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SOILS OF FOREST ECOSYSTEMS IN THE ZAGREB COUNTY

TLA ŠUMSKIH EKOSUSTAVA ZAGREBAČKE ŽUPANIJE

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The Zagreb County is situated in the west part of central Croatia. Together with the city of Zagreb it covers the surface of 3.720 km^2, that is approx. 6,6% of the territory of the Republic of Croatia. The surface under forests and forest land is 1.560 km^2, that is about 43% of the County surface.

In the constelation of pedogenetic factors, the characteristics of forest ecosystem pedosphere in the Zagreb County are based on the physiographic properties of the following soils:

1. rendzic leptosol
2. dystric cambisol
3. calci-mollic cambisol
4. luvisol
5. planosol
6. gleysol.

In combination with these soils, as secondary units and inclusions, there occur also: regosol, rendzic-lithic leptosol, dystric leptosol, eutric cambisol, fluvisol, humic fluvisol and gleyic planosol.

In the spatial division of forest pedosphere of the County, 5 mapping units comprising the largest forest complexes are distinguished in particular. These are:

1. mapping unit with the soils on carbonate substrata of Žumberak and Medvednica
2. mapping unit with luvisols and planosols of Vukomeričke gorice
3. mapping unit with prevailing planosols of piedmont regions and hills
4. mapping unit with gleysols of the Kupa basin, Turopoljski lug, Varoški lug and Lonjsko polje
5. mapping unit with dystric cambisols on metamorphites of Medvednica.

These 5 mapping units cover more than 63% of the County forests and are bearers of basic characteristics of the complete forest ecosystem pedosphere.

Key words: Zagreb county, soil, pedosphere

INTRODUCTION
UVOD

The Zagreb County is situated in the western part of central Croatia. Together with the city of Zagreb it covers an area of 3.720 km^2, that is approximately 6,6% of the territory of the Republic of Croatia. Forests and forest land cover 1.560 km^2, or approximately 42% of the total surface of the County1. Such high percentage of forest area as well as the fact that one third of the population of Croatia lives in this County indicate the importance of forest ecosystems for the County. For stable forest ecoystems a very important feature is multifunctionality of soil. The soil is a key ecological niche of forests, which by its production, protective and infrastructural roles is bearer of forest multifunctionality, and so is for most forests in the region of this County, too.

The first scientific researches of features of soils in this region, including conditions of their origin and development, date from the 19th century and refer to farmland. The first more intensive researches of forest ecosystem soils are the works of Gračanin (1939, 1941, 1948, 1960), Kovačević et al. (1963), Martinović (1975), Mayer (1976) and Vranković (1973). The most extensive pedological researches in Croatia refer to the preparation of the national soil map. In the period from 1960 to 1985, the whole of the County area was analyzed and mapped in scale 1:50 000. The Zagreb County is covered by 18 sheets of soil map. The results of this inventory of soils - i.e. the sheets of soil map with explanations and monography of soils of the upper Posavina (Kovačević et al. 1972) - make the basis of this paper in the analysis of physiographic properties and geographical features of forest soils.

FEATURES OF SOIL GENESIS
ZNAČAJKE GENEZE TLA

The pedogenetic factor (the factor of formation - origin and development - of soils) is a substance, force, condition or relationship, or a combination thereof, that acts, has acted or can act on the soil parent material and/or on the soil in the direction of its change (Buol et al. 1980).

According to the actual understanding of soil genesis, the pedogenetic factors are: parent material, climate, relief and organisms, and their main sources are: lithosphere, atmosphere, hydrosphere and biosphere.

Sizes of areas given in this work have been determined by digitalization of the available cartographic materials, namely of the topographic map in scale 1:25 000, from which the forest countours were taken, and of the Basic Pedological Map of the Republic of Croatia in scale 1:50 000.

PARENT MATERIAL
MATIČNI SUPSTRAT

In terms of lithology, the region of the city of Zagreb and the Zagreb County is of a very complex and distinctly heterogenous structure. Distribution of forests being chiefly in a mosaic-like form, the characteristics of parent material are described here for the entire

County, and the main data source is the basic geological map of this area (Basch 1983, Pikija 1987, Šikić et al. 1978). In this area, 5 geomorphological and lithological complexes with a large number of lithological units can be distinguished, namely :

I. Medvednica
II. Flatland and hilly area of the left Sava riverside
III. Alluvial Sava valley
IV. Samoborsko gorje and Žumberak
V. Plešivica piedmont region and Vukomeričke gorice with the central hilly area and the Kupčina basin.

Such division, however, corresponds only partly with the geological or geotecktonical characteristics of the region, but in terms of the pedogenetics, it establishes the best relationship between the parent material, vegetation and relief.

Medvednica mountain
Medvednica

The basic, central ridge of Medvednica is built of metamorphosed diabases and gabbros, and, to a larger extent, of the low level metamorphism schists known as the representatives of green schist facies (Velić, 1994). They show a great variety of structure. Thus, for instance, there were found clay schists, quartz-sericite-clay schists, calci-quartz schists, quartzites, marbles and phyllites. On the surface they are quite crumbly, especially varieties with clay (tendency to swell). On these rocks, dominant soil units are dystric cambisols and dystric leptosols.

On the north-east Medvednica, generally the metamorphosed carbonates as well as the quartz-sericite and quartz-chlorite schists are distinguished.

The west and south-west parts of Medvednica are of extremely complex structure. On the north-west mountainsides there is a group of sediments with sandstones, siltites, as well as limestones and dolomites with sporadically marked bedding (thin bedded micaceous sandstones and flaky marly limestones). The west and south-west Medvednica, in general, is predominantly of calcareous-dolomitic structure.

The southern slopes of Medvednica, from Podsused to Šestine, Markuševec and Čučerje is a variable width zone of various sedimentation products, such as breccias, conglomerates, marls, clays and limestones. Southwardly, this zone is continued by marls, clays and sands. The southernmost and south-east slopes of

Medvednica are built of the so-called slope and terrace sediments: loams, clays, sands and gravels, in frequent mutual alternations (Šikić et al. 1978).

Flatland and Hilly Region of the Sava Left Riverside
Ravničarsko i brežuljkasto područje lijevoga savskoga zaobalja

1. The Upper Pontic sands, marls and clays of the south-east slopes of Medvenica extend in the form of a wide belt from Remete to the east and north-east, as far as to the Lonja River valley. A typical enclave of such sediments is Štakorovečki brijeg, too. The most often they include also larger or smaller amounts of silt size particles, so there are transitions toward silty sands, sandy silts and finally silts with the sand component of as low as 15%.

