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Soil of the lower valley of the Dragonja river (Slovenia)

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ABSTRACT

Soil of the lower valley of the river Dragonja developed under specific soil-forming factors. Soil development in the area was influenced by alluvial sediments originating from surrounding hills, mostly of flysch sequence rocks, as a parent material, Sub-Mediterranean climate and the vicinity of the sea. Different soil classification units (Gleysol and Fluvisol) were proposed for that soil in previous researches. The aim of our study was the evaluation of morphological, chemical and mineralogical characteristics of soil, based on detailed soil description and analyses, and to define the appropriate soil classification units. Field examinations revealed that the soil had a stable blocky or subangular structure and did not express substantial hydromorphic forms. Soil pH value was ranging from 6.9 to 7.5. In most locations electroconductivity (ECe) did not exceed 2 ds/m. Base saturation was high (up to 99 %), with a majority of Ca^{2+} ions. Exchangeable sodium percentage (ESP) was ranging from 0.2 to 3.8 %, which is higher compared to other Slovenian soils but does not pose a risk to soil structure. Soil has silty clay loam texture with up to 66 % of silt. Prevailing minerals were quartz, calcite and muscovite/illite. No presence of swelling clay mineral montmorillonite was detected. According to Slovenian soil classification, we classified the examined soil as alluvial soil. According to WRB soil classification, the soil was classified as Cambisol.

Key words: soil classification, soil properties, mineralogical characteristics, salinity

IZVLEČEK

TLA SPODNJEGA DELA DOLINE REKE DRAGONJE (SLOVENIJA)

Tla spodnjega dela doline reke Dragonje so se razvila pod vplivom specifičnih tlotvornih dejavnikov. Rečni sediment iz kamnin flišnega porekla kot matična podlaga, submediteransko podnebje in prisotnost morja so vplivali na razvoj tal. Predhodne raziskave tal na tem območju so tla različno poimenovale; uvrščale so jih bodisi med oglejena bodisi obrečna tla. Namen naše raziskave je bil na osnovi natančnega opisa morfoloških latnosti tal in kemičnih ter mineraloških analiz podati predlog poimenovanja tal. Ugotovili smo, da imajo tla obstojno poliedrično ali oreškasto strukturo in ne izkazujejo intenzivnih hidromorfnih oblik. pH je od 6.9 do 7.5. Na večini vzorčnih mest elektrokonduktivnost nasičenega vzorca tal ne presega 2 ds/m. Zasičenost z bazami je visoka (do 99 %), prevladujejo kalcijevi ioni. Izmenljivi delež Na je od 0.2 to 3.8 %. Tekstura je meljasto glinasto ilovnata, z deležem melja do 66 %. Prevladujoči minerali v tleh so kremen, kalcit in muskovit/illit. Nabrekljivih glinenih mineralov (montmorillonita) nismo ugotovili. Na osnovi slovenske klasifikacije tla uvrščamo med obrečna tla, po WRB klasifikaciji med kambična tla.

Ključne besede: klasifikacija tal, lastnosti tal, mineraloška sestava, slanost

1 INTRODUCTION

Soil of the lower Dragonja river valley formed on alluvial deposits of weathered flysch. The majority of the recent sediments were deposited by the River Dragonja, cutting its riverbed along the contact between flysch rocks and limestone, discharging in the sea near Sečovlje in the form of a minor delta (Pleničar et al., 1973a; 1973b). X-ray diffraction analyses of recent sediment underlying

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the Sečovlje saltpans showed prevalence of quartz and low Mg-calcite over clay minerals (illite and chlorite group minerals) and minor content of feldspars and dolomite (Ogorelec et al., 1981). The recent sediments of Sečovlje Draga lie over Eocene flysch rocks, where up to 15 cm thick calcarenite beds interchange with marls. Sharp contact between them is at 40 m depth. Sediment pollen analyses showed that Holocene forest vegetation was continuously thermophile, indicating that the entire sediment has been deposited in postglacial times, i.e. less than 10,000 years ago. In the past, the Dragonja River flow has been much more turbulent and able to deposit large amounts of sediment in short periods of time. According to calculations, the average rate of sedimentation was 2.9 cm per year. Such a quantity of sediment material could be explained only by postglacial tectonics, e.g. gradual subsidence of Sečovlje coast, along which the Dragonja River delta has been simultaneously filled up (Ogorelec et al., 1981). Recent climate is Sub-Mediterranean. Average annual temperature and precipitation rate for the period 1971-2000 were 12.8 °C and 931.2 mm, respectively (Slovenian environment agency, 2014).

