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The application of cartographic method and pedological analysis of soil quality in the Rasina District as a basis for selecting suitable grapevine rootstocks for vineyards intended for wine grape production

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Cartographic method in soil analysis,
Grapevine rootstocks,
Wine grape production.

Abstract

The focus of the research is on the pedological analysis of soils dominating in the vineyard production zone, as well as on a specific number of locations that may be used in the near future for planting vineyards with wine grape varieties. For the purposes of this study, 35 locations were selected for investigation.The selection of locations for the research was based on field experience, the application of cartographic methods in terrain relief analysis, exposure of selected locations, determination of accurate coordinates of selected locations and the influence of terrain slope. In addition to choosing desired grape varieties, the proper selection of suitable grapevine rootstocks is one of the most crucial factors for successful vineyard cultivation.

1. INTRODUCTION

The Rasina District covers an area of 2667 km^2, with arable land comprising approximately 160,000 hectares. According to the 2012 census, vineyard production is established on an area of 6375 hectares. Viticulture is one of the most significant agricultural branches in the structure of agricultural production in the Rasina District. Vineyard areas in the Rasina District are located in the municipalities of Aleksandrovac, Trstenik, Kruševac, Varvarin, Brus and Ćićevac, falling under the `Three Moravas` region. Wine grape production significantly surpasses table grape production. The direction of wine grape production has slowly shifted over the past decades and the transitional period, moving from mass wine production to cultivating higher quality foreign and traditional varieties for the production of premium wines.

Throughout Serbia, including the Rasina District, there has been an increasing trend in the vineyard acreage in recent years. In addition to choosing desired grape varieties, the proper selection of suitable grapevine rootstocks is one of the most crucial factors for successful vineyard cultivation. Particularly in wine grape production, rootstocks can impart specific characteristics to the wine, both positively and negatively. Errors in selecting the right combination of noble grape varieties and rootstocksmade at the outset cannot be easily corrected later and can result in low yields or poor grape quality, sometimes leading to premature vineyard removal. The grapevine rootstock acts as a link between the cultivated variety and the soil, needing to be compatible and adaptable to the soil conditions where the vineyard is established.

The focus of this research was to examine some basic geophysical features of the terrain and chemical characteristics of dominant soil types in the Rasina vineyard area. The goal was to provide fundamental guidelines for selecting suitable grapevine rootstocks when establishing vineyards.

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2. SUB-AREA OF RESEARCH AND WORK METHODS

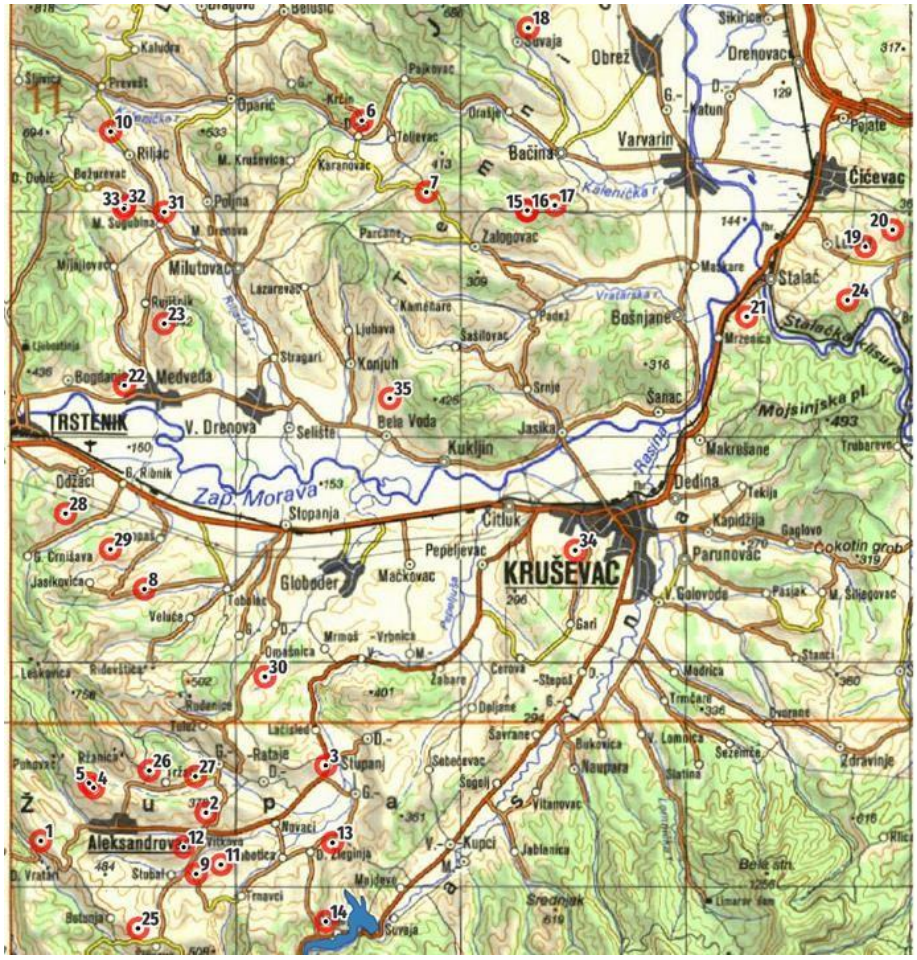
Given the pronounced pedodiversity in the territory of the Rasina District, the focus of the research was on soils dominating in the vineyard production zone, as well as on a specific number of locations that may be used for vineyard planting with wine grape varieties in the near future. For the purposes of this project, 35 locations were selected for investigation.