2. The terrestral carbonate-free loess is a typical sediment of the northern part of this complex. It is mosaically criss-crossed by alluvial, moor argillaceous and argillo-silty, and deluvial-proluvial sedimentary materials.

The terrestrial loess deposits have been preserved on the lowest south-east slopes of Medvednica, from the northern part of the Zagreb urban area in the west to Zelina and Šalovec in the north-east. They lie on morphological elevations near Dugo Selo, Glavničica and Štakorovec. The soil types predominant on these sediments are planosol and luvisol.

3. Large areas of diluvial-proluvial sediments are distinguished in the north part of the Zagreb urban area, as far as to Sesvete. The narrow elongated formations lie at the foot of morphological elevations near Dugo Selo and Štakorovec, the largest area being located in the Zelina depression between Šašinovec and the Nespeš stream valley. The marshy-moor sediments are a typical unit in the south part of the complex. They extend to the east from Zagreb as far as to Vrbovec, south from the magistral road Zagreb - Bjelovar, to the south to Ivanić and in the narrow tarrace segment of the Sava alluvium between Zagreb and Oborovo. Here, the question is about gleyed loess which, unlike the terrestrial one, nearly always is calcareous. In the flood planes of Črnec, Lonja and Zelina, this loess is overlaid by sediments of recent marshlands (most of them reclaimed now), which are thin (< 1 m) and present the markedly humizated clay silts (Basch 1982).

4. Sediments of recent streams are laid perpendicularly to the sloping grounds of Medvednica east and south-east slopes in the flood plane of Vrbovec's Črnec, Dulepska and the Lonja River upper stream. They are of a very heterogeneous lithological structure.

The Sava Flood Valley
Naplavna savska dolina

The Sava flood valley is characterized by gravel-sand and loam-clay deposits overlaying the old lacustrine sediments.

1. The alluvium of recent streams is limited now to small river islands, beaches and sand-shelfs of the Sava River and to a lesser degree of the Krapina River.

2. The alluvium of the Sava first and second terraces is, in some localities, more than 100 m thick. Its average thickness is between 30 and 40 m; in the longitudinal profile it increases in the west-east direction while in the cross-section it decreases when approaching the Sava valley edges.

The second Sava terrace is developed with minor interruptions throughout the Sava stream, from the border with Slovenia to Oborovo. It consists of alteration of coarse-grained gravels and sands. The amount of sand in relation to gravel increases in the south-east direction, and petrographic structure is very varied. Most often there occur well rounded and elongated pebbles of carbonate rocks, then of chert, quartzite, sandstone and eruptive rocks.

The first Sava terrace is developed fragmentarily along the Sava stream, from the Slovenian border to Jakuševec. It is less wide than the previous one and on it dominant is the coarse-grained gravel. The layers of pure sand are thinner and less frequent, but mineral composition is the same as in the second terrace.

3. The flood sediments (the inundation area facies), as a thin cover of fine-grained material, lie over almost the entire Sava River valley. These are mainly sand-clay silts with transition into silty clays.

Samoborsko gorje and Žumberak
Samoborsko gorje i Žumberak

This south-west area of the City and the County is characterized chiefly by calcareous sediments. These are dolomites, subordinately limestones, marls, shales, cherts and tuffs of Triassic age. The Upper Triassic dolomites are the most important lithological elements and soil parent material in the east Žumberak pedosphere. They extend from the Sava and Krka Rivers in the north to Plešivica - Slavetić - Rude stretch in the south. In the north-east Žumberak as well as in the central part of Samoborsko gorje there are also deposits of Jurassic limestones, calcareous breccias, siliphicated limestones, cherts and dolomites.

In addition to these sediments, in a somewhat larger area there are also, mosaically spread, the Upper Cretaceous breccias, conglomerates, shales, marls, calcareous clastites and cherts.

Plešivica piedmont region and Vukomeričke gorice with the Kupčina basin
Plešivičko prigorje i Vukomeričke gorice sa središnjim brežuljkastim područjem i dolinom Kupčine

In its western part, in the region of Plešivica and Samoborsko gorje, this complex is a continuation of marls, sands, sandstones, conglomerates and breccias.

This is a unique zone from Sv. Nedjelja through Sv.Jana to Novakovića gorice. Thus, the region of Samobor presents a lithological enclave with proluvial gravels, sands and clays in its piedmont part, and terrestrial carbonate-free loess in the valley near the Sava River. These Aeolic deposits of terrestrial loess continue from Sv.Nedjelja and Marija Gorica hills through the continuous zone of Turopolje to the south-east, between Vukomeričke gorice and the Sava valley. Their main characteristic is a very small percentage of calcium carbonate, and they are known also by the name of "clayed loess", "carbonate-free loess" and "marbled loams" (Pikija 1987).

In the east part of this zone, near Buševec, between Vukomeričke gorice and the Sava valley, there are the deluvial-proluvial silts, sands and gravels, while mosaically between Rakov Potok and Hudi Bitek as well as near G. Lukovac, the moor loess deposits occur, too (Šikić et al. 1978).

The south part of the City and the County is represented, in terms of lithology, by the Plio-Pleistocene sediments - gravels, sands, clays and sporadically sandstones and conglomerates. This is the region from Rakov Potok to the south and south-west, as well as to the south-east through Vukomeričke gorice as far as to Pokupsko. The fine-grained sediments are determined as sands, silty sands, clay sands, silts, clay silts and silty or sandy clays.

Table 1. Typical lithosequence in the Zagreb County forest pedosphere
Tablica 1. Karakteristične litosekvence u pedosferi šuma Zagrebačke županije

Nr. *Br.*	Rocks *Stijene*	Soil *Tlo*
1	Quartz-sericite-schists, green schist *Kvarc-sericitni škriljac, zeleni škriljac*	Distric leptosol - Distric cambisol *Ranker - distrični kambisol*
2	Quartz-calcite-sericite schists, calcite phyllites *Kvarc-kalcit-sericitni škriljac, kalcitni filiti*	Rendzic leptosol - Eutric cambisol *Rendzina - eutrični kambisol*
3	Clays, loams *Gline, ilovine*	Planosol *Pseudoglej*
4	Sacharoide dolomite *Saharoidni dolomiti*	Rendzic leptosol *Rendzina*

The southern part of this complex, toward the Kupčina and Crna Mlaka basin, is built mostly of the Holocene clay deposits with interbeds and lens of sands, clay sands and clay gravels.

