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Characteristics and Classification of Gleyic Soils of Banat

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Summary: In this paper we investigated basic characteristics of gleyic soils of Banat and presented different interpretations and classification of these soils. Twelve profiles were analyzed to access their physical and chemical properties. Investigated humogley profiles were predominantly clayic with vertic properties and under different influence of groundwater. Most of these soils we classified in Vertisols, but some of them we considered as Gleysols or Chernozems RSG (reference soil group). Eugley was under stronger influence by groundwater than humogley and showed textural uniformity, less clay content and notably higher average content of $CaCO_3$. Eugley profiles we classified in Gleysols RSG. Every new analyzed soil profile has to be considered in particular regarding its diagnostic horizons, properties and materials and cannot be transferred from actual national classification to RSG by default.
Key words: Banat, eugley, Gleysols, humogley, soil classification, Vertisols

Introduction

Humogleys comprise one of the most important soil resources in Serbia. This soil covers 370,000 ha of the Republic of Serbia and most of it is located in Banat (228,000 ha). Humogley is characterized with both humic and gleyic horizons which gives this soil its name. According to Soil Classification of Yugoslavia (Škorić et al. 1985), which is predominately focused on genetic properties, humogley is considered as hydromorphic black soil developed under influence of groundwater and classified in A-G class. Regarding its geomorphologic properties, it is soil of the lowest parts of river flood areas, lower river and loess terraces and large depressions which were mainly under permanent influence of water in some cases even until up to soil surface. About 200 years ago humans first started performing hydrotechnical amelioration at these wastelands and this has been performed until today. Significant areas of these wetlands were included in arable lands by making pipe drainage in combination with open channel systems. Knowing that Banat was covered by huge muddy areas, Ianoş (2004) claims that drainage in Romania gave huge lands to agriculture. Humogley is predominately clayic as a result of clayic parent material or destruction of minerals and argillo-synthesis induced by excessively wet conditions and alternate oxidizing and reducing processes in dry and wet periods during season. These alternate wet and dry conditions are a prerequisite for development of vertisols. Aleksandrović et al. (1973) found high clay content in "hydromorphic vertisols" of Vojvodina and highest percent of montmorillonite clay which is evenly distributed within profile. The same authors also concluded that humogleys have higher content of montmorillonite clay in relation to other investigated soils (chernozems, cambisols, solonchaks and solonetz).

Strong influence of surface flooding water induces a large number of humogey localities significant leaching of $CaCO_3$ despite its clayic texture. On the other hand, in the same climatic conditions most of areas under humogley were not affected by this process due to stronger influence of groundwater. However, most of them were not affected by leaching indicating prevailing ground water effects, and the most responsible factor for this is dominant influence of ground water. Alluvial and lake deposits, redeposited loess and sand are parent materials for humogley formation. Miljković (1996)

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characterized humogley as potentially fertile soil with main problem related to clayic texture, which in combination with long wet period induces poor air-water relationship.

Eugley is the soil of the wetlands much more affected by water than humogley, with evidence of gleyic colour near the surface and groundwater level even higher than 80 cm. Most of the total eugley area in Vojvodina (15,269 ha) is situated in Banat (7,186 ha).

Recognizing the different characteristics of hydromorphic soils developed in river flood areas and river valley depressions, the correct classification of these soils becomes unclear. Especially heterogenic are hydromorphic clayic soils of Banat lowlands, influenced by groundwater which can be salinized or alkalized. One of the ideas for classification of hydromorphyc soil with vertic properties was to separate it as a new soil type called "gleyic vertisol". This idea was included in proposal of Soil Classification of Yugoslavia in Ohrid in 1963, but was later abandoned because of different ways in moistening between vertisol and humogley. In the current Soil Classification of Yugoslavia (Škorić et al. 1985) the term "gleyic vertisol" does not exist, while current Soil Map of Vojvodina R-1:50000 (Nejgebauer et al. 1971) contains this term. Certainly, "gleyic vertisol" covers 79,770 ha in Banat (Živković et al. 1972) and this term is still under debate between researchers in Serbia.