According to the Soil map of Slovenia 1:25.000, soil of the lower valley of the Dragonja River are characterised as alluvial soil (pedocartographic unit 1086, Figure 1). Earlier studies, which have been made for intended hydromeliorations (Bašić, 1976), reported gleyic properties in the soil, which was thus classified as gley soil. In the study "Soils of the Slovenian Coastal region" (Stepančič et al., 1984) the soil of the investigated area was also classified as gley soil. The renaming of the recognized type to alluvial occurred later, at the time of digitalization and merging of individual soil maps. Revision of the soil map, charting lower valley of Dragonja River (Soil map Buje), was done by Šporar et al. (1994). The researched area is currently in agricultural land use; vineyards and orchards are prevalent. The exception is the northern part, which is abandoned and in the process of overgrowing due to socio-economic factors. Speculations have been raised for this area about lower soil fertility, salinity and extreme hydromorphic soil properties (Rupreht, 2008). Since the Soil map does not refer to any saline soils in Slovenia, we decided to examine the properties of the soil in more detail. The aim of our research was also to propose an appropriate soil name according to Slovenian and WRB soil classification, taking in account morphological, chemical and mineralogical soil properties.

2 MATERIALS AND METHODS

2.1 Field examination

Research area was examined with soil probing (18 locations) from the surface to the depth of 100-120 cm. Four soil profiles were dug to the depth of 80 to 100 cm and described according to the Guidelines for soil description (FAO, 2006). Field examination was done in March and April 2013, March 2014 and January 2015. Locations of the profiles and probings were identified with GPS and are presented in Figure 1. Soil samples were taken from each soil horizon of the profiles for mineralogical and chemical analyses, and from three different depths of soil probes (0-30 cm, 30-60 cm and 80-100 cm) for measurement of electroconductivity.

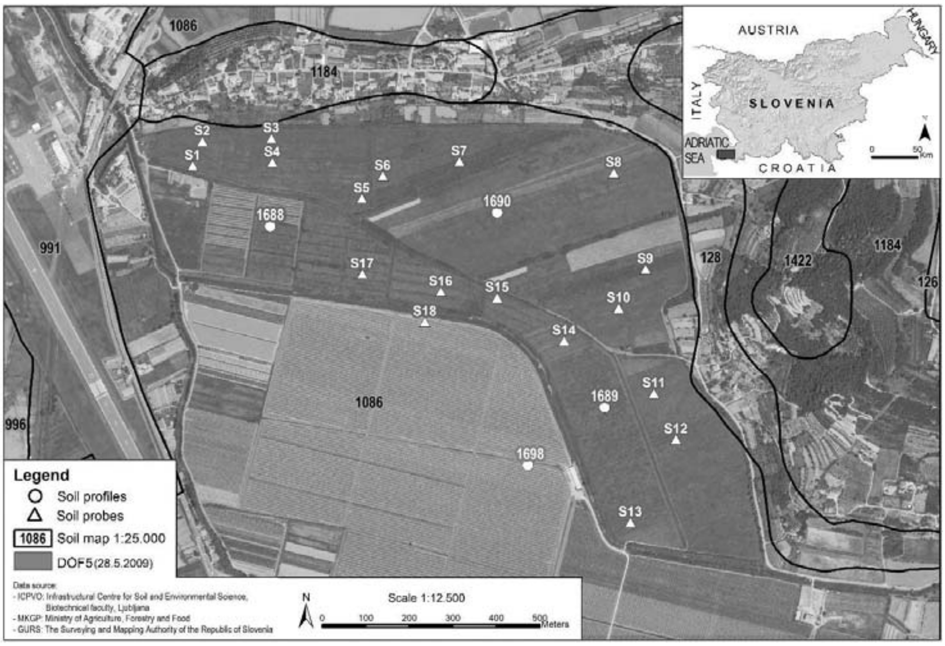

Figure 1: Locations of soil profiles and probes and information of Soil map of Slovenia 1: 25.000. Soils of the research area belong to pedocartographic unit 1086, which consists of two pedosystematic units: 60 % alluvial soil, eutric, deep, on loamy alluvium and 40 % alluvial soil, eutric, deeply gleyed, on loamy alluvium. Soils of surroundings are: pedocartographic unit 128 – Eutric brown soil, on Eocene flysch, colluvial; pedocartographic unit 1184 – Eutric brown soil, on Eocene flysch, calcareous, shallow and pedocartographic unit 991 – Urban area

2.2 Soil analyses

For analysis, soil samples were air-dried and sieved to 2 mm (ISO 11464, 2006). Soil pH was measured in a 1/2.5 (v/v) ratio of soil and 0.01 M $CaCl_2$ suspension (ISO 10390, 2005). Organic matter content was determined by modified Walkley–Black titrations (ISO 14235, 1998), soil texture by the pipette method (ISO 11277, 2009), carbonate content volumetrically after soil reaction with HCl (ISO 10693, 1995), easily extractable P (P_2O_5) and K (K_2O) colorimetrically according to Egner-Riehm-Domingo (ÖNORM L 1087, 1993). Cation exchange capacity (CEC) was determined as a sum of base cations measured after soil extraction with ammonium acetate (pH = 7) and extractable acidity determined with $BaCl_2$ method (Soil Survey laboratory methods manual, 1992). Results are shown in table 1.