From the point view of soil genesis, the most important characteristics of rocks are chemical composition and wear properties. In this respect we can talk about rocks with different status of nutrients, the rocks with various physical and chemical properties of wear, and finally the lithosequence of soils (Tab. 1).

CLIMATE
KLIMA

Climatically, the Zagreb County is a transitory region where, in addition to the influence of general circulation characteristical for these latitudes, a strong modifying influence of the Pannonian plane and the large mountain ranges of Alps and Dinaric Alps is felt either, that compensates to a certain degree the Atlantic and especially the Mediterranean influences.

In terms of the general climatic characterization, the Zagreb County according to the Thorntwait's classification has humid climate, and according to the Köppen's classification moderately warm rainy climate of Cfwbx" type. Over the year there is no dry season, and precipitations are distributed in a regular manner. These climatic features exclude the frosty and exudative type of soil water regime. The extreme climatic characteristics in the sense of climate perhumidity are typical for the highest parts of Medvednica and Žumberak only. With regard to the recognizable influence of recent climate to the pedogenesis, it can be said that in this relatively small region there are no climate-sequence soils, namely the series of soils whose pedosystematic belonging and physiographic characteristics are attributable to the climatic influence only.

On some soils of this region, according to their physiographic properties and the general characteristics of pedosphere, the Paleoclimatic influences are noticeable, which are attributable to the Pleistocene period. These are as dominant in one case the typical endomorphological symptoms of the so-called tundra soils, which are present in the largest number of silty and silty clay soils on loams and clays.

ORGANISMS
ZOOCENOZA

Organisms, as a group of pedogenetic factors, play an important role in the soil genesis, in particular by the production of organic matter, the organic and mineral substance transformation processes and the migration processes. The most evident determinant of organisms as the factor of soil genesis is vegetation. The question is of course, about the soils under one and only type of vegetation, the forest vegetation, so in this sense we can talk about the influence of particular forest species or associations on the properties of the soil and its evolution. This being outside the framework of the general description of soils, it is enough to say that the forest vegetation structure is made of a wide spectrum of associations, from the willows and poplars of the Sava alluvial terrace to the beech forests and the beech and fir forests in the upper parts of Medvednica and Žumberak, and that there are no distinctly marked phytosequences.

RELIEF
RELJEF

By redistribution of substances and energy on the soil surface, the relief plays an important role in the soil development and in the formation of physiographic properties of particular soils.The most direct influence of relief on soil properties, by means of the redistribution of substances on the soil surface and by lateral movement of water through the soil profile, is seen in the conditions of pronounced inclinations of the ground. Physical wearability of parent material and excessive anthropogenetic impacts in such circumstances are factors which facilitate gradual impoverishment of the upper, higher parts of the ground in organic matter, the decrease of profile depth and a general change of soil physical properties, in both the deflation zones and the accumulation zones. In the conditions with carbonate parent material, such as flysch and marl, the shallow soil and high pH-value in the upper parts of the slope, as well as the higher depth and power of humus-accumulating horizon in the slope lower parts are particularly visible.

The influence of relief on the distribution of soil types can be shown by the toposequence type series on the mountains and hills as well as by the hydrotoposequence type complexes in flatland parts of the County.

The influence of relief on the general pedogenetic processes is manifested most by the *migration* of soil solid particles and solution. The term used most often to designate carrying of soil particles over the surface and their accumulation in less turbulent parts of relief or water basins is *erosion.*

Under conditions of steeper slopes, being exposed also has an important influence on organic matter transformation processes and this by the correction of hydrothermal regime and microbiological activity. This affects humification, mineralization of organic matter etc.

In the flatland parts of the County, by regulating water table in relation to the soil profile (and surface) and by distributing the flood and stagnant water over the soil surface, the microrelief forms determine the intensity and dynamics of oxido-reduction processes in the soil, namely various types of hydrogenization.

The analysis of pedogenetic factors of forest soils in the Zagreb County indicates a great variability in the structure of soil cover as well as in the soil properties and evolution trends. A specific character to this variability is provided by parent material and relief, so a clear distinction is possible between:

- soils on silicates and metamorphites of Medvednica
- soils on limestones and dolomites of Žumberak and Medvednica
- soils on cohesive carbonate clastites
- soils on alluvial clastites
- soils on Aeolian sediments
- soils on pleistocene loams and clays,

and on the other side:

- soils of inundation areas

- soils of terrace planes
- soils of fluvial-marshy planes (Crna Mlaka depression)
- soils of loess plateaux
- soils of hills (Vukomeričke gorice, Marija Gorica hills)
- soils of premountain steps
- soils of mountain ranges (Medvednica and Žumberak with Samoborsko gorje).

PHYSIOGRAPHICAL PROPERTIES OF SOILS
FIZIOGRAFSKA SVOJSTVA TALA

The properties of soils for such pedogenetically heterogenous region can be illustrated on the most frequent soils and soil groups. The question being about forest ecosystems, the largest weight is given to the most important soil properties for the growth and development of forest vegetation.

RENDZIC-LITHIC LEPTOSOL
VAPNENAČKO-DOLOMITNA CRNICA

The rendzic-lithic leptosol is insignificantly represented soil, and this on the highest peaks of Žumberak only. The soil is developed over pure limestones, it is shallow, very humose and of neutral to weakly acid reaction. It is mostly in the form of cambic rendzic-lithic leptosol. These soils are of a very low production potential, occurring as inclusions with calci-mollic cambisols and luvisols.

RENDZIC LEPTOSOL
RENDZINA

The rendzic leptosol has a very large share in the forest ecosystems of the Zagreb County. The most frequent are three subtypes:

- rendzic leptosol on dolomite
- rendzic leptosol on marl and marly limestones
- rendzic leptosol on Miocene limestones.