The aim of this study was to investigate chemical and physical characteristics of humogley and eugley, which will enhance understanding of its genesis and behavior and to classify it according to the FAO 2006 classification (IUSS Working Group WRB, 2006).

Materials and Methods

Site Descriptions

Banat is a geographical and historical region in central Europe divided among three countries - Serbia, Romania and Hungary. The western part of Banat is an eastern part of Vojvodina province of Serbia. Located in the south part of the Carpathian basin, Banat is influenced by moderate continental climate which is characterized by hot dry summer and cool winter. Mean annual temperature and rainfall for

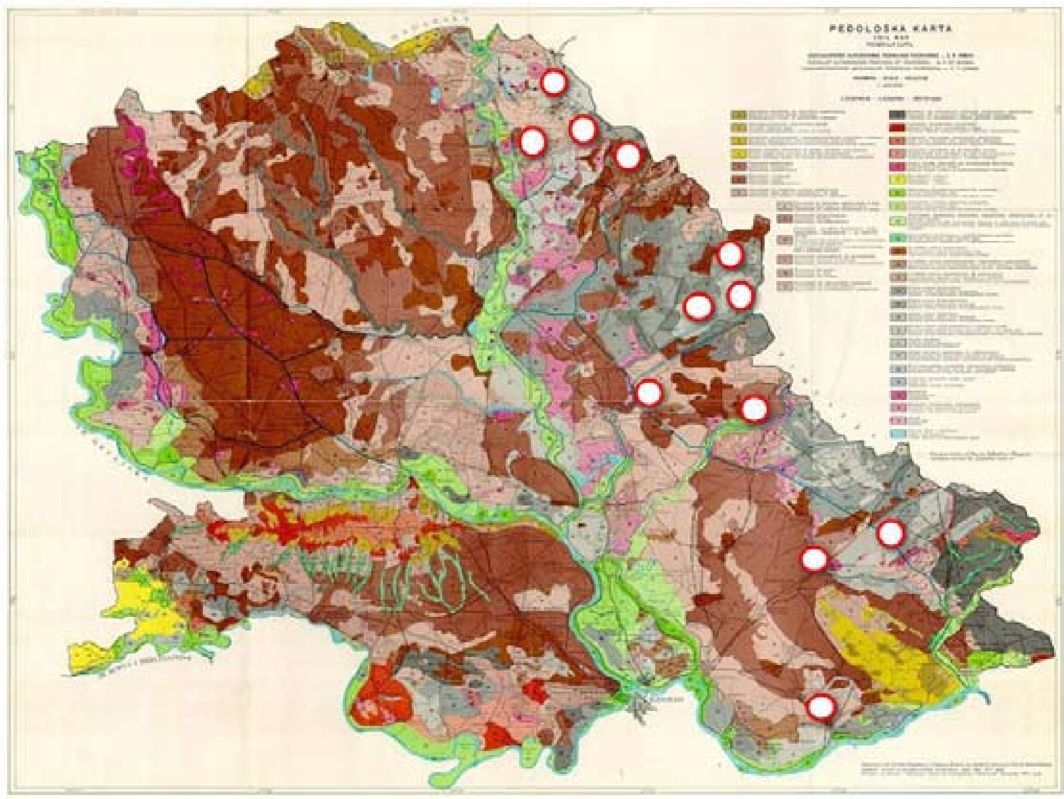

Figure 1. Locations of the investigated soil profiles in Banat on the Soil map of Vojvodina
Slika 1. Lokacije ispitivanih profila u Banatu na Pedološkoj karti Vojvodine

north (Kikinda), middle (Zrenjanin) and south (Vršac) Banat fall in the range of 10.7-11.3°C and 540-650 mm. Twelve locations were selected to represent studied soil types (Fig. 1). Ten profiles under humogley (Banatsko Karađorđevo, Crna Bara, Vojvoda Stepa, Banatsko Aranđelovo, Jankov Most, Mokrin, Hetin, Skorenovac, Čoka and Vršački Ritovi) and two profiles under eugley (Boka and Alibunar) were analyzed. Most of the studied soils were arable land and some of them were under natural vegetation.

