskiy & Val'Kov, 2006).
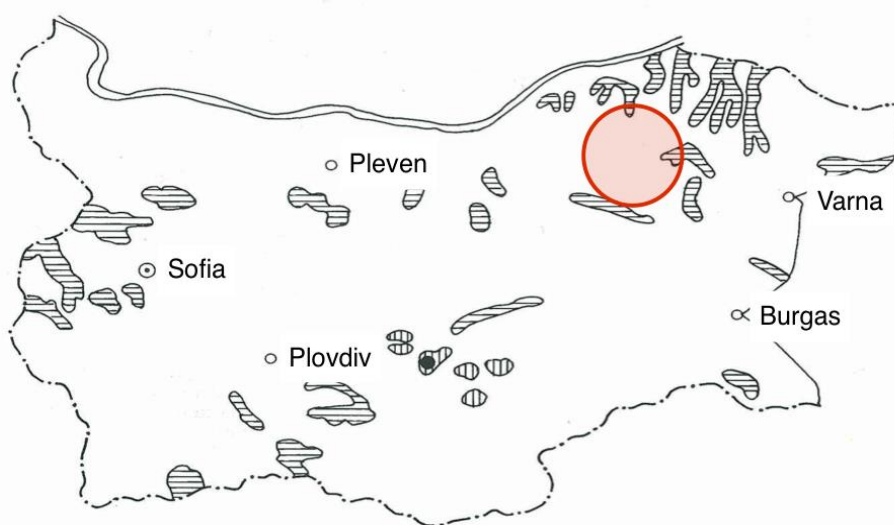

Fig. 1. *Distribution of Rendzinas in Bulgaria and subject of the study (Koynov et al., 1998)*

The purpose of this study is to analyse key properties of Rendzinas, as well as the factors of soils formation in the Ludogorie region, in order to facilitate the planning and implementation of activities related to the restoration and increase of productivity of forest ecosystems in the region.

Material and Methods

The subject of our study are Humus-Carbonate soils (Rendzic Leptosols, FAO, 2006) occurring in Ludogorie region. They are found in the Lower forest vegetation zone (0 - 600 m above sea level) of the Moesian forest vegetation area (Zahariev, 1979), Ludogorie subregion (Fig. 1). The studied area covers 3000 m^2 (Fig.1). The seven soil pits were made at representative plots whose slope did not exceed 10%. The samples were taken at a depth of ~ 0 - 25 cm and 25 - 40 cm

The following methods were used to analyze the soil samples:

- bulk density (Q), according to the Kachinsky method (Donov et al., 1974);
- relative density (D) by the pycnometer method (Donov et al., 1974);
- total porosity (P) through calculation from bulk density and relative dencity (Donov et al., 1974);
- water resistance (percentage of water resistant aggregates), by Adrianov's method (Donov et al., 1974);
- plant available water capacity (PAWC), by a laboratory method, through calculation from field capacity and permanent wilting point (Donov et al., 1974);
- soil texture, using the sedimentation method (ISO 11277);
- humus content by the Turin method (Donov et al., 1974);
- Total N content, by a modified version of the classic Kjeldahl method;
- C/N ratio – calculation method;
- content of mobile forms of Mg, Ca, Na and K, by using atomic absorption spectroscopy (extraction of 0.1 mol/l solution of $BaCl_2$);
- soil acidity (pH in water extraction and $CaCl_2$ extraction) – measured potentiometrical;
- $CaCO_3$ by Shaibler`s method (NEN-ISO 10693).
- The results have been statistically processed using the STATISTICA 6 software. The arithmetic means (M) and standard deviations (±SD) have been calculated.

Results and Discussion

The soil forming factors are important conditions that influence the nature, direction and speed of soil forming processes (Donov, 1993). The key factors are climate, biota, topography, and parent material.