Rendzic leptosol on dolomite is almost always the low production potential soil, and stands with such soil are characterized by dry and shallow rhizosphere. This rendzic leptosol subtype is represented most in the cartographic units 4 and 6, in the region of Žumberak and Samoborsko gorje, on the south and south-east slopes of Medvednica as well as in its north-east part. The dominant influence on the pedogenesis and properties of this soil has parent material - the physically very wearable dolomite. The soil evolution on such material being very slow, rendzic leptosols are the dominant type of soil on it. These soils are normally shallow, no matter whether calcareous, decarbonated or cambic. In the cambic varieties the depth is somewhat higher (more than 30 cm on the average). They are characterized by meagerness on the plant available phosphorus (Tab. 2). On these soils generally

Table. 2. Mean parameter values of physiographic properties of the A-horizon of some frequent soils
Tablica 2. Srednje vrijednosti parametara fiziografskih svojstava A- horizonta nekih zastupljenijih tala

Soil *Tlo*	Parent material *Matični supstrat*	Plant community *Biljna zajednica*	n	Depth of A- horizon *Deblj. A- horiz.*	Texture *Mehan. sastav - sadržaj čestica (%)* Gravel sand; *Krupni pijesak* (KP) Fine sand; *Sitni pijesak* (SP) Silt; *Prah* (P) Glina; *Clay* (G)				pH		Humus *Humus*	Total nitrogen *Ukupni dušik*	Mob. Phosph *Mob. fosf.*	Mob. Potass. *Mob. kalij*	Karbonates *Karbonati* ($CaCO_3$)
					(KP)	(SP)	P	G	H_2O	1M KCl			P_2O_5	K_2O	
				(cm)	%						g kg-1		mg kg-1		g kg-1
Rendzic leptosol *Rendzina*	Limestones *Mekani vapnenci*	*Epimedio-Carpinetum betuli* /Ht. 1938/ Borh. 1963	4	20.0	9.4	31.8	31.0	27.8	7.9	6.9	177.8	9.40	90.7	234.8	97.5
	Dolomite *Dolomit*	*Lamio orvale-Fagetum sylvaticae* Ht. 1938	3	17.0	3.9	23.3	45.0	27.8	7.5	6.4	86.0	2.77	8.5	140.0	86.3
Calci-mollic cambisol *Smeđe tlo na vapnencu*	Limestone *Vapnenac*		3	16.0	5.5	28.8	38.1	27.6	5.4	4.3	107.7	3.20	26.0	142.5	0.0
Eutric cambisol *Eutrično smeđe tlo*	Marl *Lapor*		5	7.5	3.8	34.0	34.3	27.9	6.1	5.1	88.6	4.12	39.0	274.8	0.0
Dystric cambisol *Distrično smeđe tlo*	Schist *Škriljci*	*Luzulo-Fagetum sylvaticae* Ht. 1938	13	12.0	15.8	34.1	31.0	19.1	4.8	3.9	111.5	4.17	73.0	178.9	0.0
	Schist *Škriljci*	*Querco-Castaneetum sativae* Ht. 1938	4	5.0	30.6	17.3	29.9	22.3	4.6	3.9	216.0	5.90	112.5	208.8	0.0
Luvisol *Lesivirano tlo*	Loess *Prapor*	*Carpino betuli-Quercetum roboris* /Anić 1959/ emend. Rauš 1969	5	6.0	3.0	47.8	31.6	17.6	5.2	3.9	53.6	2.34	66.2	134.2	0.0
Planosol *Pseudoglej*	Pleistocene loams *Pleistocenske ilovine*	*Epimedio-Carpinetum betuli* /Ht. 1938/ Borh. 1963	9	16.0	4.3	35.9	40.7	19.2	4.8	3.7	37.6	1.41	5.3	98.2	0.0
		Genisto elatae-Quercetum roboris Ht. 1938	9	9.0	1.6	38.8	41.2	18.4	4.8	3.9	59.3	2.83	18.9	139.8	0.0
Gleyic planosol *Pseudoglej-glejno tlo*			3	12.0	1.3	20.9	43.8	33.9	5.2	4.0	64.7	3.33	121.0	148.3	7.0
Gleysol *Močvarno glejno tlo*		*Carpino betuli-Quercetum roboris* /Anić 1959/ emend. Rauš 1969	3	12.0	0.9	47.7	31.7	19.6	4.7	4.0	49.7	2.83	93.0	134.7	0.0
Fluvisol *Aluvijalno tlo*	Alluvium *Aluvij*	*Salici-Populetum nigrae* Rauš 1973	3	13.0	2.1	48.9	36.5	12.6	7.6	7.0	68.0	1.75	35.7	109.0	219.1

the beech forests of poor standing grow, most of which of a limited economic importance. On the south-east slopes of Medvednica and on Žumberak, the sessile oak and hornbeam forests are developed on such rendzic leptosols, too.

Rendzic leptosol on marl and marly limestone is found on Žumberak, in the north-east parts of Medvednica and on Marija Gorica hills. These are mostly deeper soils with a higher production potential than that of the rendzic leptosols on dolomite. Symptomatic for these soils is that their depth corresponds relatively well with the inclination of slopes (Kovačević et al. 1972). Thus, on steep slopes these rendzic leptosols are calcareous to the very surface, while on slight slopes they are debasificated, cambic and in alteration with eutric cambisols and luvisols. By texture, they are predominantly clay loams, of moderate to poor permeability and on slopes very susceptible to erosion. On these soils, on Žumberak and Medvednica, the beech forests and the sessile oak-hornbeam forests are represented about equally, while on Marija Gorica hills the sessile oak - hornbeam forests of medium standing grow.

Rendzic leptosol on the Miocene limestones occupies relatively small areas in the area of calcareolus parent material. In relation to the rendzic leptosols on dolomite and marl, this rendzic leptosol subtype has the most favorable physiographic properties for forest vegetation growing.These soils are with a relatively deep A-horizon (Tab. 2), of loamy texture. On them, on Medvednica, the sessile oak and hornbeam forest grows, less frequently the beech forest, while on Plešivica and Marija Gorica hills the sessile oak and common hornbeam forest is developed.

In addition to the said rendzic leptosol subtypes, it is interesting also a mosaic-like occurrence of rendzic leptosols on calcitic phyllites on Medvednica (Vranković 1973), where they occur in combination with dystric cambisols and dystric leptosols.

DYSTRIC LEPTOSOL
RANKER DISTRIČNI

The dystric leptosol occurs on phyllites and schists on Medvednica. This soil is limited to steeper slopes, where it represents a permanent stage due to erosion and colluvial processes. It is usually in association with the dystric cambisol which is the main constituent in such association. This is a shallow to moderately deep and skeletal soil, with the lowest production potential of all other soils on the rocks of green schist facies. It is of acid reaction, loamy texture, very humose, and the limiting factor of its fertility is shallowness.

CALCI-MOLLIC CAMBISOL
SMEĐE TLO NA VAPNENCU

This soil occurs on pure limestones in the central and southern parts of Žumberak as well as in the north-east part of Medvednica. It is in association with rendzic-lithic leptosols and luvisols, as well as rendzic leptosols. With rendzic leptosols it usually occurs in a mosaic-like form on dolomite which physically do not

wear so much, so in the profile there is a very thin layer of worn away carbonate on its bottom. The moderately deep and deep varieties of these soils are of high production potential, with loamy to clay-loamy texture, and on them the high quality beech stands are developed. The lowest quality is in the soils in association with rendzic leptosols, and shallow varieties in general.

