Journal of the Serbian Chemical Society
JSCS@tmf.bg.ac.rs • www.shd.org.rs/JSCS

J. Serb. Chem. Soc. 81 (4) S140–S144 (2016)
Supplementary material

SUPPLEMENTARY MATERIAL TO

Fruška Gora mountainous environments – assessing the impact of geological setting and land use on soil properties

TAMARA ĐORĐEVIĆ[1], MILICA KAŠANIN-GRUBIN[2], GORDANA GAJICA[2]*, ZORICA POPOVIĆ[3], RADA MATIĆ[3], LJUBA JOSIĆ[4], MILAN MILENKOVIĆ[1], ALEKSANDAR LAZAREVIĆ[1] and BRANIMIR JOVANČIĆEVIĆ[1]

[1]*University of Belgrade, Faculty of Chemistry, Studentski trg 12–16, 11000 Belgrade, Serbia,* [2]*University of Belgrade, Institute of Chemistry, Technology and Metallurgy, Center of Chemistry, Njegoševa 12, 11000 Belgrade, Serbia,* [3]*University of Belgrade, Institute for Biological Research "Siniša Stanković", Bulevar despota Stefana 142, 11000 Belgrade, Serbia and* [4]*Public Enterprise "National park Fruška Gora", Trg Zmaj Jove 1, Sremska Kamenica, Serbia*

J. Serb. Chem. Soc. 81 (4) (2016) 459–468

GENERAL FACTS AND GEOLOGICAL DETAILS ABOUT SAMPLING LOCATION

The surface of the Earth is about 510 million km^2 out of which 149 million km^2 is land.[1] The land is of great importance for the human population since it is the source of many raw materials such as water, clay, sand, gravel, minerals and different types of fuels. The largest part of the production of human food also depends on the land. However, considering that the human population is constantly increasing, there are growing requirements for living space, industry and traffic, all of which negatively impact natural resources. Currently, land degradation is considered as one of the most important global environmental problems. It causes a persistent decline in land productivity and provision of ecosystem services.

During the last 50 years, about 5 billion ha of land have been modified by human activities, which is ≈43 % of the Earth's vegetated land.[2] On the global scale, the surface of vulnerable land and land affected by degradation have been increasing during the last decades and it was found that unsustainable land management is one of the key drivers of land degradation.[3] In order to assess the effect that these alterations have on biodiversity and ecosystem services and to realize appropriate planning and management measures for conserving the environment, it is essential to identify and quantify changes caused by land degradation.[4]

* Corresponding author. E-mail: ggajica@chem.bg.ac.rs

The Fruška Gora is located between the Danube and Sava Rivers and most of the mountain area lies on the territory of Serbia, while a small part belongs to the eastern part of Croatia (the study area is shown in Fig. S-1). In the east–west direction, Fruška Gora is ≈75 km long, while in the north–south direction the largest width is ≈15 km. The total area of the mountain is around 500 km^2.

Fig. S-1. Map of sampling locations.

The Fruška Gora mountain range consists of three parts: central, west and east part. Central part has mountain peaks with the average height between 440–460 m.a.s.l. The west part of the range is a flat highland (≈200 m.a.s.l), built of limestone. The east part of the range has gradually lower heights and the dominant rock type is loess. Geologically, Fruška Gora is heterogeneous and consists of rocks of various composition and age. The oldest rocks in Fruška Gora are Palaeozoic phyllites and micashists. Mesozoic rocks are represented by Triassic red and gray sands and shales, conglomerates and breccias. Tertiary sediments outcrop in the peripheral parts of Fruška Gora and they consist of coal layers along with limestones, marls and sands. Quaternary sediments are represented by thick layers of loess that cover the lowest parts of the Fruška Gora Mt.[1]

The Fruška Gora Mt. is hydrographically very rich. The surrounding humid continental climate is altered by the vegetation on the mountain, creating a specific microclimate. The lowest average temperature is in January (–0.6 °C) while the highest average temperature is in July (21.4 °C), giving an average annual temperature of 11.2 °C. The average annual precipitation is ≈351 mm.[2]