The selection of research locations was based on field experience, the application of cartographic methods in terrain relief analysis, exposure of selected locations, determination of accurate coordinates of selected locations, and the influence of terrain slope. A pedological map (Map No. 1 in the annex) and the results of a survey conducted among grape growers were also used.

Representative locations included parcels designated for vineyard planting with wine grape varieties, vineyards in exploitation, and parcels with spontaneous vegetation that could be used for vineyard planting in the near future.

For the implementation of this study, the following maps were created: Map of the Rasina District and spatial distribution of the examined locations, Relief map of the Rasina District with spatial distribution of examined locations, and Exposure map of the terrain relief of locations from which samples were taken. These maps were used to analyze the suitability of the mentioned locations considering terrain relief, elevation, exposure, slope, and other relief characteristics for grapevine cultivation.

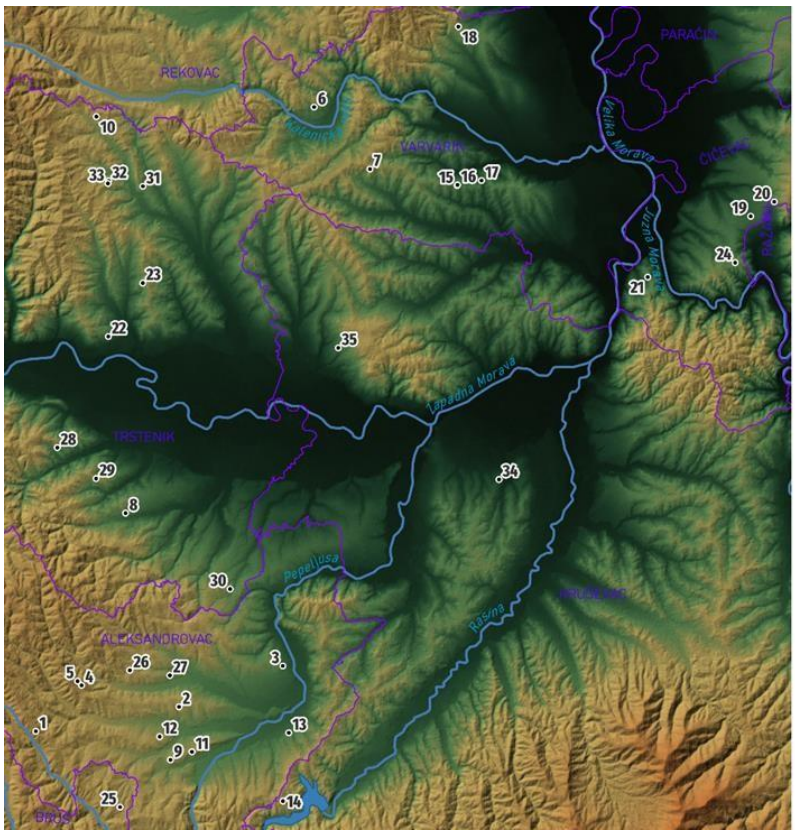
Map No. 1 – Map of the Rasina District and Spatial Distribution of Examined Locations