DYSTRIC CAMBISOL
DISTRIČNO SMEĐE TLO

The genesis of this soil is connected with the quartz-silicate metamorphites and sediments of Medvednica, Žumberak (the parts of Plešivica and Samoborsko gorje) and Marija Gorica hills. These are soils of A-(B)-C profiles, of acid to high acid reaction (Tab.2), loamy to sandy loamy texture, and their depth depends on the kind of parent material (slates, schists, phyllites, sandstones, conglomerates, cherts, sands), the direction of schistosity in schists and phyllites and the inclination of slopes. Their production potential depends on the depth and the trophic level. The low fertility variants are sandy, shallow, possibly skeletal, very acid and with a poor cation exchange capacity (CEC). On these soils, the beech and fir associations, the mountain beech forests, the sessile oak and sweet chesnut forests and the sessile oak forests grow.

EUTRIC CAMBISOL
EUTRIČNO SMEĐE TLO

This soil is developed on marls, Miocene limestones, loess and carbonate alluvium. The largest areas of the eutric cambisol on marl and Miocene limestons are on Žumberak, while other variants occur in rare inclusions with other soils, so stagnic and gleyized variants are found, too. The eutric cambisol on marl and limestone has a high production potential. These soils are moderately deep to deep, of loamy clay texture, of low acidity and with the high base cationic exchange capacity. On these soils, the mountain beech forests and the sessile oak and common hornbeam forests grow.

LUVISOL
LESIVIRANO TLO

This soil is very frequent in the County forest ecosystems. It occurs in different variants and forms on both the carbonate and the silicate and silicate-carbonate parent material, except on sandstones, alluvial sediments and diluvial clays. The most frequent varieties are those on loess and loams of Vukomeričke gorice, while somewhat less frequent are varieties in the Plešivica boundary area and to the north from Vrbovec. These soils are deep to very deep, and of very high production potential. On the luvisols of Vukomeričke gorice and Plešivica the sessile oak and common hornbeam association and the beech forests are developed, while in levelled positions, on the pseudogleyized or gleyized varieties, the common oak and common hornbeam forests grow. On Medvednica, the luvisols on metamorphites

are very rare, usually in lower, levelled positions. On Žumberak, they are a bit more frequent and occur on limestones and marls in the mountain beech forests and the sessile oak and hornbeam forests. On such parent material, these are the soils with the best physiographic properties and of the highest production potential. For this reason, in the past many of them were made suitable for farming by forest clearing, especially those in level positions.

REGOSOL
KOLUVIJALNO TLO

Regosol is soil occurring usually in stream and torrent gullies of Medvednica, Žumberak and Samoborsko gorje, especially on levelled parts of steep slopes. The physigraphic properties of these soils do not depend on the properties of parent material but on the material displaced from higher positions in relief. This fact explains the great diversity in physiographic properties of these soils. Nevertheless, it can be said that, in the cartographic units in which these soils are found, the most often they are of the highest production potential. In rare cases, however, as a limiting factor a high skeletal character or prevailing reduction conditions inside the profile occur.

PLANOSOL
PSEUDOGLEJ

The planosol is the most represented type of soil in the forest ecosystem pedoshpere of the County. Especially spread is the slope subtype on diluvial loams and clays. Dominant on this soil is the sessile oak and hornbeam forest, and to a lesser extent the mountain beech forest. These are acid to very acid soils of loamy texture, with very bad drainage characteristics and unfavorable proportions of capillary and non-capillary pores. Nevertheless, in the natural forest ecosystems of the County, these are the soils of a high production potential. In relation to the planosol on loams, the planosol on marl and loess is an eutric variant with favorable physiographic properties (pH value in water above 5,5, the high CEC value).

The flatland planosol is characterized by a slight lateral flow inside the profile, with the wet phase longer than that in the slope subtype. On this soil, the most frequent association is that of sessile oak and hornbeam as well as the association of common oak and large greenweed. Of all forest soils, the planosol has the smallest humus reserve per unit of surface.

GLEYSOL
MOČVARNO GLEJNO TLO

This soil is hydrologically conditioned either by the high ground water table (inside the profile or even above the surface) or by an extremely bad natural drainage of relief depressions. This results in the occurrence of reduction processes in a part of profile or in the whole profile.

Depending on the origin of excess water and the character of hydrogenization, the various subtypes of gleysol occur. Particularly unfavorable, physiologically, are amphygleyic gleysol vertic varieties. The correction factor of physiographic properties of these soils is their water regime. This is at the same time also the limiting factor of production potential when the prevailing reduction conditions inside the profile are concerned.

Gleysol is the most represented on the alluvial sediments of the Sava flood plane. This includes the north-east parts of Odransko polje (Turopoljski lug) and Lonsko polje (the Žurica forest). A larger forest surface with gleysols is also the forest complex Varoški lug, between Vrbovec and Ivanićgrad, as well as the parts of the Kupa basin. The most frequent plant associations on these soils are the common oak forest with greenweed and the common oak and common hornbeam forest. On the vertic amphygleyic gleysol, the common ash forest with late snowflake often occurs, while on the organogenic vertic amphygleyic gleysols the black alder forest with berry alnus is often developed, too.

According to Mayer (1996), in the last decades in the soils of basin ecosystems unfavorable hydrological changes took place, especially in respect to the old stands. These changes are consequences of various infrastructural works (channels, roads, etc.), resulting most often in the lower water table and the physiological drought in the rhizosphere, or in a long lasting surface water stagnation. Particularly alarming is phenomenon of tree withering in Žutica and Turopoljski and Varoški lug. Due to such extremely strong anthropogenic impacts on the soil, the Žutica forest is the most endangered forest complex in the County. The research of redox potential (Vranković and Bašić 1989) showed that in some marshy parts of this forest unfavorable reduction conditions last throughout the vegetation season.

Under conditions of a stable, undisturbed, water regime the hypogleyic gleysol subtype, in particular in the loamy to loamy-clay variant, is the soil of high production potential. On such soils our most valuable common oak and hornbeam forests and the common oak forests with greenweed grow.

In association with the gleysol, especially the hypogleyic gleysol subtype, the texturally heavy soils, which in the upper part of profile have characteristics of planosol and in the lower part those of gleysol, are found sporadically. These are the planosol-gleyic soils, usually with vertic features.

All these soils generally are non- calcareous.