The climate has a direct influence on the temperature and moisture of the soil, and an indirect one on the biota. In terms of climate, the subject of study falls within the European continental climate zone, the temperate continental climate subzone, middle climatic region of the Danubian hilly plain (Forest management plan, 2013). The average annual temperature of the studied area varies between 10.6 and 11.7°C, the average annual rainfall from 493 - 616 mm, with a peak rainfall in June and a minimum in February or March. The vegetation

period lasts approximately 6 ½ months. The winter is cold and relatively dry with an average temperature in January of -2.1°C. There is small amount of rain in the range of 85 - 120 mm, and the number of days with solid snow cover average 41-63. The summer is relatively warm with an average temperature in July ~ 20.2°C. There is significantly more rainfall in the summer than in the winter, and the amount of rain ranges between 160 - 230 mm. This is due to the hilly *terrain* typical of this region and is favourable for the formation and development of internal mass convective clouds and the frequent occurrence of showers (Forest management plan, 2013).

When the amount of rainfall increases and the vegetation cover decreases, the leaching process, which involves the release of base cations, including carbonates, intensifies. This may gradually convert Rendzinas into the respective zonal soil type. Higher plants are the most significant *biotic* factors that shape the formation of soils, the microclimate, supply the soil with organic matter and influence its composition and properties (Donov, 1979).
The plants involved in the process that formed the studied soils are mainly species that grow in alkaline soils. Leter Cupać et al. (2007) in the forest sites, predominating were deciduous species, mostly oak (*Quersuc cerris* L. and *Quercus pubescens* Willd.) with occasional hawthorn (*Crataegus spp*.), hornbeam (*Carpinus spp*.) and ash (*Fraxinus spp*.) trees.
The zonal oak forests are dominated or co-dominated by Turkey oak (*Quercus cerris* L.), Hungarian oak (*Quercus frainetto* Ten.)*,* field maple (*Acer campestre* L.), flowering ash (*Fraxinus ornu*s L.), field elm (*Ulmus minor* Mill.)*,* silver linden (*Tilia tomentosa* Moench)*,* spindle tree (*Euonymus verrucosus* Scop.), etc. The shrub communities consist of common hawthorn (*Crataegus monogyna* Jacq), blackthorn (*Prunus spinose* L.)*,* smoke tree (*Cotinus coggygria* Scop), common lilac (*Syringa vulgaris* L.)*,* etc. The grass vegetation also consists mainly of calciphilous species such as zigzag clover (*Trifolium medium* L.)*,* wood false brome (*Brachypodium sylvaticum* (Huds.) Beauv)*,* pheasant's eye (*Adonis vernalis* L.)*,* bloody geranium (*Geranium sanguineum* L.)*,* purple gromwell (*Lithospermum purpurocaeruleum* L.)*,* bellflower (*Campanula bononiensis* L.)*,* etc.

The parent material is the main soil-forming factor in the formation of Rendzinas. their formation and distribution are mainly related to the chemical and mineral composition of the carbonate parent rock (Donov, 1993), as well as to its physical, chemical and mineral properties. The soil texture, structure and soil reaction depend largely on the parent material (Donov, 1993; Malinova, 2010). The main parent materials of the studied soils are limestone, as well as marlstone. Limestone is made mainly of calcite ($CaCO_3$), which is either in a finely crystalline state or a solid mass. Marlstone is made of different proportions of clay and calcareous materials, and hence has properties inherent to clay and limestone, i.e. it becomes pliable when wet and effervescent when treated with hydrochloric acid (Petrova & Bogdanov, 2012). The soils profiles of the studied Rendzinas is characterized by a total thickness of ~ 40 cm. The morphological structure can be expressed by the designation Ak – Dk or Ak - Ck. The humus-accumulative A-horizon containing a carbonate skeleton (expressed by means of the suffix *k*) is dark to black and is enclosed by a hard carbonate rock (Dk) or weathered materials (Ck). The thickness of this horizon is relatively big, and equals the total thickness of the soil. Limestone and marlstone rocks hearly take up the entire profile. The structure is "crumb" and "granular". Based on their rocks (hard and soft), at sub-type

level the studied soils fall between the common Rendzinas (Haplic) and Pararendzinas (Hypercalcic).

The data of the physical parameters change slightly with the soil profile depth (Table 1). This coincides with the lack of texture differentiation typical of Rendzinas (Patterson, 1982.). The bulk density (Q) is 1.16 g/cm^3 at 0-25 cm depth and 1.33 g/cm^3 at 25-40 cm depth. The relative density (D) is 2.57 and 2.61 respectively. The total porosity (P) is relatively high, 54% in the upper (0-25 cm) and 49% in the lower (25-40 cm) layer. These results indicate favourable physical and mechanical properties which result in lack of stickiness and crust formation and low resistance to cultivation. The aggregate composition of the studied soils is characterized by high water resistance, and their percentage is close to the maximum 99.5% at 0-25 cm depth and 99.0% at 25-40 cm depth (Table 1). This is consistent with the high content of humus and calcium, which play a major role in the formation of a water resistant structure.