Soil salinity was evaluated with tree parameters: electroconductivity of saturated sample (ECe), exchangeable sodium percentage (ESP) and Sodium adsorption ratio (SAR). ECe was calculated from electroconductivity of soil extract (ECw) measured in a 1/5 (v/v) ratio of soil and deionised water (ISO 11265), using factor 9. Sodium adsorption ratio was calculated as a ratio between concentrations of Na^+ versus Ca^{2+} and Mg^{2+} (equation 1) measured in soil water extract (1:5). Exchangeable sodium percentage was calculated as a ratio between Na and cation exchange capacity (equation 2).

$$SAR = \left(\frac{Na^+}{\frac{1}{2}(Ca^{2+} + Mg^{2+})^{1/2}}\right) \qquad \text{equation 1}$$

$$ESP = \left(\frac{Na^+}{CEC}\right) 100 \qquad \text{equation 2}$$

Qualitative mineral composition of the non-oriented air dried samples was determined by X-ray diffraction (XRD) using a Philips PW 3830/40 diffractometer equipped with CuKα radiation and a graphite monochromator. The X-ray radiation was generated at a voltage of 40 kV and a current of 30 mA. Data were recorded in the range $2^\circ \leq 2\Theta \leq 70^\circ$. Diffractograms were analysed using the PANalytical X'Pert HighScore software.

3 RESULTS AND DISCUSSION

3.1 Soil morphological characteristics

The four examined profiles were very similar in morphological properties. As a result of trench ploughing, a layer with anthric properties (P horizon) formed in the soil. However, due to abandoned land use and the area regrowing with herbs, weeds, grasses and bushes a less than 10 cm thick pale A surface horizon could be distinguished on the top of the anthric matrix in soil profiles 1688, 1689 and 1690. In these three profiles the effect of trench ploughing was visible at depths between 23 and 42 cm. In profile 1698, which is still in agricultural use, two P horizons formed and extended to a depth of 57 cm. Aric P horizons were followed by two layers of clayey sediments with morphological properties showing an initial transformation from alluvial layer to cambic horizon. At the deepest soil layer gleyic properties were recognized by very weakly expressed mottles with reductimorphic colours (IUSS Working Group WRB, 2014). However, soil probing revealed that the mottles have been almost always detected lower than 80 cm. Reductimorphic colour only appeared in profile 1690 at 110 cm as matrix colour GLEY1 6/5GY (greenish gray) according to Munsell, 2013. In all soil profiles well developed, stable, blocky subangular and angular soil structure was clearly observable. No platy or prismatic structure has been recognised even in the lowest examined horizons.

Table 1: Morphological characteristics of soil

Profile	Horizon	Soil depth (cm)	Colour*	Structure	Consistency when moist	Roots	Pedogenetic forms
1688	A	0 - 6	10YR 4/3	blocky-subangular	friable, sticky	many	-
1688	P	6 - 23	10YR 5/3	blocky	friable, sticky	common	-
1688	I(B)	23 - 50	10YR 6/3	blocky	friable, sticky	few	-
1688	II(B)	50 - 80	10YR 6/4	blocky	friable, sticky	very few	few mottles
1689	A	0 - 8	10YR 5/3	blocky-subangular	friable, plastic	common	-
1689	P	8 - 42	10YR 5/4	blocky-subangular	friable	few	-
1689	I(B)	42 - 65	10YR 5/4	blocky	friable	very few	-
1689	II(B)	65 - 80	2,5Y 6/2	blocky	firm	very few	few mottles
1690	A	0 - 8	10YR 4/3	blocky-subangular	friable, sticky	common	
1690	P	8 - 30	10YR 5/3	blocky	friable	few	
1690	I(B)	30 - 65	2,5Y 4/4	blocky	friable, sticky	very few	
1690	II(B)	65 - 80	2,5Y 4/4	blocky	firm, plastic	very few	
1690	III(Go)	80-110+	2,5Y 5/6, GLEY1 6/5GY	blocky	firm, plastic	no	weak mottles
1698	P1	0-29	10YR 4/4	blocky	firm, frable	many	-
1698	P2	29-57	10YR 4.5/4	blocky	firm, friable	common	-
1698	I	57-80	10YR 5/4	blocky	firm, friable	few	-
1698	II	80-100	10YR 5/4	blocky	firm, friable	no	-

