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PROPERTIES OF LIMESTONE MOLLIC LEPTOSOLS IN THE "MRKONJIĆKO" FOREST MANAGEMENT AREA

OSOBINE KREČNJAČKIH CRNICA MRKONJIĆKOG ŠUMSKO-PRIVREDNOG PODRUČJA

Ilija Čigoja[1]*, Marijana Kapović Solomun[1], Saša Eremija[2], Goran Česljar[2]

[1] University of Banja Luka, Faculty of Forestry, Bulevar vojvode Petra Bojovića 1A, 78000 Banja Luka
[2] Institute of Forestry, Kneza Višeslava 3, 11030 Belgrade
*e-mail: ilija.cigoja@sf.unibl.org

Abstract

The paper describes the physical and chemical properties of limestone Mollic leptosols, as one of the most common soil types in the forest management area "Mrkonjićko". Research was carried out in two forest management units (FMU): "Dubička gora" in compartment 60 and "Ovčara", in compartments 18 and 64. The „Mrkonjićko“ forest management area is located in the southwestern part of the Republic of Srpska, under the influence of a mountain climate. The research aims to study the physical and chemical properties of limestone Mollic leptosols in different environmental conditions and define their ecological production potential. Three soil profiles were opened, and soil samples were taken from genetic horizons. The laboratory analysis included investigations of the soil's standard physical and chemical properties. The total depth of the analyzed profiles ranges from 16 to 20 cm. The textural class is loam, while the soil reaction in H_2O is neutral. Analyzed soils are poor in available phosphorus, and the supply of K_2O ranges from medium to good. The physical and chemical properties of the investigated soil profiles are generally favorable for the growth and development of vegetation. However, the depth of this soil type is a limiting factor in its productivity.

Key words: ecological production potential, Mollic leptosol, productivity

1. INTRODUCTION / UVOD

Soil formation is conditioned by the mutual relationship of several pedogenetic factors: parent material, relief, vegetation, climatic factors, and a human segment as an indispensable one. The process of development and basic properties of soil on limestone depend primarily on the chemical composition of the parent material, i.e. ratio of $CaCO_3$ and insoluble residue, which accumulates after the dissolution and leaching of calcium carbonate, as a source of the mineral part of the soil (Knežević & Košanin, 2006; Kapović Solomun et al., 2018). Knowledge of the ecological production potential of the soil, by researching its physical and chemical properties, as well as knowledge of the vegetation-floristic condition should be the starting point for long-term planning of forest management with optimal use of the productive possibilities of habitats and preservation of the ecological value of forests (Tepavac,

2021). Better planning of forestry development in the Republic of Srpska requires deep research of the land cover in terms of spatial variability, type-land combination, and especially their qualitative-quantitative parameters (Eremija, 2015; Eremija et al., 2017). Knežević & Košanin (2004) state that relief and the nature of limestone are the main factors differentiating land cover. Surface rockiness and stoniness of limestone terrains is an indispensable feature of the areas where Mollic leptosol appears, as well as the mosaic of limestone soils in a small area. Soil formation on limestone terrains is characterized by a long pedogenesis. Thus, Mollic leptosols can be considered old soils. Knežević & Košanin (2009) also state that compact limestones, whose main feature is the low insoluble residue content (usually lower than 1%), condition a long and specific genesis. Limestones dissolve very slowly, so the content of insoluble residue from which soils are formed is limited, Mollic leptosols have a long pedogenesis and as such must be protected from the erosion to which they are susceptible, especially if one takes into account the period required for soil re-formation on limestones (Kapović et al., 2013). It can be stated that this soil type is practically non-renewable (Kapović & Knežević, 2010). The karst nature of the terrain and the pedoclimatic dryness of the Mollic leptosol can be significantly compensated if there is a sufficient amount and proper distribution of precipitation in the areas where it occurs. Eremija (2007) points out the strong influence of the parent material on the genesis and properties of the soil in the area of the "Dubička gora" FMU, manifested through the mineralogical-chemical composition and type of rock decomposition. FMA "Mrkonjićko" is characterized by optimal conditions for developing natural, highly productive, and vital forest ecosystems (Kapović & Eremija, 2009a). The same authors state that habitat conditions, orographic factors, a large amount of precipitation, and especially the edaphic component, created due to the variability of the bedrock and soil types, contribute to this. The researched soils are located in different vegetation conditions. Kapović & Eremija (2009b) state that soil is the ecological factor that conditions the development of forest vegetation, but also limits its productivity. Morphogenetic studies of the soil, along with laboratory analyses of physical and chemical properties, serve as a basis for evaluating the ecological production potential. Classification recognizes Mollic leptosol as the humus-accumulative class, belonging to the order of automorphic soils (Škorić et al., 1985). This research aims to analyze the physical and chemical properties of limestone Mollic leptosols developed in different environmental conditions, the definition of their productivity, and the assessment of the production potential in the mentioned area.