Geological diversity along with microclimatic variations contribute to great biological diversity and during 1960, this area was declared a National Park. In accordance with the geological, and consequently, pedological and hydrological characteristics, Fruška Gora is characterized by diverse and rich flora, fauna and vegetation. The forests on Fruška Gora used to cover an area of 113000 ha until World War II, and thereafter, the forests have been replaced with meadows, fields, vineyards and orchards, so now only 25000 ha are forested. The whole area of Fruška Gora, including wider peripheral areas, counts about 1500 species, subspecies and varieties of vascular plants. The predominant types of vegetation are mesophillic or thermo-mesophillic deciduous forests that cover approx. 90 % of the total area of the National Park. The forest community *Querco-Carpinetum betuli* is most frequently present, formed by sessile oak (*Quercus petraea*) and hornbeam (*Carpinus betulus*), with the significant share of silver lime (*Tilia tomentosa*). Silver lime, that occupies about 30 % of the total forests found in area, represents a kind of floristic-vegetation hallmark of Fruška Gora, unique in the European framework. Among them, relict and endemic species are of exceptional value and scientific importance, for example daphne-laurel (*Daphne laureola*), mouse thorn (*Ruscus hypoglossum*), buthcher's broom (*Ruscus aculeatus*), European bladdernut (*Staphylea pinnata*), (*Sternbergia colchiciflora*), (*Cheilanthes marantae*), sweet vernal (*Adonis vernalis*), pasqueflower (*Pulsatilla grandis*), fern leaf peony (*Paeonia tenuifolia*) and pygmy iris (*Iris pumilla*). All of these plant species, as well as the number of others (approx. 50 different taxa from the area of Fruška Gora) are protected by a special law on protection of natural rarities (the Law of the Republic of Serbia).[1]

SAMPLING DETAILS

Thirty soil samples at 0–20 cm were collected from four slopes differing in bedrock and/or land cover. Soils on two slopes developed on serpentinite, and the other two on marls. One of each has forest and the other meadow as the main type of land cover (Fig. S-1).

Serpentinites and marls were chosen because they have different properties. Serpentinite are created by autometamorphism process (metamorphic process of the rock which is using the remains of its own solid solution at a temperature of 400 °C) of peridotite which consists of olivine, enriched with magnesium and iron. Marls are sedimentary rocks that consist of carbonates (calcite and dolomite) and clay minerals (kaolinite, montmorillonite or illite). In order to analyze spatial influence of the hillslope position on the soil properties, samples were taken from the top, from the middle and from the foothill of the slopes.

TABLE S-I. Descriptive statistics and two-way ANOVA of following soil properties: pH, *Eh*, *EC* and *TDS*; *n* = sample size; *a* = mean (standard deviation); ns = non-significant difference; *b* = *F*-test statistic with the number of degrees of freedom; * = statistically significant difference ($P \leq 0.05$)

Soil	*n*	pH	*Eh*	*EC*	*TDS*
Serpentinite	15	5.89 (0.39)[a]	1.72 (32.56)	90.78 (61.46)	42.57 (27.06)
Rock type (A)					
Marls	15	7.48 (0.66)	–90.93 (23.54)	169.91 (46.05)	83.91 (21.56)
		[b]$F_{1,26}$ =102.78*	$F_{1,26}$= 87.90*	$F_{1,26}$ = 15.07*	$F_{1,26}$ = 21.77*
Meadow	18	6.88 (1.14)	–49.35 (65.27)	122.28 (67.50)	59.95 (33.74)
Land use (B)					
Forest	12	6.4 (0.56)	–37.49 (35.11)	142.44 (66.85)	68.17 (29.74)
		$F_{1,26}$ = 10.91*	ns	ns	ns
Meadow	9	5.84 (0.47)	7.95 (40.17)	60.51 (14.09)	28.61 (6.98)
Serpentinite					
Forest	6	5.97 (0.22)	–7.63 (14.65)	136.18 (78.34)	63.52 (33.09)
Meadow	9	7.91 (0.34)	–106.65 (7.12)	184.04 (29.97)	91.30 (12.65)
Marls					
Forest	6	6.83 (0.43)	–67.35 (18.92)	148.70 (60.01)	72.82 (28.27)
Interactions (A×B)		$F_{1,26}$ = 17.20*	$F_{1,26}$ = 8.72*	$F_{1,26}$ = 10.04*	$F_{1,26}$ = 11.97*

TABLE S-II. Descriptive statistics and two-way ANOVA of the available cations in soil; *n* = = sample size; *a* = mean (standard deviation); ns = non-significant difference; *b* = *F*-test statistic with the number of degrees of freedom; * = statistically significant difference ($P \leq 0.05$)