*soil colour was identified using Munsell soil colour chart

3.2 Chemical and physical soil characteristics

Analyses of soil samples confirmed soil homogeneity established already by field observation. Texture was silty clay loam with a high proportion of silt (from 57 to 65 % and very low amount of sand, less than 5 %). Soil pH was neutral to slightly alkaline and reached 7.5 at deepest horizons. High pH values were the result of high content of carbonates, which were in the range from 24.1 to 28.9 % and originated from flysch material. The amount of organic matter decreased with soil depth and varied among profiles due to the different land use. In profile 1698, which was located in the vineyard; P horizon contained 2.4 % of soil organic matter. In profiles 1688, 1689 and 1690, which were located in the abandoned orchard or vineyard, soil organic matter in the humus-accumulative horizons ranged from 4.4 to 7.5 %. Higher content of organic matter is a consequence of overgrowth processes, mostly with grasses and herbal plants. All horizons were rich in plant-available potassium as the result of high contents of clay minerals (illite/muscovite) as well as intensive fertilization. Soil from profiles 1688 and 1689 also had high content of plant-available phosphorus due to fertilization in the past. Cation exchange capacity was high; ranging from 38 to 43 $mmol_c$/100 g soil. The high proportion of clay contributes most to the high CEC. Base saturation was very high, almost 99 %. Among cations Ca^{2+} ions were prevalent (from 88 to 99 %).

Table 2: Chemical and physical soil characteristics

Profile	Horizon	Soil depth	Sand	Silt	Clay	Texture	pH	Org. matter	C	N	C/N	P_2O_5	K_2O	Carbonate
		cm	%	%	%			%	%	%		mg/100g		%
1688	A	0 - 6	< 2	60	39	SCL	7.0	7.5	4.3	0.48	9.1	26.0	63.1	24.1
1688	P	6 - 23	< 2	59	40	SCL	7.2	3.7	2.1	0.32	6.6	11.4	41.3	24.9
1688	I(B)	23 - 50	4	57	39	SCL	7.3	2.2	1.3			3.5	28.1	26.1
1688	II(B)	50 - 80	< 2	60	41	SC	7.4	1.5	0.9			2.9	22.3	26.1
1689	A	0 - 8	5	64	31	SCL	6.9	5.1	3.0	0.41	7.4	35.8	60.7	24.1
1689	P	8 - 42	3	64	33	SCL	7.3	2.1	1.2	0.22	5.4	8.0	37.2	28.6
1689	I(B)	42 - 65	2	64	34	SCL	7.4	1.2	0.7			2.8	20.4	27.8
1689	II(Go)	65 - 80	< 2	61	38	SCL	7.4	1.0	0.6			3.0	20.4	27.4
1690	A	0 - 8	< 2	60	39	SCL	7.0	4.6	2.7	0.37	7.3	4.2	35.0	25.7
1690	P	8 - 30	2	59	39	SCL	7.2	2.3	1.3	0.24	5.4	2.7	25.0	25.3
1690	I(B)	30 - 65	< 2	57	42	SC	7.4	1.2	0.7			1.7	22.8	27.4
1690	II(Go)	65 - 80	< 2	58	41	SC	7.4	1.0	0.6			2.4	21.8	27.0
1698	P1	0-29	2	66	32	SCL	7.2	2.4	1.4	0.13	10.8	9.1	28.9	27.3
1698	P2	29-57	3	65	32	SCL	7.2	2.5	1.4	0.12	11.7	6.6	20.8	27.7
1698	I	57-80	< 2	64	36	SCL	7.4	1.3	0.8	0.07	11.4	2.5	15.7	28.9
1698	II	80-100	2	64	34	SCL	7.5	0.9	0.5	0.06	8.3	2.3	14.2	26.2

3.3 Soil salinity

In most locations electro-conductivity of saturated soil samples (ECe) did not exceed 2 ds/m (Table 3); only in location of Profile 1690 and in deeper soil horizons/layers (probe 2 and 3) ECe exceeded 4 ds/m. Higher ECe at soil depth > 80 cm in the locations of probes 2 and 3 could be explained with inflow of the seawater. Salinity parameters in the profile 1690 could not be properly explained; they might be connected to excavation works for a local water supply. Higher ECe in the upper soil layers compared to the deeper soil layers is more likely the result of fertilization than to negative water balance or capillary action. The researched area has a high water table and due to capillary action water can rise through the soil matrix to the surface. However in winter, when precipitation is much higher than evapotranspiration (Table 5), salts move down through the soil profile. We assume that intensive leaching occurred also in the years 2013 and 2014, due to high precipitation rates (Table 5).