FLUVISOL
ALUVIJALNO TLO

Owing to hydrotechnical works and regulation of most flatland rivers, there is no regular flooding and alluvial sediment accumulation in the flood region. The relatively small surfaces under forests, that remained in the region regularly flooded by the Sava River, are represented by the willow and poplar forests. They grow on the soils formed by periodical sedimentation of alluvial sediment under

the influence of carrying power of water. In the profile, these soils show the bedding without any clear morphological signs of genetic horizons. In terms of the texture, these are mainly sand to gravel-sand alluviums with carbonate particles of silty soil. As the question is about relatively small surfaces along the Sava River, these soils have no economic significance. Their production potential is relatively low, that is due to their gravel-sand texture and, consequently, to an extremely unfavorable proportion of capillary and non-capillary pores and insignificant sorption capacity.

GEOGRAPHICAL CHARACTERISTICS OF SOILS
GEOGRAFSKE ZNAČAJKE TALA

The presentation of spatial relations in the forest ecosystem pedosphere of the Zagreb County is based on the attached cartogram (Fig. 1) and the structure of mapping units (Tab.3). The soils of the whole of County forest area are shown by means of 23 complex mapping units (Tab. 3), whose complexity is in compliance with the map scale. The specificity of distribution in space of forest soils and pedocartographic units in the County region has been determined by the above mentioned pedogenetic factors. In this respect, very important is the anthropogenetic factor by which the spatial dimension of forest cover is defined directly. On the attached cartogram, 5 cartographic units comprising the largest forest complexes are clearly distinguished. These are:

1. mapping unit 2 with the soils on carbonate parent material of Žumberak and Medvednica;
2. mapping unit 13 with luvisols and planosols of Vukomeričke gorice;
3. mapping unit 16 with prevailing planosols of piedomont region and hills;
4. mapping unit 23 with gleysols of the Kupa basin, Turopoljski lug, Varoški lug and Lonjsko polje;
5. mapping unit 7 with dystric cambisols on the metamorphites of Medvednica.

These 5 mapping units cover more than 63% of the County forests and are bearers of basic characteristics of the complete forest ecosystem pedosphere.

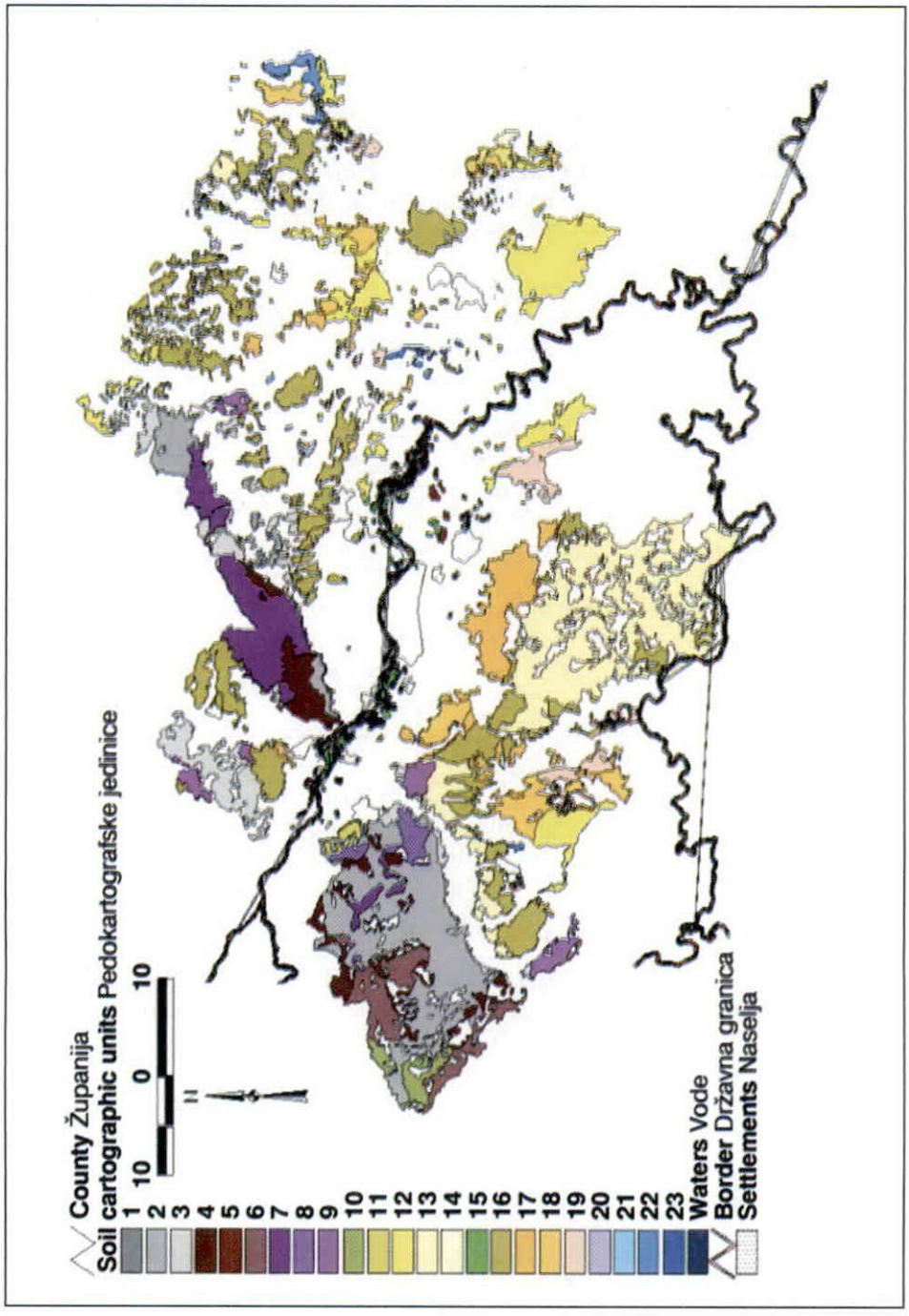
County Županija
Soil cartographic units Pedokartografske jedinice
10 0 10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Waters Vode
Border Državna granica
Settlements Naselja

Table 3. Mapping units of the forest pedosphere of the Zagreb County
Tablica 3. Pedokartografske jedinice šumskih ekosustava Zagrebačke županije