2. MATERIAL AND METHODS / MATERIJAL I METOD RADA

2.1 Research area / Područje istraživanja

The research area is located in the southwestern part of the Republika Srpska, i.e. the northwestern part of Bosnia and Herzegovina. According to the ecological-vegetational zones of BiH (Stefanović et al., 1983), the „Mrkonjićko“ FMA belongs to the area of the internal Dinarides, the western Bosnian limestone-dolomite area. The research object includes the Ključ-Petrovac and Koprivnica regions (part of the Lisina mountain). The research was carried out in two forest management units (FMU): "Dubička gora" in compartment 60 and "Ovčara" in compartments 18 and 64 of the „Mrkonjićko“ forest management area, which are mostly covered by limestone-dolomite rocks. According to the horizontal distribution of forest vegetation, Stefanović (1977) stated that the research area belongs to the western Balkan region of sessile oak and European hornbeam (*Quercо-Carpinetum*), including areas with moder-

ate-continental climate characteristics. Pure stands of beech forests (*Fagetum montanum illiricum*) are most represented in the area of the FMU "Dubička gora". The mixed forests of beech, fir, and spruce (*Piceo-Abieti-Fagetum*) are dominantly represented in the area of the FMU "Ovčara". The average annual air temperature (1999-2021) in the growing season for the area of the Municipality of Mrkonjić Grad is 15.9°C. The amount of precipitation in the growing season is 52% of the yearly precipitation, which is 1.119 mm.