Table 3: Parameters of cation exchange capacity and salinity

Profile	Horizon	Soil depth	Ca	Mg	K	Na	H	CEC	Base saturat.	ESP	SAR	ECe
		cm			mmol$_C$/100g				%	%		dS/m
1688	A	0 - 6	36.20	1.53	1.34	0.09	1.55	40.8	96.1	0.22	0.09	1.88
1688	P	6 - 23	37.68	1.32	1.12	0.08	0.75	41.0	98.0	0.20	0.09	1.43
1688	I(B)	23 - 50	37.85	1.26	0.55	1.25	0.70	41.6	98.3	3.00	1.85	3.77
1688	II(B)	50 - 80	38.35	1.56	0.41	0.81	0.75	41.9	98.1	1.93	1.13	2.52
1689	A	0 - 8	34.61	1.18	1.32	0.08	1.35	38.6	96.4	0.21	0.08	1.88
1689	P	8 - 42	37.03	0.95	0.70	0.67	0.50	39.9	98.7	1.68	1.02	2.52
1689	I(B)	42 - 65	36.85	1.11	0.37	0.33	0.45	39.2	98.7	0.84	0.57	1.52
1689	II(Go)	65 - 80	38.98	1.42	0.43	0.45	0.50	41.8	98.8	1.08	0.84	1.97
1690	A	0 - 8	38.35	1.30	0.72	1.67	1.25	43.3	97.0	3.86	3.75	6.12
1690	P	8 - 30	38.86	1.15	0.49	1.50	0.50	42.5	98.8	3.53	2.31	4.22
1690	I(B)	30 - 65	38.43	1.38	0.46	0.72	0.60	41.6	98.6	1.73	1.39	2.42
1690	II(Go)	65 - 80	39.03	1.66	0.45	1.73	0.60	43.5	98.6	3.98	3.24	4.22
1698	P1	0-29	33.04	1.12	0.65	0.07	0.95	35.9	97.2	0.19	0.10	1.17
1698	P2	29-57	33.71	1.12	0.51	0.09	1.05	36.4	97.3	0.25	0.30	1.17
1698	I	57-80	35.99	1.42	0.37	0.11	1.4	39.3	96.4	0.28	0.29	1.08
1698	II	80-100	34.32	1.49	0.32	0.13	0.55	36.8	98.6	0.35	0.61	1.08

Table 4: Electroconductivity of soil samples from soil probing

Soil probe	Altitude	ECe (dS/m)		
	[m a.s.l.]	0 - 30 cm	30 - 60 cm	> 80 cm
S1	1.4	1.35	1.35	2.52
S2	1.2	1.43	2.88	11.78
S3	1.5	0.90	1.35	3.97
S4	1.5	1.35	1.27	1.27
S5	1.9	1.43	1.43	1.35
S6	1.8	1.35	1.27	1.17
S7	1.5	1.35	1.27	2.78
S8	2.1	1.53	1.27	1.17
S9	2.7	1.35	1.27	1.35
S10	2.7	1.35	1.17	2.25
S11	3.5	1.17	1.08	1.17
S12	4.0	1.35	1.08	1.35
S13	3.9	1.17	1.08	1.27
S14	2.6	1.17	1.17	1.08
S15	2.4	1.27	1.17	1.08
S16	2.4	1.27	1.17	1.17
S17	2.2	1.08	1.43	1.08
S18	2.4	1.27	1.35	1.27

Exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) were in the range from 0.2 to 3.8 % and from 0.08 to 3.75 %, respectively. ESP values in some soil horizons were higher compared to other soils in Slovenia where the share of sodium ions on adsorption complex is less than 1 % (Prus, 2007). However negative effects on soil structure are less probable;

ESP below 10 % or SAR below 13 % does not pose a risk to soil structure (Brady and Weil, 2002; Rowell, 1994). Additional protection for the soil structure was probably provided by high content of Ca^{2+} ions in the soil.

Table 5: Average monthly temperatures, precipitation, potential evapotranspiration and water balance for the period 1971-2000 and for the years 2012, 2013 and 2014 (Data source: Slovenian environment agency, 2014)