Nr. Br.	Dominant unit of soil *Dominantna jedinica tla*	Other units of soil *Ostale jedinice tla*	Inclusions *Inkluzije*	Površina *Area* (ha)	Zastupljenost *Participation* (%)
	2	3	4	5	6
1	Calci-mollic leptosol *Vapnenačko dolomitna crnica*	Calci-mollic cambisol *Smeđe tlo na vapnencu i dolomitu*	Luvisol; Rendzic leptosol *Lesivirano tlo na čistim vapnencima i dolomitima; Rendzina na mekim vapnencima*	74	0.05
2	Rendzic leptosol *Rendzina na dolomitu i dolomitiziranom vapnencu*	Calci-mollic cambisol; LuvisolSmeđe na dolomitu; *Lesivirano na dolomitu i vapnencu*	Calci-mollic leptosol *Vapnenačko-dolomitna crnica*	21128	13.57
3	Rendzic leptosol *Rendzina na laporu i mekim vapnencima*	Luvisol *Lesivirano tlo na laporu*	Gleysol; Dystric cambisol; Regosol *Močvarno glejno tlo; Distrično smeđe tlo; Koluvijalno tlo*	9393	6.03
4	Calci-mollic cambisol *Smeđe tlo na dolomitu*	Rendzic leptosol *Rendzina na dolomitu;*	*Lesivirano tlo na dolomitu, tipični i akrični*	6258	4.02
5	Eutric cambisol *Eutrično smeđe tlo na aluvijalnom nanosu, tipično, tipično oglejeno i vertično oglejeno*	Eutric cambisol *Eutrično smeđe tlo na pretaloženom lesu, tipično i tipično oglejeno*	Gleysol *Močvarno glejno tlo*	408	0.26
6	Eutric cambisol *Eutrično smeđe tlo na laporu i mekom vapnencu*	Rendzic leptosol; Luvisol; Calci-mollic cambisol *Rendzina na lapor; Lesivirano tlo na silikatno-karbonatnim supstratima; Smeđe tlo na vapnencu i dolomitu*	Regosol *Koluvijalno tlo*	4892	3.14
7	Dystric cambisol *Distrično smeđe tlo na metamorfitima i klastitima*	Luvisol *Lesivirano tlo na silikatnim supstratima*	Dystric leptosol; Regosol *Ranker; Koluvijalno tlo*	9107	5.85
8	Dystric cambisol *Distrično smeđe na silikatnim klastitima*	Luvisol *Lesivirano tlo na silikatnim klastitima; Ranker regolitični*	Regosol; Rendzic leptosol *Koluvijalno tlo distrično; Rendzina na laporu i mekim vapnencima*	1815	1.17
9	Dystric cambisol *Distrično smeđe tlo, tipično i pseudooglejeno na nevezanim klastitima*	Planosol; Luvisol *Pseudoglej obronačni; Lesivirano tlo, tipično, pseudooglejeno i dvoslojno*	Regosol *Koluvijalno tlo*	3210	2.06
10	Luvisol *Lesivirano tlo na čistim vapnencima i dolomitima, tipično*	Calci-mollic cambisol *Smeđe tlo na vapnencu u dolomitu, lilimerizirano;*	Calci-mollic leptosol *Vapnenačko-dolomitna crnica*	1698	1.09
11	Luvisol *Lesivirano tlo na čistim vapnencima i dolomitima, tipično i akrično*	Luvisol *Lesivirano i distrično smeđe tlo na škriljcima i pješčenjacima*	Calci-mollic cambisol *Smeđe tlo na vapnencima i dolomitima*	533	0.34
12	Luvisol *Lesivirano tlo na laporu i pleistocenskim ilovinama*	Planosol; Rendzic leptosol *Pseudoglej obronačni; Rendzina na laporu, karbonatna*	Leptosol *Koluvijalno tlo s dominacijom sitnice*	1304	0.84
13	Luvisol *Lesivirano tlo na lesu, ilovinama i pjeskovitim ilovačama, pseudooglejeno*	Luvisol; Planosol *Lesivirano tlo na lesu, tipično; Pseudoglej obronačni*	Regosol; Gleysol; Dystric cambisol *Koluvijalno tlo; Močvarno glejno tlo; Distrično smeđe tlo na lesu;*	25489	16.37
14	Luvisol *Lesivirano tlo na praporu*	Planosol *Pseudoglej obronačni*	Regosol; Gleysol *Koluvijalno tlo; Močvarno glejno tlo*	802	0.51
15	Fluvisol *Aluvijalno tlo, karbonatno*	Fluvisol; Gleysol *Aluvijalno livadno tlo, karbonatno; Močvarno glejno tlo*		1454	0.93
16	Planosol *Pseudoglej obronačni*	Planosol; Luvisol; Dystric cambisol *Pseudoglej ravničarski; Lesivirano tlo na lesu; Distrično smeđe tlo*	Gleysool; Regosol, Rendzic leptosol *Močvarno glejno tlo; Koluvijalno tlo, aluvijalno-koluvijalno; Rendzina*	27719	17.80

Nr. *Br.*	Dominant unit of soil *Dominantna jedinica tla*	Other units of soil *Ostale jedinice tla*	Inclusions *Inkluzije*	Površina *Area* (ha)	Zastupljenost *Participation* (%)
	2	3	4	5	6
17	Planosol *Pseudoglej ravničarski*	Planosol; Luvisol; Regosol *Pseudoglej obronačni; Lesivirano tlo na lesu, pseudooglejeno; Koluvijalno tlo, aluvijalno-koluvijalno*	Gleysool *Močvarno glejno tlo*	8688	5.58
18	Planosol *Pseudoglej ravničarski*	Planosol; Luvisol; Gleysol *Pseudoglej-glejno tlo; Lesivirano tlo na lesu, tipično i pseudooglejeno; Močvarno glejno tlo*	Eutric cambisol; Regosol *Eutrično smeđe tlo, pseudooglejeno; Koluvijalno tlo, aluvijalno-koluvijalno*	8836	5.67
19	Gleyic planosol *Pseudoglej-glejno tlo*	Planosol; Luvisol *Pseudoglej ravničarski; Močvarno glejno tlo*	Fluvisol *Aluvijalno livadno tlo*	3671	2.36
20	Gleysol *Močvarno glejno tlo*	Gleyic regosol *Koluvijalno tlo, aluvijalno koluvijalno, oglejeno*	Planosol; Gleyic planosol *Pseudoglej ravničarski; Pseudoglej-glej*	1054	0.68
21	Gleysol *Močvarno glejno tlo*	Humic fluvisol *Aluvijalno livadno tlo*	Fluvisol *Aluvijalno tlo*	45	0.03
22	Gleysol *Močvarno glejno tlo, hipoglejno*	Gleyic planosol *Pseudoglej-glejno tlo; Pseudoglej na zaravni*	Gleysol *Močvarno glejno tlo amfiglejno*	1873	1.20
23	Gleysol *Močvarno glejno tlo, amfiglejno, većinom nekarbonatno*	Gleysol *Močvarno glejno tlo, hipoglejno, većinom nekarbonatno*	Fluvisol; Gleysol; Gleyic planosol *Aluvijalno tlo; Pseudoglej-glej; Močvarno glejno tlo, tresetno*	16276	10.45

CONCLUSIONS
ZAKLJUČCI

In the constelation of the pedogenetic factors, the characteristics of forest ecosystem pedosphere in the Zagreb County are based on the physiographic properties of the following soils:

1. rendzic leptosol
2. dystric cambisol
3. calci-mollic cambisol
4. luvisol
5. planosol
6. gleysol.