Soil	*n*	Ca^{++}	K^{+}	Mg^{++}	Na^{+}
Serpentinite	15	43.63 (28.94)	20.23 (8.13)[a]	18.69 (13.69)	12.98 (8.41)
Rock type (A)					
Marls	15	147.85 (76.24)	46.85 (18.40)[b]	25.65 (10.63)	10.66 (3.44)
		$F_{1.26}$ = 22.63	$F_{1.26}$ = 82.61*	ns	ns
Meadow	18	105.17 (85.95)	25.84 (11.06)a	16.62 (7.41)	12.64 (7.96)

TABLE S-II. Continued

Soil	*n*	Ca^{++}	K^{+}	Mg^{++}	Na^{+}
Serpentinite	15	43.63 (28.94)	20.23 (8.13)[a]	18.69 (13.69)	12.98 (8.41)
		Land use (B)			
Forest	12	81.60 (63.92)	45.10 (23.81)[b]	30.50 (14.30)	10.60 (2.83)
		ns	$F_{1,26}$ =36.23*	$F_{1,26}$ =12.82*	ns
Meadow	9	35.67 (17.56)	17.43 (5.33)	12.78 (5.50)	14.45 (10.52)
		Serpentinite			
Forest	6	55.58 (39.57)	24.42 (10.22)	27.54 (17.88)	10.78 (3.34)
Meadow	9	174.67 (67.26)	34.24 (8.52)	20.45 (17.88)	10.82 (4.08)
		Marls			
Forest	6	107.62 (76.15)	65.76 (10.82)	33.45 (10.43)	10.42 (2.52)
Interactions (A×B)		$F_{1,26}$ = 4.69*	$F_{1,26}$ = 14.70	ns	ns

TABLE S-III. Descriptive statistics and two-way ANOVA of the organic parameters; *n* = = sample size; a = mean (standard deviation); ns = non-significant difference; *b* = *F*-test statistic with the number of degrees of freedom; * = statistically significant difference ($P \leq 0.05$)

Soil	*n*	*C*	*N*	*C*/*N*
Serpentinite	6	1.70 (0.39)	0.11 (0.02)	15.81 (1.29)
		Rock type (A)		
Marls	6	2.15 (0.94)	0.14 (0.05)	14.65 (1.54)
		$F_{1,8}$ = 102.78*	$F_{1,8}$ = 10.08*	$F_{1,8}$ = 16.56
Meadow	6	1.38 (0.21)	0.10 (0.01)	14.00 (0.76)a
		Land use (B)		
Forest	6	2.47 (0.62)	0.15 (0.04)	16.45 (0.81)b
		$F_{1,8}$ = 10.91	$F_{1,8}$ = 21.33*	$F_{1,8}$ = 74.06
Meadow	3	1.42 (0.18)	0.10 (0.01)	14.68 (0.21)
		Serpentinite		
Forest	3	1.97 (0.34)	0.12 (0.02)	16.94 (0.53)
Meadow	3	1.33 (0.27)	0.10 (0.02)	13.32 (0.09)
		Marls		
Forest	3	2.97 (0.33)	0.19 (0.02)	15.97 (0.80)
Interactions (A×B)		$F_{1,8}$ = 10.64*	$F_{1,8}$ = 21.33*	ns

REFERENCES

1. http ://www.physicalgeography.net/fundamentals/8o.html (last accessed Sep. 30, 2015)
2. N. C. Brady, R. R. Weil, The Nature and Properties of Soils, 13th ed., Prentice Hall, Upper Saddle River, New Jersey, USA, 2002, p. 960
3. L. Salvati, M. Carlucci, J. Environ. Manage. 145 (2014) 299
4. A. Regos, M. Ninyerolac, G. Moré, X. Pons, Int. J. Appl. Earth Obs. Geoinf. 38 (2015) 1
5. M. Toljić, L. Matenco, M. N. Ducea, U. Stojadinović, J. Milivojević, N. Đerić, Global Planet. Change 103 (2013) 39
6. http://www.hidmet.gov.rs/podaci/meteo_godisnjaci/Meteoroloski%20godisnjak%201%20 -%20klimatoloski%20podaci%20-%202014.pdf (last accessed November 30, 2015).