br	mz_imel	"opstina_im"	Ekspozicija
1	DONJI VRATARI	ALEKSANDROVAC	SW
2	Vitkovo	ALEKSANDROVAC	SW
3	GORNJI STUPANJ	ALEKSANDROVAC	E
4	DRENČA	ALEKSANDROVAC	S
5	DRENČA	ALEKSANDROVAC	E
6	DONJI KRČIN	VARVARIN	SW
7	MARENOVO	VARVARIN	E
8	VELUĆE	TRSTENIK	S
9	LJUBINCI	ALEKSANDROVAC	NE
10	RILJAC	TRSTENIK	SW
11	BOBOTE	ALEKSANDROVAC	SW
12	Vitkovo	ALEKSANDROVAC	NE
13	DONJA ZLEGINJA	ALEKSANDROVAC	N
14	ĆELIJE	KRUŠEVAC	SW
15	BAČINA	VARVARIN	E
16	BAČINA	VARVARIN	NW
17	BAČINA	VARVARIN	N
18	OBREŽ	VARVARIN	NE
19	LUČINA	ĆIĆEVAC	SW
20	MAĆIJA	RAŽANJ	W
21	GRAD STALAĆ	ĆIĆEVAC	W
22	MEDVEĐA	TRSTENIK	SE
23	RUJIŠNIK	TRSTENIK	W
24	STALAĆ	ĆIĆEVAC	S
25	BOTUNJA	BRUS	NE
26	TRŽAC	ALEKSANDROVAC	E
27	GORNJE RATAJE	ALEKSANDROVAC	SE
28	GORNJI RIBNIK	TRSTENIK	S
29	LOPAŠ	TRSTENIK	S
30	DONJA OMAŠNICA	TRSTENIK	SE

Figure 1. Map of the Rasina District and Spatial Distribution of Examined Locations

(Prof.dr.sc. Ivan Filipović, dr.sc. Milan Đorđević)



br	mz_imel	"opstina_im"	Ekspozicija
1	DONJI VRATARI	ALEKSANDROVAC	SW
2	Vitkovo	ALEKSANDROVAC	SW
3	GORNJI STUPANJ	ALEKSANDROVAC	E
4	DRENČA	ALEKSANDROVAC	S
5	DRENČA	ALEKSANDROVAC	E
6	DONJI KRČIN	VARVARIN	SW
7	MARENOVO	VARVARIN	E
8	VELUĆE	TRSTENIK	S
9	LJUBINCI	ALEKSANDROVAC	NE
10	RILJAC	TRSTENIK	SW
11	BOBOTE	ALEKSANDROVAC	SW
12	Vitkovo	ALEKSANDROVAC	NE
13	DONJA ZLEGINJA	ALEKSANDROVAC	N
14	ĆELIJE	KRUŠEVAC	SW
15	BAČINA	VARVARIN	E
16	BAČINA	VARVARIN	NW
17	BAČINA	VARVARIN	N
18	OBREŽ	VARVARIN	NE
19	LUČINA	ĆIĆEVAC	SW
20	MAĆIJA	RAŽANJ	W
21	GRAD STALAĆ	ĆIĆEVAC	W
22	MEDVEĐA	TRSTENIK	SE
23	RUJIŠNIK	TRSTENIK	W
24	STALAĆ	ĆIĆEVAC	S
25	BOTUNJA	BRUS	NE
26	TRŽAC	ALEKSANDROVAC	E
27	GORNJE RATAJE	ALEKSANDROVAC	SE
28	GORNJI RIBNIK	TRSTENIK	S
29	LOPAŠ	TRSTENIK	S
30	DONJA OMAŠNICA	TRSTENIK	SE

0 5 km

Figure 2. Relief Map of the Rasina District with Spatial Distribution of Examined Locations

(Prof.dr.sc. Ivan Filipović, dr.sc. Milan Đorđević)