Soil Sampling and Analyses

Studying physical and chemical properties of soil is essential to understand its genesis, behaviour and evolution. Hence, we took disturbed and undisturbed (100 cm^3 cylinders) soil samples from every genetic horizon. Disturbed samples were air dried and sieved through a 0.2 mm sieve prior to analysis. Particle density and soil bulk density were measured by the pycnometer method and core method, respectively. Total porosity was calculated from particle density and soil bulk density. Soil texture was determined by the pipette method. Apparatus for determination of water-permeability of undisturbed soil sample was used according to Živković (1968). Soil acidity in 1:2.5 soil water and soil KCl suspension as well as pH value of soil paste were determined using pH meter. The $CaCO_3$ content was determined volumetrically using Scheibler calcimeter. Humus content was determined by wet oxidation method with $K_2Cr_2O_7$, while the total nitrogen content was calculated empirically from organic carbon content. P_2O_5 and K_2O content was determined by Al-method. Total salt content in water saturated soil paste and electrical conductivity of saturated soil extract were measured using conductometer.

Results and Discussion

Soil Properties

In order to determine characteristics of the examined profiles, soil properties were presented separately for surface (0-30cm) horizon and the whole profile.

Textural analysis of humogley profiles (Tab. 1) showed that clay content reaches even 58.3% and more clayic composition were in upper (0-30cm) horizons with texture varying from loamy to heavy clay. Parent material was substantially different and varying from sandy (86.8% coarse sand) to clayic (49.2% clay). Eugley shows textural uniformity (Tab. 2) and less clay content through profile. The bulk and particle density was lower in surface horizon than in lower horizons of humogley, but eugley showed higher particle density in surface horizon. Khresat & Taimeh (1998) observed lowest bulk density in Ap horizon of vertisols which increased with depth and explained that it was related to organic matter content and by loosening of the soil material. Filtration of humogley varies from good ($8.36 \cdot 10^{-3}$ cm/s) to low ($2.18 \cdot 10^{-5}$ cm/s), while eugley shows even very low values ($6.50 \cdot 10^{-6}$ cm/s). Only three profiles of humogley are not calcareous from surface. The $CaCO_3$ content ranged from 0% to 38.30% and increased with depth for both studied soil types. Eugley showed notably higher average content of $CaCO_3$ than humogley in both, whole profile and surface horizon which can be explained with greater influence of groundwater on eugley. In surface layer humus content ranged from 1.50% to 5.23% (humogley) and from 1.82% to 3.44% (eugley). Witkowska-Walczak (2003) found 4.1-5.5% humus in arable layer of mollic gleysol which is higher than observed humus content in our study. The pH measured in water reached very high values (9.26, 9.63 and 10.03) in surface horizons of three humogley profiles and one eugley (9.66) due to high level of sodium in these samples. Total salt content in two humogley profiles reaches 0.22% and 0.35% but only in lower horizons. Studied huomogley have high average content (29.00 mg/100g) of P_2O_5 and very high-harmful average content of K_2O (57.54 mg/100g) in surface horizon (0-30 cm), while eugley showed low average content (5.70 mg/100g) of P_2O_5 and optimal (24.96 mg/100g) of K_2O for same depth. According to our findings, it can be emphasized that high clay content can be a factor which could limit high agricultural potential of humogley, in addition to poor air-water regime and high pH values. Özsoy & Aksoy (2007) found summer drought, low organic matter content, high contents of clay and $CaCO_3$, formation of the hard pan and water infiltration as main limitation factors regarding vertisols productivity for selected samples that vertisols they studied. Based on the analysis of over 77,000 samples in Vojvodina, there is a negative balance of soil organic matter and we can expect further reduction in fertility and deterioration of physical and chemical properties of soil (Sekulić et al. 2010). Nešić et al. (2008) cite that preventive actions are most important for protection of soil from degradation, identifying hazards and finding appropriate solutions to overcome them. One of the preventive actions is implementation of Soil Fertility Control System, which was established in 1980 and legislated in 1985 (Vasin et al. 2006).