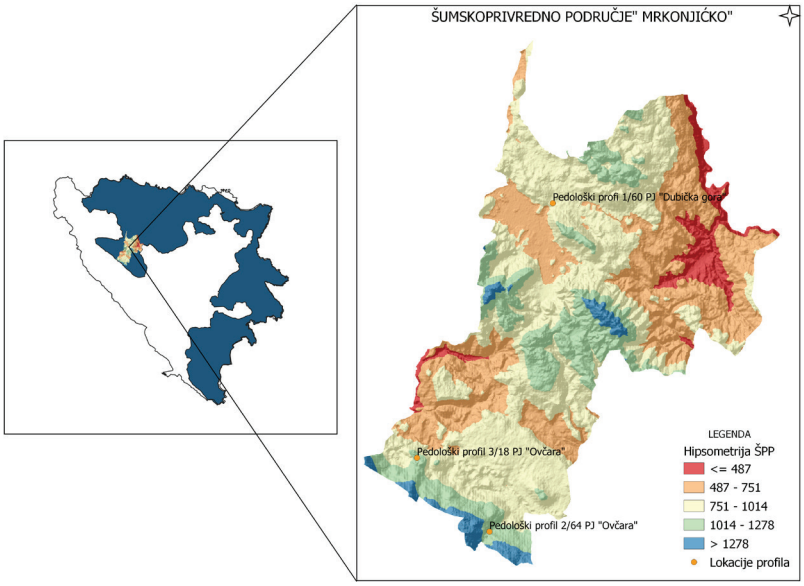

Figure 1. Research area / **Slika 1**. Područje istraživanja

2.2 Methods of research / Metode istraživanja

Soil research was carried out in two phases, i.e. field and laboratory. The first phase was related to terrain research, which included: the recognition of the field characteristics, the selection of a place for the opening soil profiles, the study and description of the external and internal soil morphology, and soil sampling for laboratory studies. A total of three pedological profiles were opened, one profile in each compartment (Table 1). The criteria for selecting the location of the soil profile opening were: vegetation type, exposure, and slope. The classification of the analyzed soil profiles was carried out according to the Soil Classification of Yugoslavia (Škorić et al., 1985) and the WRB classification (FAO, 1998).

The second phase of the research included laboratory analyses that were performed in the soil laboratory of the Institute of Forestry in Belgrade according to the following methodology:

- Granulometric composition of the soil by the sedimentation method using Na-pyrophosphate as a peptizing agent (Racz, 1971). Based on the granulometric composition of the soil, the textural class was determined using the ISSS triangle.
- Active acidity potentiometrically in H_2O (Cencelj, 1966; Živković, 1966), and soil classification according to the reaction of the soil solution was determined by the US Natural Resources Conservation Service (Knežević & Košanin, 2007).

Table 1. Basic data from the sampling site of soil profiles / **Tabela 1**. Osnovni podaci sa mjesta uzorkovanja profila

Number of profiles / Broj profila	**Forest management unit** / Privredna jedinica	**Compartment** / Odjeljenje	**Elevation** / Nadmorska visina (m)	**Exposure** / Ekspozicija	**Slope** / Nagib (°)	**Rockiness** / Stjenovitost (%)	**Coordinates** / Koordinate
1/60	Dubička gora	60	794	SZ / NW	2	60	X= 6 419 908 Y= 4 926 700
2/64	Ovčara	64	1123	SI / NE	5	40	X= 6 414 400 Y= 4 898 203
3/18	Ovčara	18	1054	S/N	1	60	X= 6 408 100 Y= 4 904 607

- Hydrolytic acidity (Y1) and the sum of adsorbed base cations (S) by the Kappenn method (Živković, 1966).
- The content of total humus was determined by wet combustion in a mixture of potassium hydromate ($K_2Cr_2O_7$) and sulfuric acid (H_2SO_4) using the Tjurin method (Škorić & Racz, 1966), and the soil classification according to the humus content was determined using the Gračanin method (Škorić & Sertić, 1966).
- Total nitrogen content according to the Kjeldah method (Džamić et al., 1966), and soil classification according to the total nitrogen content according to Woohltmann (Knežević & Košanin, 2007).
- Carbon and nitrogen ratio - calculation.
- The content of forms of phosphorus and potassium easily available to plants by the AL-method according to Egner-Richm, with the use of the colorimetric technique for determining phosphorus and the flame photometric technique for determining potassium, and the provision of the soil with these elements according to the limit values for the AL-method (Džamić et al. 1996).

3. RESULTS AND DISCUSSION / REZULTATI I DISKUSIJA

Tables 2 and 3 show the results of the physical and chemical properties of the researched soil profiles. These data will be used to describe in detail the characteristics of limestone-dolomite Mollic leptosol in this part of the paper, which will be described by comparing the obtained results.

The soil profile in the area of the FMU "Dubička gora" was opened at an elevation of 794 m, on the northwestern exposure. The elevation of the soil profiles opened in the FMU "Ovčara" ranges from 1054 m in compartment 18 to 1123 m in compartment 64, with northern and northeastern exposure.. The parent material is limestone. Other data on the soil profiles are shown in Table 1.