Table 1. *Physical properties of the soils*

Depth, cm	n	Q g/cm^3		D		P %		Water resistant aggregates %		PAWC mm	
		M	±SD	M	±SD	M	±SD	M	±SD	M	±SD
0-25	7	1.16	±0.01	2.57	±0.01	54	±1	99.5	±0.5	49	±4
25-40	7	1.33	±0.02	2.61	±0.01	49	±1	99.0	±0.5		

The plant available water capacity (PAWC), which represents the amount of soil moisture absorbed by plants, is relatively low, 49 mm (Table 1). This can be explained by the relatively small total thickness of the soil, and mainly by the specific features of the parent material. The high permeability of limestone ensures rapid water drainage.

Geological parent material was found to have a predominant influence on the texture of Rendzinas soils (Cupać et al., 2006b). Rendzinas are soils in which the the texture varies from loamy to clay-loamy (Venturella, 2004) and clay textured (Tümsavaş & Aksoy, 2008). The soil texture data are presented in Table 2. The fractions of sand (63 μm – 2 mm), silt (2 μm – 63 μm) and clay (< 2 μm) were determined. According to the texture, the soil falls into the "Silty clay loam" category at 0-25 cm depth and into the "Silt loam" category at 25-40 cm depth (FitzPatrick, 1986). In both layers the silt fraction has the highest percentage, 52.14% and 62.46%, respectively. In the upper (0-25 cm) layer the sand fraction is 11.29%, and the clay, 36.61%. In the lower (25-40 cm) layer the percentage of the sand fraction almost doubles, 18.61%. This increase is mainly at the expense of clay. Its percentage decreases almost two-fold – 18.93%. The sand fraction is assumed to be completely chemically inactive, as it is composed mainly of primary materials, particularly quartz (Petrova & Bogdanov, 2012). The chemical activity of the soil is determined by the silt fraction, if it prevails, and mostly by the relative share of the clay fraction. The results from the study on the chemical composition of the soils, presented in Tables 3 and 4, confirm this statement. The significant silt and clay contents also suggest that there is comparatively better

availability of nutrients than in other Primitive soils in the Leptosols group, to which the studied Rendzinas also belong.

Table 2. *Soil texture*

Depth, cm	n	Sand %		Silt %		Clay %		Texture class
		M	±SD	M	±SD	M	±SD	
0-25	7	11.29	±0.42	52.14	±0.71	36.61	±0.53	silty clay loam
25-40	7	18.61	±5.28	62.46	±5.60	18.93	±0.35	silt loam

Humus content is mostly high (Harbar & Poznyak, 2016), and rarely medium, in the A horizon (Cupać, 2006a). Rendzinas are predominantly rich and very rich in total nitrogen in the uppermost layer of horizon A, and medium or well supplied in the layer below it. Enrichment of humus in nitrogen, shown as the C:N ratio, is mostly medium, and rarely low (Cupać, 2006a).

The black colour in the humus-accumulative horizon is due to the significant humus content. The mineralization of organic matter is hindered by the large amounts of $CaCO_3$ and low moisture, which are due to the characteristics of the parent rock. Hence, humic substances accumulate and the humus-accumulative horizon thus formed is relatively thick for primitive soils (Bogdanov et al., 2015).

Table 3 presents the results from the study on some chemical characteristics of the soil. The humus content is relatively high, 6.75% in the upper (0-25 cm) layer and 2.88% in the lower (25-40 cm) layer, which is typical of the common Rendzinas. The amount of total nitrogen in both layers isn't high, i.e. 0.163% and 0.057%, respectively.

The ratio of the amount of total carbon to the amount of total nitrogen (C/N) in the soil indicates the degree of decomposition of organic matter. The values of this indicator are hither in the upper (22.54) layer then the the lower layer and (25.67). In our study C/N ratio in is a higher than the C/N ratio in other study of Rendzinas (Radmanović et. al., 2015b) This is indicative of the rate of mineralization of organic matter, which largely depends on the microbiological activity of the studied soils under the complex influence of the soil-forming factors. The parent rock plays a major role as its specific features determine the prevalence of humus forming processes and humus accumulation over the mineralization processes in the soil formation of chernozems.