Table 1. Minimum, maximum and average values of main physical and chemical properties of humogley
Tabela 1. Minimalne, maksimalne i prosečne vrednosti glavnih fizičkih i hemijskih osobina humogleja

Humogley	CS*	FS	S	C	F	SMz	SMp	TP	$CaCO_3$	Humus	N	pH	pH	P_2O_5	K_2O	SA	ECe	pH
		%			cm/s	g/cm^3		%		%		KCl	H_2O	mg/100g		%	mS/cm	soil paste
max	86.80	62.74	42.90	58.30	$8.36\cdot10^{-3}$	1.70	2.95	61.70	37.61	5.28	0.30	8.75	10.03	64.00	132.00	0.35	9.06	9.85
min	0.08	8.20	1.80	3.20	0	1.08	2.24	31.73	0.00	0.19	0.01	5.57	6.85	1.10	5.00	<0.03	0.42	6.19
$max_{0\text{-}30cm}$	29.10	52.28	41.08	58.30	$8.36\cdot10^{-3}$	1.54	2.79	60.10	19.01	5.23	0.30	8.12	9.30	64.00	132.00	0.12	1.80	8.85
$min_{0\text{-}30cm}$	0.24	10.50	13.16	25.08	$2.18\cdot10^{-5}$	1.09	2.24	36.63	0.00	1.50	0.11	5.57	6.85	4.90	21.40	<0.03	0.42	6.19
average	6.44	31.37	28.77	34.01	$7.50\cdot10^{-4}$	1.53	2.64	41.82	15.47	1.53	0.10	7.46	8.52	14.09	39.40	0.09	1.84	8.19
$average_{0\text{-}30cm}$	4.31	31.68	26.83	37.19	$1.48\cdot10^{-3}$	1.40	2.54	44.32	4.62	3.16	0.20	7.00	8.01	29.00	57.54	0.06	0.80	7.59

***CS**-Coarse sand**; FS**-Fine sand**; S**-Silt**; C**-Clay; **F**-Filtration; **SMz –** Bulk density; **SMp –** Particle density; **TP**-Total porosity; **SA**-Total salt content; **ECe** – El. conductivity of saturated soil extract at 25°C.
***CS**-Krupan pesak**; FS**-Sitan pesak**; S**-Prah**; C**-Glina; **F**-Filtracija; **SMz –** Zapreminska masa; **SMp –** Prava specifična masa; **TP**-Ukupna poroznost; **SA**-Ukupan sadržaj soli; **ECe** – El. konduktivitet saturisanog ekstrakta zemljišta na 25°C.

Table 2. Minimum, maximum and average values of main physical and chemical properties of eugley
Tabela 2. Minimalne, maksimalne i prosečne vrednosti glavnih fizičkih i hemijskih osobina eugleja