The depth of the soil profiles ranges from 16 to 20 cm (Figure 3). The shallowest one was opened in compartment 18 (FMU "Ovčara"), while the profiles in the other two compartments are of identical depth. Ćirić et al. (1971) state that the Mollic leptosols formed in Bosnia under pure beech stands have a depth of up to 30 cm, which implies that the analyzed Mollic leptosols are somewhat shallower. The depth of the soil is a significant factor in its produc-

Table 2. Physical properties of soil / **Tabela 2**. Fizičke osobine zemljišta

Number of profiles / Broj profila	**Horizon** / Horizont	**Depth** / Dubina (cm)	**Granulometric composition of soil** / Granulometrijski sastav zemljišta (%)						**Soil texture class** / Teksturna klasa
			Coarse Sand / Krupan pijesak	**Fine Sand** / Sitni pijesak	**Silt** / Prah	**Clay** / Glina	**Total sand** / Ukupan pijesak	**Total Clay** / Ukupna glina	
1/60	A	7-20	2.69	38.81	33.70	24.80	41.50	58.50	Loam / Ilovača
2/64	A	3-20	1.91	49.29	30.60	18.20	51.20	48.80	Loam / Ilovača
3/18	A	5-16	2.26	43.54	31.20	23.00	45.80	54.20	Loam / Ilovača

Table 3. Chemical properties of soil / **Tabela 3**. Hemijske osobine zemljišta

Number of profiles / Broj profila	**Horizon** / Horizont	**Depth** / Dubina (cm)	pH	**Adsorption complex** / Adsorptivni kompleks					**Total** / Ukupni		C/N	**Available** / Pristupačni	
				T	S	T-S	V	Y1	humus	N		P_2O_5	K_2O
			H_2O	cmol/kg			%	cm^3	%			mg/100g	
1/60	A	7-20	7.16	62.43	57.81	4.61	92.61	7.09	34.51	0.48	41.65	3.26	21.40
2/64	A	3-20	7.08	73.92	67.93	5.99	91.90	9.21	45.11	0.63	41.44	4.73	19.90
3/18	A	5-16	6.66	65.48	56.74	8.74	86.66	13.44	18.66	0.58	18.82	4.73	22.50

Figure 2. Pedological profiles in compartments 60, 64, and 18 / **Slika 2**. Pedološki profili u odjeljenjima 60, 64 i 18 (© I. Čigoja)

tivity (Knežević & Košanin, 2007), according to the same authors, the investigated profiles are classified as shallow soils. Limestone Mollic leptosols are generally shallow, which is a limiting factor in their productivity (Đogić et al., 2020). The investigated profiles are characterized by the presence of an organic horizon of varying thickness, ranging from 3 cm in the profile in compartment 64 of the "Ovčara" FMU to 7 cm in the profile opened in compartment 60 in the area of the "Dubička gora" FMU. A strong organic horizon indicates a slow decomposition of organic residues, which can be considered a normal phenomenon in soils with an A-R profile structure. Research by Eremija (2008) shows that Mollic leptosols in the FMU "Dubička gora" have a developed organic horizon 3-7 cm thick, with a humified Oh layer.

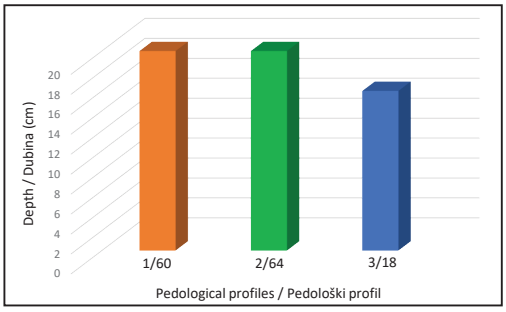

Figure 3. Depth of pedological profiles (cm) / **Slika 3**. Dubina pedoloških profila