1971-2000													
Month	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Avg/ Total
Average temp.	4.1	4.5	7.4	11.6	16.4	20.1	22.5	21.7	17.6	13.6	8.4	5.1	12.8
Precipit.	56.3	47.1	61.3	65.3	68.8	85.8	57.6	78.1	123.8	120.5	91.3	75.3	931.2
Evapo-transpir.	30	41	66	90	125	142	163	149	98	64	38	29	1035
Water balance	26.3	6.1	-4.7	-24.7	-56.2	-56.2	-105.4	-70.9	25.8	56.5	53.3	46.3	-103.8
2012													
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Avg/ Total
Average temp.	3.5	1.5	9.9	12.8	16.6	22.7	25.5	24.7	19.8	14.9	11.7	5.0	14.0
Precipit.	20.1	20.6	0.1	50.4	117.2	35.1	6.9	36.5	96.5	88.2	145.2	72.9	689.7
Evapo-transpir.	34.7	50.9	88.1	88.5	134.2	161.0	200.3	178.3	103.8	58.4	37.9	25.6	1161.7
Water balance	-14.6	-30.3	-88.0	-38.1	-17.0	-125.9	-193.4	-141.8	-7.3	29.8	107.3	47.3	-472.0
2013													
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Avg/ Total
Average temp.	5.6	4.8	7.4	13.2	16.5	20.5	24.3	23.2	18.9	15.3	1.4	6.9	13.2
Precipit.	89.6	99.2	166.2	75.1	118.5	63.8	5.2	53.1	77.8	95.3	190.2	21.1	1055.1
Evapo-transpir.	25.4	40.1	51.6	92.5	112.9	160.9	194.9	179.6	106.4	53.3	43.3	30.4	1091.3
Water balance	64.2	59.1	114.6	-17.4	5.6	-97.1	-189.7	-126.5	-28.6	42	146.9	-9.3	-36.2
2014													
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Avg/ Total
Average temp.	9.4	9.8	10.8	13.9	16.2	21.6	21.7	21.5	17.9	15.4	13.0	7.8	14.9
Precipit.	87.6	171.7	47.4	124.1	89	55	264.7	94.5	208.5	115.4	139.3	65.2	1462.4
Evapo-transpir.	24.2	33.2	79.2	81.5	119.8	160.3	134.3	131.4	83	60.4	30.2	28.8	966.3
Water balance	63.4	138.5	-31.8	42.6	-30.8	-105.3	130.4	-36.9	125.5	55	109.1	36.4	496.1

3.4 Mineralogical characteristics of soil

All the soil samples from different profiles and horizons consisted of the same minerals. Prevailing minerals were quartz, calcite, and muscovite/illite (Table 6). Small amount of plagioclases and vermiculite/chlorite group minerals were present in some samples. Muscovite and illite could not be distinguished with certainty due to their similar structure, and vermiculite/chlorite due to their low quantity. A semi-quantitative sample composition estimated by X'Pert HighScore software was controlled and calibrated by measurement of carbonate content (Table 2).

Table 6: Mineralogical characteristics of soil: estimated mineral content in %, minerals presented in traces are marked with *

Profile	Horizon	Quartz	Calcite	Muscovite/Illite	Vermiculite/Chlorite	Plagioclase
1688	P1	40	30	30	*	*
1688	P2	30	30	30	*	10
1688	I	40	20	35	5	
1688	II	45	35	20	*	*
1689	A	45	30	15	*	10
1689	P	40	30	15		15
1689	I	30	35	25		10
1689	II	45	35	15	5	*
1690	A	45	35	17	3	
1690	P	40	35	20	*	5
1690	I	30	40	15	5	10
1690	II	35	35	30		
1698	P1	45	25	20		10
1698	P2	50	30	15		5
1698	I	40	30	15	5	10
1698	II	40	30	20	*	10

Diffractograms of different horizons from the same profile (Figure 2) clearly show that not only mineral composition but also ratios between minerals are similar. The influence of soil depth on mineral composition is minimal. Comparison of samples from the upper soil horizons (P2) of all profiles exhibits the same similarity (Figure 3), which indicates to the same soil forming factors for all the research area. The presence of swelling clay minerals, especially of montmorillonite, a member of the smectite group, was checked by careful examination of the XRD pattern. The presence of swelling clay mineral montmorillonite could not be confirmed in any of the soil samples. There is a possibility that the peak of montmorillonite was overlapped with vermiculite/chlorite, but even in that case the amount of montmorillonite would be small.

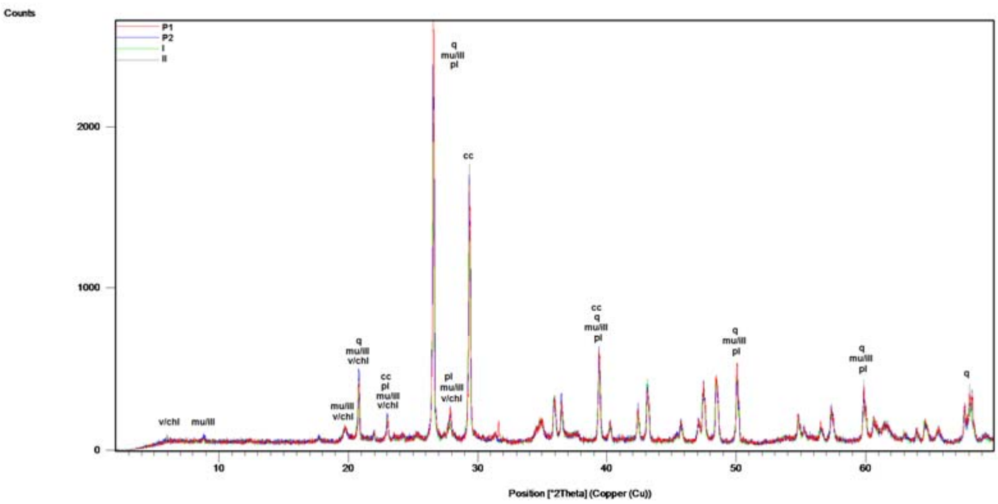

Figure 2: Diffractograms for the profile 1698. Peaks of minerals are labelled with following abbreviations: v/chl – vermiculite/chlorite, mu/ill – muscovite/illite, q – quartz, cc- calcite, pl – plagioclase