Eugley	CS	FS	S	C	F	SMz	SMp	TP	$CaCO_3$	Humus	N	pH	pH	P_2O_5	K_2O	SA	ECe	pH
		%			cm/s	g/cm^3		%		%		KCl	H_2O	mg/100g		%	mS/cm	soil paste
max	10.80	51.48	38.40	38.84	$8.53\cdot10^{-4}$	1.71	2.81	52.16	38.30	3.44	0.24	8.66	9.89	9.30	33.51	0.14	3.33	9.01
min	0.10	23.42	16.20	20.68	$6.50\cdot10^{-6}$	1.31	2.47	39.14	6.37	0.29	0.02	7.17	8.31	1.10	8.20	<0.03	0.48	7.91
$max_{0\text{-}30cm}$	10.80	50.04	30.28	38.84	$4.37\cdot10^{-4}$	1.55	2.78	51.65	26.36	3.44	0.24	8.14	8.86	8.50	33.51	0.05	1.27	8.26
$min_{0\text{-}30cm}$	1.70	29.18	18.48	20.68	$6.50\cdot10^{-6}$	1.31	2.71	44.24	6.37	1.82	0.13	7.17	8.31	2.90	16.40	0.05	0.48	7.91
average	2.70	40.06	27.77	29.47	$3.89\cdot10^{-4}$	1.58	2.71	44.77	24.80	1.00	0.07	8.06	9.20	4.33	15.21	0.08	1.80	8.57
$average_{0\text{-}30cm}$	6.25	39.61	24.38	29.76	$2.22\cdot10^{-4}$	1.43	2.75	47.95	16.37	2.63	0.18	7.66	8.59	5.70	24.96	0.05	0.88	8.09

***CS**-Coarse sand**; FS**-Fine sand**; S**-Silt**; C**-Clay; **F**-Filtration; **SMz –** Bulk density; **SMp –** Particle density; **TP**-Total porosity; **SA**-Total salt content; **ECe** – El. conductivity of saturated soil extract at 25°C.
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Soil Genesis and Classification

The soils we investigated are identified as humogleys and eugleys according criteria of Soil Classification of Yugoslavia (Škorić et al. 1985). On the Soil Map of Vojvodina (Nejgebauer et al. 1971) we found investigated localities defined as humogleys, gleyic vertisols, eugleys, chernozems and solonchaks.

Eugley profiles were strongly influenced with groundwater and due the appearance of diagnostic properties (reducing conditions and gleyic colour pattern) we classified it in Gleysols RSG (reference soil group) at first level of classification according FAO 2006 classification (IUSS Working Group WRB, 2006). But humogley profiles were more or less influenced by groundwater and many of them have high clay content and vertic properties which can cause serious doubt regarding RSG classification these soils. In majority of the investigated profiles we cannot identify reducing conditions within 50 cm of the mineral soil surface as mandatory