The transition between the organic and humus-accumulative horizons is sharp and irregular. The humus-accumulative horizon A is well-developed with stable spheroid structural aggregates. The color of A horizon is black in profiles from compartments 60 and 64, while the color of the same horizon in the profile from compartment 18 is dark brown, which corresponds to the findings of other authors (Eremija, 2008; Knežević & Košanin, 2009). The color and humus content of the mentioned profiles also indicate favorable thermal properties. The investigated soil profiles (Table 2) have a loamy texture, as the most favorable textural class that enables a favorable water-air regime. Đogić et al. (2020) state that the Mollic leptosols formed in the predominant *Piceo omorikae - Abietetum* community at the Tijesni Do location in the Republic of Srpska have a loamy texture, while Eremija (2008) for the same type of soil in the area of Dubička gora states the presence of a sandy loamy texture. According to research (Knežević & Košanin, 2009; Kapović & Knežević, 2010), organogenic and organo-mineral Mollic leptosols are characterized by a silt loamy texture, while browned Mollic leptosols are silt clay loams. The mechanical composition of Mollic leptosols can be loam to clay-loamy (Ćirić et al., 1971). Loam, as a textural class, provides optimal ecological conditions in the soil, primarily affecting a favorable water-air regime, due to the even ratio of larger and smaller fractions in the profile. The fine sand fraction dominates all three profiles (38.81 - 49.29%). The content of total sand is the highest in the profile opened in compartment 64 (51.20%), while the lowest one is in the profile opened in FMU "Dubička gora", with a content of 41.50%. The content of total clay has the opposite values compared to the above (Figure 4).

The chemical properties of the investigated profiles are shown in Table 3. The active pH reaction is neutral, with values range 6.66 to 7.16 (Figure 5). The lowest value was recorded in the soil profile in compartment 18. Although this is the shallowest profile, it can be concluded that the soil processes of leaching are pronounced. Research by other authors shows that Mollic leptosols in different areas have a strongly to weakly acidic or neutral soil reaction (Knežević & Košanin, 2009), which is confirmed by research (Eremija, 2008; Kapović & Knežević, 2010).

The humus content of all three profiles is generally high (18.66 - 45.11%), although there are differences. The highest humus content is in the profile in compartment 64, where the organic horizon is shallow, indicating that the plant decomposes fast, while the lowest humus content is in the profile in compartment

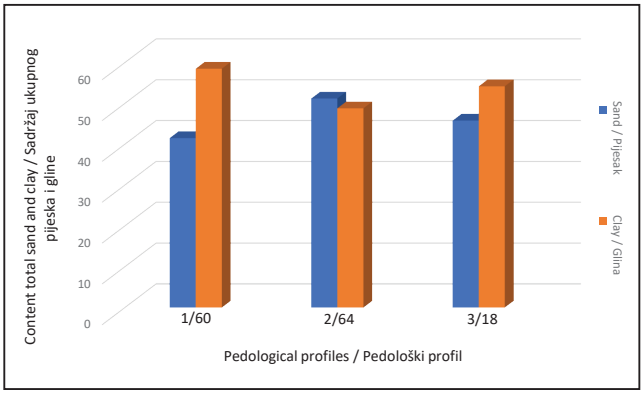

Figure 4. Content of total sand and total clay(%) / **Slika 4**. Sadržaj ukupnog pijeska i ukupne gline

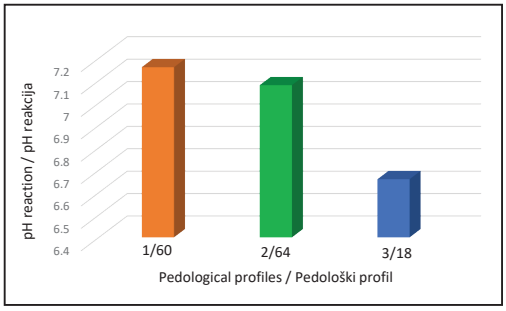

Figure 5. Soil reaction of the investigated soil profiles / **Slika 5**. Reakcija zemljišta istraživanih profila