Later Radmanović et al. (2015a) Rendzinas indicate the dominant influence of soil chemical characteristics (carbonate content and pH value). The soil reaction is consistent with the characteristics of the parent materials and is neutral to slightly alkaline (Table 3). The higher pH in the lower (25-40 cm) layer may be explained by the proximity to the parent material and the increased presence of carbonates in in the parent rock.

Table 3. *Chemical composition and soil properties*

Depth, cm	n	Humus %		Total N %		C/N		pH /H_2O/		pH /$CaCl_2$/		CaCO3 %	
		M	±SD	M	±SD	M	±SD	M	±SD	M	±SD	M	±SD
0-25	7	6.75	±0.41	0.163	±0.001	22.54	±0.72	6.63	±0.37	6.21	±0.54	8.65	0.06
25-40	7	2.88	±0.08	0.057	±0.016	25.67	±2.08	7.66	±0.05	7.17	±0.05	23.18	0.09

The pH values in the $CaCl_2$ extract are 6.21 in the upper (0-25 cm) layer and 7.17 in the lower (25-40 cm) layer (Table 3). This indicates that the exchangeable acidity, which is an indicator for degradation processes, is small (Ignatova & Damyanova, 2010).

In general, the studied soils are poor in mobile nutrients such as K (a crucial element of plant nutrition and is the second largest nutrient assimilated by plants after nitrogen (Marschner, 2012)), Na and Mg (excluding Ca) (Table 4). These elements have important implications both for the soil properties and for plant development, and their content in the different soil layers depend on the combination and influence of the soil-forming factors.

Table 4. *Content of some of the major mobile nutrients in the soil*

Depth, cm	n	Mg mg/100g		Ca mg/100g		Na mg/100g		K mg/100g	
		M	±SD	M	±SD	M	±SD	M	±SD
0-25	7	13.1	±2.1	280.1	±13.9	3.1	±0.5	5.7	±1.9
25-40	7	7.2	±0.5	297.2	±22.3	2.1	±0.6	2.7	±0.2

The results obtained show a higher content of Ca, which is related to its presence in the parent material. The tendency of calcium to form complex insoluble compounds with humic substances and water-resistant aggregates of crumb and granular structure (Knežević & Košanin, 2010). On the other hand, the presence of calcium carbonate reduces solubility and the availability of nutrients.

Conclusions

The complex influence of soil formation factors determines a chernozem type of soil formation with a higher intensity of humus formation and humus accumulation processes. This is a result of the dominant role of the parent material and its properties as a soil-forming factor.

The studied Rendzinas soils are suitable for wide variety of crops (FitzPatrick, 1986). They provide favourable conditions for the development of forest tree species such as Turkey oak (*Quercus cerris* L.), Hungarian oak (*Quercus frainetto* Ten.)*,* field maple (*Acer campestre* L.), flowering ash (*Fraxinus ornus* L.)*,* field elm (*Ulmus minor* Mill.)*,* silver linden (*Tilia tomentosa* Moench)*,* black pine (*Pinus nigra* Arn.), etc.

The studied soils are characterized by favourable physical properties, e.g. water-resistant crumb and granular structure, porosity and bulk density Their low supply of plant available water is due to the high permeability of the parent material.

The humus and total nitrogen are not in low contents, but the tendency of calcium to form complex insoluble compounds with humic substances (Knežević & Košanin, 2010) is a prerequisite for reduced accessibility of N and humus.

The calcium content is naturally higher given the specific features of the parent material. Antagonism between the ions of Ca and K, Ca and Mg (Jorova, 1995) is a prerequisite for reduced accessibility of K and Mg, although, soil texture, with a predominant presence of silt and clay, allows for higher nutrient content than that of other primitive soils.

Activities for the restoration and productivity increase of the ecosystems in the region should be planned in accordance with soil characteristics and particularly with its specific chemical composition. The high Ca content limits nutrient assimilation. This requires that action be taken to improve the nutrient availability in these soils to meet the requirements of plant species.

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