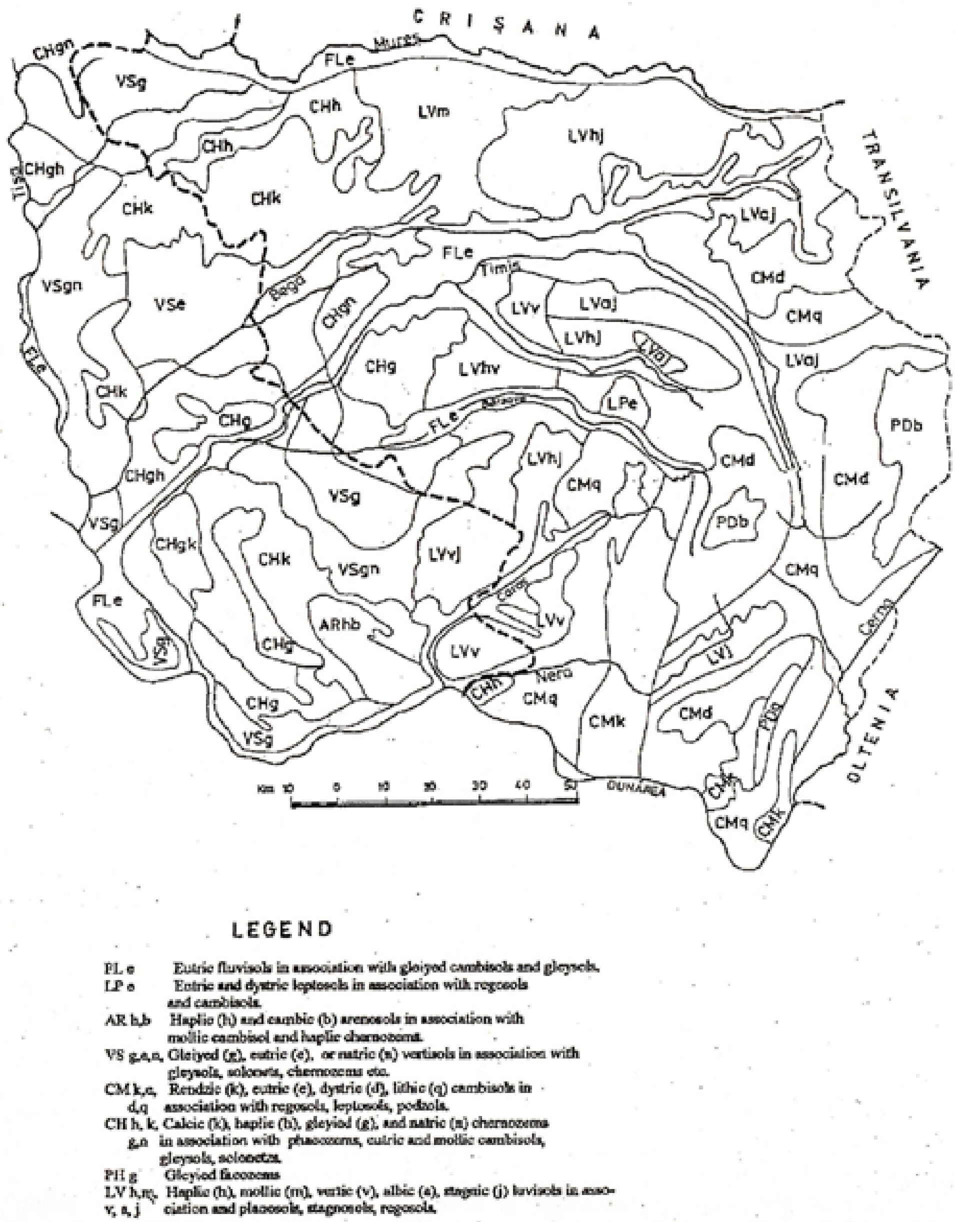

Figure 2. The soil associations in Banat (Source: Ianoş 1997, cit. Ianos 1995; Nejgebauer 1972)
Slika 2. Asocijacije zemljišta Banata (Izvor: Ianoş 1997, cit. Ianos 1995; Nejgebauer 1972)

diagnostic property for Gleysols RSG. Influence of groundwater was an evident soil-formation process on these humogleys but these soils in Banat were exposed to more terrestrial genesis many years after drainage. It is recognized that an understanding of soil-forming processes contributes to a better characterization of soils but that they should not, as such, be used as differentiating criteria according FAO 2006. One important fact of Gleysols genesis is that these soils are often under water and cannot express vertic properties as consequence of wetting and drying conditions specific for vertisols. Belić et al. (2003) claim that drought is a regular phenomenon in the climatic conditions of the Vojvodina Province. Most of humogley profiles we analyzed are able to shrink when dried and to swell when moistened, which refers to vertisols. Adjei-Gyapong & Asiamah (2002) expressed the view for an introduction of vertic qualifier in the Gleysols RSG. We found that in half of the investigated profiles, vertic horizon and minimal horizon differentiation was probably the result of pedoturbation. Živković et al. (1972) cited Nejgebauer & Kukin (1966) who concluded that heavy humogleys in Potisje have similar clay content and composition (smectite group) as typical vertisols on tertiary clayic lake sediments or clayic regolith of alkaline rocks in central Serbia, Macedonia and Bulgaria. Large percent of clay from smectite group is the main constituent of vertisols. Craciun et al. (2010) say that dominant mineralogical components of the clay from soils of Banat area are illite and smectite.