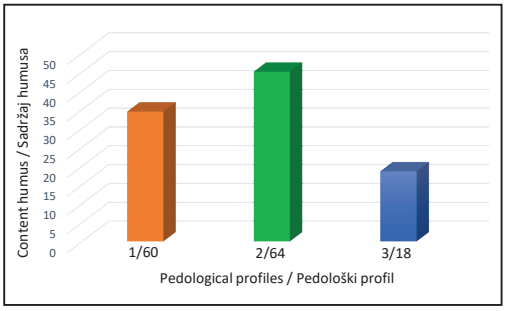

Figure 6. Humus content of the investigated profiles (%) / **Slika 6**. Sadržaj humusa istraživanih profila

18 (Figure 6). Mollic leptosols, as one of the most common limestone types of forest soils, are characterized by a high humus content. Eremija (2008) states that organo-mineral Mollic leptosols have a good supply of humus and nitrogen availability.

The humus richness of the mentioned profiles influences the high total cation adsorption capacity (Cvjetićanin et al. 2009; Golić, 2021), as well as other properties that characterize the soil adsorptive complex, which ranges from 62.43 - 73.92 cmol/kg. The highest total adsorption capacity in the profile in compartment 64, while the lowest was in profile 1/60 in the area of FMU "Dubička gora", although the humus content in this compartment is not the lowest. Hydrolytic acidity values are not high and range from 7.09 to 13.44 cm^3. The humus-accumulative horizon is well provided with base cations (56.74 - 67.93 cmol/kg) and the degree of soil saturation with bases is very high and ranges from 86.66% in profile 3/18 to 92.61% in profile 1/60. Investigations by Kapović & Knežević (2010) show that the Mollic leptosols in the Romanija area also have a high degree of base saturation. Nitrogen richness is another important feature of these soils. Nitrogen content ranges from 0.48% in profile 1/60 to 0.63% in profile 2/64, which is directly related to the humus content. According to the Woohltmann classification (Knežević & Košanin, 2007), all three profiles are classified as very rich, when it comes to the content of total nitrogen in the soil. Investigated soils are

poor in phosphorus, with values ranging from 3.26 to 4.73 mg/100g. Knežević & Košanin (2010) state that all limestone soils are poor in readily available phosphorus. The content of available potassium has some variability, profile 2/64 contains 19.90 mg/100g K_2O and is classified as medium-supplied soils, while profiles 1/60 and 3/18 are well supplied with values of 21.40 mg/100g and 22.50 mg/100g (Figure 7). Mollic leptosols are generally characterized by a low phosphorus content , sometimes below the detection limit, while the content of easily accessible potassium supply is medium to good.

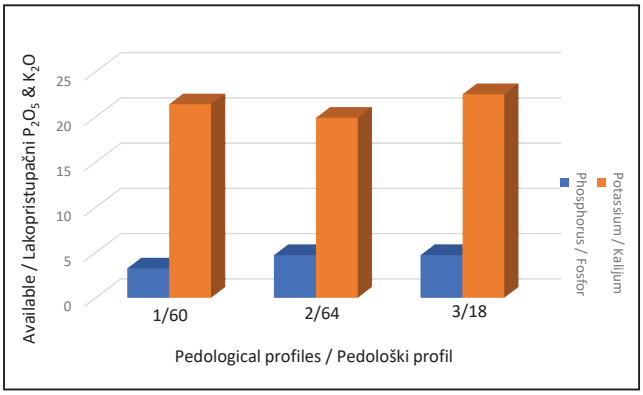

Figure 7. Content available P_2O_5 & K_2O (mg/100g) / **Slika 7**. Sadržaj lako pristupačnih P_2O_5 i K_2O

The physical properties of the investigated profiles indicate a favorable granulometric composition in all three profiles, as manifested by good water-air properties and adsorptive capacity. However, the depth of all three profiles is a limiting factor of productive capacity, which indicates that the analyzed soils cannot be classified as highly productive. Hadžić et al. (2002) state that Mollic leptosols belong to the seventh soil quality class and are mainly used as natural grasslands or under forests. Knowledge of soil properties enables maximum use of production potential through applying adequate management measures (Kapović Solomun et al., 2015). According to the classification of Škorić et al. (1985), we classify the studied soil as **limestone-dolomite black soil**, while according to the WRB soil classification (FAO, 1998), the following soil type was identified: **Mollic leptosols**.