The soils with the highest production potential in the County forest ecosystems are luvisols. On various subtypes of this soil, three very important associations are found, namely the mountain beech forest, the sessile oak and hornbeam forest and the common oak and hornbream forest. Particularly favorable physiographic properties are those in the loess overlaid luvisols.

The soils with a limited production potential are various shallow soils, such as rendzic leptosols on dolomite of Žumberak, Samoborsko gorje and Medvednica, and dystric leptosols on schists of Medvednica. These soils, and consequently the forests as a whole, are of a reduced multifunctionality.

In the spatial division of forest pedosphere of the County, 5 cartographic units comprising the largest forest complexes are distinguished in particular. These are:

1. cartographic unit (2) with the soils on carbonate substrata of Žumberak and Medvednica
2. cartographic unit (13) with luvisols and planosols of Vukomeričke gorice
3. cartographic unit (16) with prevailing planosols of piedmont regions and hills
4. cartographic unit (23) with gleysols of the Kupa basin, Turopoljski lug, Varoški lug and Lonjsko polje
5. cartographic unit (7) with dystric cambisols on metamorphites of Medvednica.

These 5 cartographic units cover more than 63% of the County forests and are bearers of basic characteristics of the complete forest ecosystem pedosphere.

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TLA ŠUMSKIH EKOSUSTAVA ZAGREBAČKE ŽUPANIJE

SAŽETAK

Zagrebačka županija nalazi se u zapadnom dijelu središnje Hrvatske. Zajedno s Gradom Zagrebom prostire se na 3 720 km^2, što je oko 6,6 % teritorija Republike Hrvatske. Površina šuma i šumskih zemljišta je 1 560 km^2, što je oko 42 % površine Županije.

Pedogenetske značajke pedosfere šumskih ekosustava ove Županije najjače su obilježena matičnim supstratom.

Područje Grada Zagreba i Zagrebačke županije u litološkom smislu vrlo je složene i izrazito heterogene građe.

Na tom je području moguće izdvojiti 5 geomorfološko-litoloških kompleksa s nizom litoloških jedinica.

I. Medvednica
II. Ravnično i brežuljkasto područje lijevoga savskoga zaobalja
III. Naplavna savska dolina
IV. Samoborsko gorje i Žumberak
V. Plešivičko prigorje i Vukomeričke gorice sa središnjim brežuljkastim područjem i dolinom Kupčine.

Glavne su skupine matičnih supstrata:

1. metamorfiti Medvednice
2. vapnenci i dolomiti Žumberka, Samoborskoga gorja i Medvednice
3. lapori i meki vapnenci Žumberka s Plešivicom i Samoborskim gorjem, Medvednice i marijogoričkih brda
4. pleistocenske ilovine i gline te prapor Vukomeričkih gorica, marijogoričkih brda, pobrđa istočnoga dijela Županije te medvedničkoga i žumberačkoga prigorja
5. kvartarni talozi Posavine i Pokuplja.

Vrlo značajni korigirajući pedogenetski čimbenici u danim geološkim i klimatskim prilikama u tom su prostoru reljef i čovjek.

U konstelaciji navedenih čimbenika obilježja pedosfere šumskih ekosustava Zagrebačke županije temelje se na fiziografskim svojstvima ovih tala:

1. rendzina
2. distrično smeđe tlo
3. smeđe tlo na vapnencima i dolomitima
4. lesivirano tlo
5. pseudoglej
6. euglej.

U kombinaciji s tim tlima, kao sporedne jedinice i inkluzije, javljaju se još: koluvijalno tlo, vapnenačko-dolomitna crnica, ranker distrični, eutrično smeđe tlo, fluvisol, humofluvisol, pseudoglej-glej.

Tla s najvećim proizvodnim potencijalom u šumskim ekosustavima Županije su lesivirana tla. Na različitim podtipovima toga tla susreću se tri vrlo značajne zajednice, a to su brdska bukova šuma, šuma hrasta kitnjaka i graba te šuma hrasta lužnjaka i graba. Osobito povoljnih fiziografskih svojstava su lesivirana tla na praporu.

Tla ograničenoga proizvodnoga potencijala su različita plitka tla, kao što su rendzine na dolomitima Žumberka, Samoborske gore i Medvednice, te rankeri na škriljcima Medvednice. Ta su tla, pa tako i šume u cjelini, smanjene multifunkcionalnosti.

S druge strane tla narušene multifunkcionalnosti su tla poplavnih ekosustava, primjerice u Turopolju, Pokuplju i Lonjskom polju. Ta tla nisu promijenila svoja svojstva, ali su se hidrološke prilike uvelike pogoršale, što štetno djeluje osobito na stare šumske sastojine. Te se promjene pripisuju različitim infrastrukturnim zahvatima u prostoru (kanali, ceste itd.), a očituju se najčešće spuštanjem razine podzemne vode i izazivanjem fiziološke suše u zoni rizosfere ili dugotrajnim stagniranjem površinske vode.

U prostornoj raščlambi pedosfere šuma u Županiji izdvaja se osobito 5 kartografskih jedinica koje obuhvaćaju najveće šumske komplekse. To su:

1. kartografska jedinica (2) s tlima na karbonatnim supstratima Žumberka i Medvednice
2. kartografska jedinica (13) s lesiviranim i pseudoglejnim tlima Vukomeričkih gorica
3. kartografska jedinica (16) s pretežito pseudoglejnim tlima prigorja i pobrđa
4. kartografska jedinica (23) s glejnim tlima Pokuplja, Turopoljskoga luga, Varoškoga luga i Lonjskoga polja
5. kartografska jedinica (7) s distričnim smeđim tlima na metamorfitima Medvednice.

Tih 5 kartografskih jedinica pokriva preko 63 % šumskih površina Županije i nositelji su temeljnih obilježja ukupne pedosfere šumskih ekosustava.

Ključne riječi: Zagrebačka županija, tlo, pedosfera