The main point of divergence between Soil Classification of Yugoslavia (Škorić et al. 1985) and FAO 2006 classification (IUSS Working Group WRB, 2006) regarding humogley and vertisol is that in the national classification vertisol is considered as soil with terrestric pedogenesis, which is contrary to FAO 2006 classification where Vertisols RSG are classified in soil group influenced by water.

If we summarize the listed characteristics of the investigated humogley profiles, we can conclude that majority refers to Vertisols not to Gleysols RSG. Hence, we classified humogley with evident presence of vertic horizon and more than 30% clay in Vertisols rather than Gleysols RSG at first level of classification. At the second level of classification we added a gleyic prefix as a qualifier intergrades to gleysol RSG and a mollic prefix as presence of mollic horizon. In the situation where we found lack of both vertic horizon and reducing conditions within 50 cm but presence of mollic horizon with appropriate colour and secondary carbonates, logically by WRB rules we classified humogley in chernozem RSG. Ćirić (1984) notes that humogley is similar to chernozem and cites name of this soil in some European classification (Schwartzerdeartigen Auenbōden, Sols Alluviaux Chernosemiques). Ianoş (2002) cites that in the western extremity of Banat plain mollic gleysols, typical gleysols, gleyed vertisols have evolved together with solonetz.

Naturally, we can conclude that every new soil profile has to be considered in particular regarding its diagnostic horizons, properties and materials and cannot be switched from actual national classification to FAO 2006 RSG by default.

Conclusions

Humogley covers 228,000 ha of Banat and comprises one of the most important soil resources in Serbia.

It is predominantly clayic soil developed on different calcareous parent materials. Most of the studied profiles show vertic phenomena. Bulk density and total porosity are little above optimal. Humogley is calcareous, but not always from surface. Average pH value is neutral to alkaline, but in some cases because presence of sodium reaches very alkaline values. Surface layer contains 1.50% to 5.23% humus and high average content of P_2O_5 and very high-harmful content of K_2O.

Eugley is soil under stronger influence by groundwater than humogley. Eugley shows textural uniformity, less clay content through profile and notably higher average content of $CaCO_3$ than humogley. Humus content ranges from 1.82% to 3.44% while average content of P_2O_5 is low and of K_2O is optimal.

High clay content, hence poor air-water regime and high pH values are factors which limiting high agricultural potential of humogley.

Soils identified as humogleys according to Soil Classification of Yugoslavia we considered as members of Gleysols, Vertisols or chernozem RSG, while eugleys we classify in Gleysols RSG according to WRB.

Every soil profile has to be considered in particular regarding its diagnostic horizons, properties and materials and cannot be switched from actual national classification to FAO 2006 RSG by default.

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Karakteristike i klasifikacija glejnih zemljišta Banata

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Izvod: U ovom radu su ispitivane osnovne karakteristike glejnih zemljišta Banata i predstavljena različita tumačenja i klasifikacije ovih zemljišta. Analizirana su fizička i hemijska svojstva dvanaest profila zemljišta. Ispitivani humogleji su uglavnom bili glinoviti i ispoljavali vertičnost, dok je uticaj podzemnih voda na svaki profil bio različit. Većinu ovih zemljišta smo svrstali u vertisole, ali neke od njih možemo klasifikovati u referentne grupe zemljišta (RSG) glejsoli ili černozemi. Euglej je bio pod jačim uticajem podzemnih voda od humogleja i pokazivao je veću teksturnu uniformnost, manji sadržaj gline i veći prosečan sadržaj $CaCO_3$. Ispitivani euglej smo svrstali ureferentnu grupu zemljišta glejsoli. Svaki novi profil zemljišta koji se bude analizirao trebalo bi da se posmatra posebno u pogledu njegovih dijagnostičkih horizonata, svojstva i materijala. Nijedan tip zemljišta ne sme biti prebačen u referentnu grupu po podrazumevanom nazivu.
Ključne reči: humoglej, euglej, glejsoli, vertisoli, Banat, klasifikacija zemljišta