4. CONCLUSIONS / ZAKLJUČCI

- FMA "Mrkonjićko" is located in the northwestern part of Republika Srpska, Bosnia and Herzegovina. Heterogeneous geological composition results in various types of forest soils. A mosaic of limestone-dolomite soil types and dystric brown soil are the most common soil covers in the researched area. The climate of the researched area is mountainous. The most represented vegetation communities in the studied compartments are *Fagetum montanum illyricum* and *Piceo-Abieti-Fagetum*.
- One soil type is identified: limestone-dolomite black soil (Mollic leptosols, according to WRB).
- The physical properties of the analyzed soil profiles are mostly favourable, especially considering the mechanical composition, which is loam in all three analyzed profiles.

Due to spheroidal aggregates and loamy texture, soils provide a favorable water-air regime and favorable thermal characteristics. The depth of the researched profiles is a limiting factor of Mollic leptosols productivity.

- The chemical properties of the researched soils are favorable. Humus richness is the main characteristic that affects neutral soil reaction. The adsorptive complex is high. Phosphorus content is deficient, while the supply of potassium is moderate to good. The analyzed profiles are very rich in nitrogen.
- Limestone Mollic leptosols in the studied compartments have favorable physical and chemical properties, however, as they are shallow soils, their ecological production value is generally low to medium and increases with depth.

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Sažetak

Rad opisuje fizičke i hemijske osobine krečnjačko-dolomitnih crnica na šumsko-privrednom području „Mrkonjićko“, jer je ovo jedan od najzastupljenijih tipova šumskog zemljišta ovog područja. Da bi se moglo pravilno upravljati i gazdovati šumama, jedan od najvažnijih koraka je procjena ekološko-proizvodnih potencijala zemljišta. Bez otvaranja pedoloških profila, opisivanja osobina zemljišta na terenu i laboratorijskih proučavanja karakteristika, nemoguće je izvršiti procjenu ekološko-proizvodne vrijednosti za neko zemljište. Istraživanja su realizovana u dvije privredne jedinice (PJ): „Dubička gora“ u odjeljenju 60 i „Ovčara“, u odjeljenjima 18 i 64. Klimatske karakteristike istraživanog područja su povoljne za razvoj šumske vegetacije. Geološku podlogu u istraživanim odjeljenjima čine krečnjaci, dok je cjelokupno šumsko-privredno područje značajno heterogenije u geološkom pogledu, što se svakako odražava i na pedološki pokrivač. U radu su detaljno prikazane fizičke i hemijske osobine za humusno-akumulativni horizont, koji je ujedno i jedini dijagnostički horizont krečnjačko-dolomitnih crnica. Istraživanja urađena u laboratoriji obuhvatila su analiziranje osnovnih fizičkih i hemijskih osobina zemljišta. Dubina analiranih profila kreće se od 16 (profil u odjeljenju 18) do 20 cm (profili u odjeljenjima 60 i 64). Mehanički sastav svih profila je ilovast, dok je reakcija zemljišnog rastvora određena u H_2O neutralna. Lako-

pristupačnim P_2O_5 istraživane krečnjačko-dolomitne crnice su siromašne, dok se snabdjevenost K_2O kreće od srednje do dobre. Na osnovu istraženih fizičkih i hemijskih osobina krečnjačko-dolomitnih crnica, može se izvesti zaključak da su osobine uglavnom povoljne za rast i razvoj šumske vegetacije, uz konstataciju da je dubina ovog zemljišnog tipa glavni ograničavajući faktor njegove produktivnosti.

Ključne riječi: ekološko-proizvodni potencijal, kalkomelanosol, produktivnost