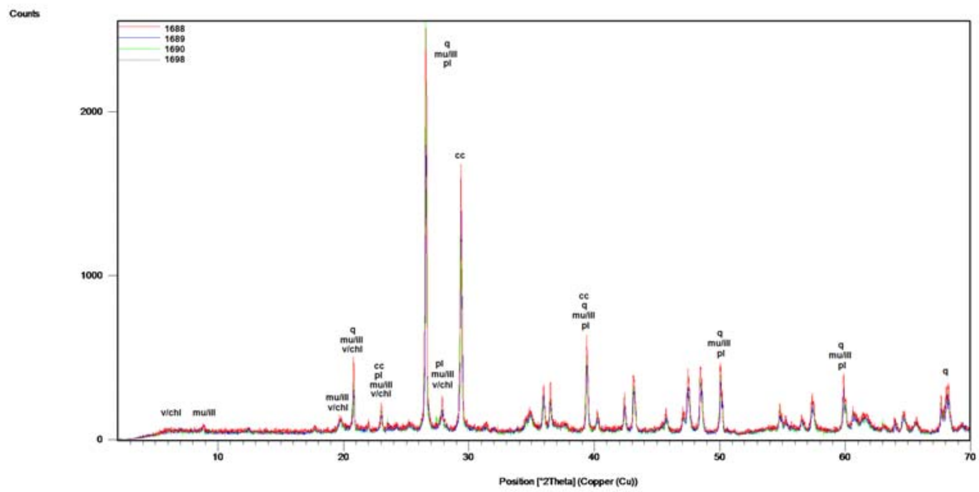

Figure 3: Diffractograms for the P2 horizons of profiles 1688, 1689, 1690 and 1698. Figure 2: Diffractograms for the profile 1698. Peaks of minerals are labelled with following abbreviations: v/chl – vermiculite/chlorite, mu/ill – muscovite/illite, q – quartz, cc – calcite, pl – plagioclase

3.5 Soil classification

Soil was evaluated with the criteria of Slovenian Soil Classification (SSC, Soil map of Slovenia 1:25.000) and World reference base for soil resources (IUSS Working Group WRB, 2014). Three classification units of SSC and reference groups of WRB were discussed: (i) Alluvial soil/Fluvisol, (ii) Gleyic soil/Gleysol (iii) Cambic soil/Cambisol. Both soil classification systems have different criteria as well as different terminology to describe the same soil properties.

The researched soil developed on the fine sediments of the river Dragonja, consequently the first idea was to classify it as Fluvisol. Fluvisols (IUSS Working Group WRB, 2014) have fluvic material ≥ 25 cm thick and starting ≤ 25 cm from the mineral soil surface; or from the lower limit of a plough layer that is ≤ 40 cm thick, to a depth of ≥ 50 cm from the mineral soil surface. Fluvic material refers to fluviatile, marine and lacustrine sediments that receive fresh material or have received it in the past and still show stratification. By the definition of WRB (IUSS Working Group WRB, 2014) stratification is evidenced by a layer that has ≥ 0.2 % soil organic carbon and has a content of soil organic carbon ≥ 25 % (relative) and ≥ 0.2 % (absolute) higher than in the overlying layer.

Alluvial soils by the definition of SSC develop on alluvial material and express either no or weak development of pedogenetic alteration. Soil horizons are difficult to recognise and soil layers are characterised and marked with roman numerals. The researched soil developed on silty clayey fluvic material with more than 0.2 % organic carbon and expresses weak development of pedogenetic alteration, i.e, a well-developed soil structure. We conclude that soil could be classified as alluvial soil according to SSC. However, the criterion of stratification for fluviatile material by WRB (IUSS Working Group WRB, 2014) is not entirely fulfilled as described above and as a consequence Fluvisol is not the appropriate reference group for the subject soil.

Soil materials develop gleyic properties if they are saturated with groundwater (or were saturated in the past, if now drained) for a period that allows reducing conditions to occur. The vicinity of the river Dragonja and fine sediments as the parent material are factors that might lead to development of Gleysols. According to WRB (IUSS Working Group WRB, 2014) Gleysols have a layer ≥ 25 cm thick and starting ≤ 40 cm from the mineral soil surface, that has gleyic properties throughout and reducing conditions in some parts of every sublayer. Gleyic properties comprise of one or both of the following: (i) layer with ≥ 95 % (exposed area) having colours considered to be reductimorphic (Munsell colour hue (moist) of N, 10Y, GY, G, BG, B, PB, or 2.5Y or 5Y with a chroma of ≤ 2, or (ii) a layer with > 5 % (exposed area) mottles, the colour of which is considered to be oximorphic.

Slovenian soil classification defines Gleysols similarly as defined by WRB (IUSS Working Group WRB, 2014); a hydromorphic surface humus horizon (Aa) must be present at depths less than 50 cm and followed immediately with both gleyic horizons (Go, Gr). Gr must start within 100 cm from the soil surface (Škorić, 1986). The researched soil did not express gleyic horizons starting ≤ 40 cm from the mineral soil surface. In profile 1689, few mottles occur (Go horizon) at 80 cm. Munsell colour hue is mostly 10 YR. Soil from the profile 1690 has Munsell colour hue 2.5Y with the chroma (4/4 or 5/6). Such colour values could be linked to flysch material. In the study "Soils of the Slovenian Coastal region" (Stepančič et al., 1984) reported about several Cambisols developed on flysch material with a Munsell colour hue 2.5Y and chroma >2. Reductimorphic colour GLEY1 6/5GY has been found as matrix colour in the layer at 110 cm soil depth. Generally less intensive expression of gleyic properties in alluvial soils could be explained by the findings of Stepančič (Matičič, 1984), who reported that ground water, due to strong fluctuations, still contains plenty of oxygen and therefore the oxidation and reduction processes in the soil profile are much less pronounced. Nevertheless, due to the morphological properties of the studied soil, it cannot be classified as Gleysol neither according to WRB nor SSC.

Soil profile structure with humus-accumulative or aric topsoil horizon and mineral subsurface is characteristic for cambic soil. Cambisols (IUSS Working Group WRB, 2014) have a cambic horizon starting ≤ 50 cm from the soil surface and having its lower limit ≥ 25 cm from the soil surface. The cambic horizon is a subsurface horizon showing evidence of pedogenetic alteration that ranges from weak to relatively strong. If the underlying layer has the same parent material, the cambic horizon usually shows higher oxide and/or clay contents than this underlying layer and/or evidence of removal of carbonates (at least ≥ 5 % by mass, absolute, fine earth fraction). The pedogenetic alteration of a cambic horizon can also be established by contrast with one of the overlying mineral horizons that are generally richer in organic matter and therefore have a darker and/or less intense colour. In this case, some soil structure development is needed to prove pedogenetic alteration.

Cambic soils, by the SSC definition consist of cambic horizon, which is a mineral soil horizon with well-expressed pedogenetic forms with less than 1 % organic matter. The soil in our research expressed homogeneity in most soil properties (clay content, carbonate content) but the stratification is evident in organic matter content and colour; organic matter content in the upper soil layer is higher. However, almost all soil layers have more than 1 % organic matter. Even though it was difficult to distinguish between alluvial and soil material, soil structure showed evidence of pedogenetic alteration.

Considering all discussed criteria Cambisol is the appropriate reference group for the subject soil according to WRB (IUSS Working Group WRB, 2014).

4 CONCLUSIONS

The researched soil has a silty clay loam texture with a high amount of silt. Soil structure is blocky or subangular with high aggregate stability. High amount of calcium carbonate content contributes to high aggregate stability. Soil has neutral or slightly alkaline pH, among base cations Ca^{2+} ions prevail (up to 99 %). Soil does not express intensive hydromorphic forms; few mottles occur only deeper in the soil profile. Exchangeable sodium percentage is ranging from 0.2 to 3.8 %. In most locations electroconductivity (ECe) does not exceed 2 ds/m; this happens only in some locations and in deeper soil layers, where ECe values exceed 4 ds/m; however in absence of morphological characteristic for salt affected soils (structure, concrete...) the soil could not be characterised as saline soil.

Measured ECe and ESP values in soil from the lower valley of Dragonja are higher compared to other soils in Slovenia. In general, higher precipitation rates in Slovenia favour elluvialilluvial processes and development of leached soils. Therefore, soils in the lower valley of the Dragonja River are rare and important for soil diversity in Slovenia.

Prevailing minerals in the soil are quartz, calcite and muscovite/illite. Plagioclase and vermiculite/chlorite were found in small amounts. The presence of swelling clay mineral montmorillonite could not be confirmed in any of the soil samples.

According to WRB soil classification, and based on morphological, chemical and mineralogical analyses, soil of the researched area could be classified as Calcaric Cambisol (aric, siltic). According to the Slovenian national soil classification, two soil types could be determined: (i) alluvial soil, calcaric and (ii) alluvial soil, calcaric, deeply gleyic.

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