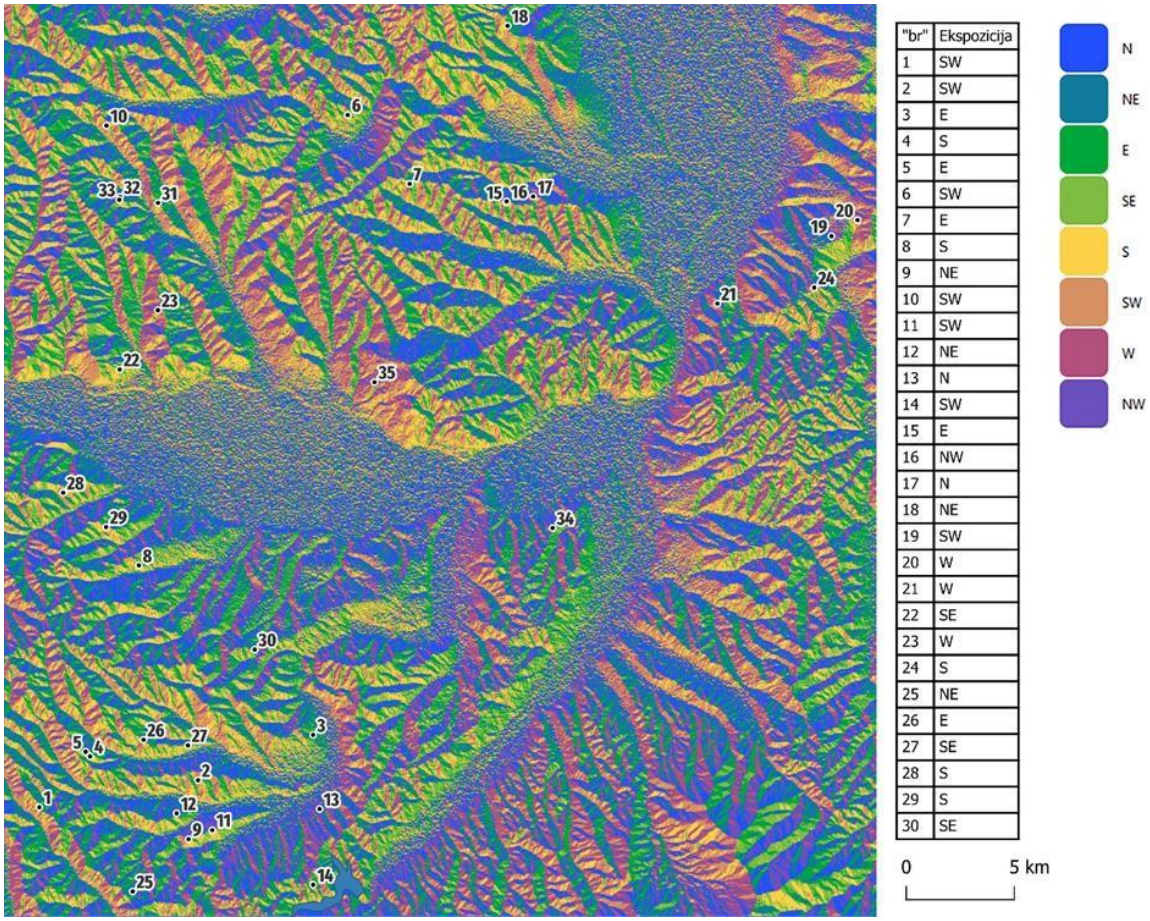
Vineyards are best planted on hilly terrains with southern, southwestern, or southeastern exposure, ensuring good sunlight for grapevines, and consequently, higher sugar and aromatic content in grapes, increased alcohol content, better grape and wine coloration. The order of favorability for other exposures is as follows: western, eastern, and less favorable northwestern, northeastern, and finally, northern exposures.

On northern exposures, it is advisable to cultivate more cold-resistant varieties and those with a shorter vegetative period. On hilly terrains, another important factor comes into play - the slope or inclination of the terrain.

On positions where the slope is greater than 10%, terracing is mandatory (which is a relatively expensive measure). The steeper the slope, the more and smaller the terraces are, and vice versa. Depending on the terrace width on the plateau, 1-4 rows of grapevines can be found. The plateau of the terrace should have a counter slope of 1-2% and a gentle slope along the length of 0.5%, enabling water drainage and preventing soil erosion. Sloped parts of terraces are covered with grass. The most favorable row direction is north-south, as it ensures even sunlight exposure to rows in the vineyard.

The optimal elevation ranges from approximately 100 to 300 meters, but successful cultivation can also be achieved at lower and slightly higher elevations in our country. Thus, in the northern parts of our country, vineyards are situated at somewhat lower elevations of 80-150 meters, while in the southern parts, elevations increase to 500 meters or more. With the increase in elevation, temperature conditions change. For every 100 meters of elevation gain, the average annual temperatures decrease by 0.5-1 °C, and the vegetative period shortens by 7-10 days."

In addition, field investigations and laboratory soil analyses were conducted.



"br"	Ekspozicija
1	SW
2	SW
3	E
4	S
5	E
6	SW
7	E
8	S
9	NE
10	SW
11	SW
12	NE
13	N
14	SW
15	E
16	NW
17	N
18	NE
19	SW
20	W
21	W
22	SE
23	W
24	S
25	NE
26	E
27	SE
28	S
29	S
30	SE

Figure 3. Exposure Map of the Terrain Relief of Locations from Which Samples Were Taken

(Prof.dr.sc. Ivan Filipović, dr.sc. Milan Đorđević)

Field research included soil sampling with an auger at depths of 0-30, 30-60, and 60-90 cm, followed by assessing soilcompactness using a penetrometer to a depth of 50 cm. Additionally, geological mapping was conducted for the purpose of creating the maps provided in the attachment. Additionally, geological mapping was conducted for the purpose of creating the maps provided in the attachment.

Figure 4. Soil Sampling.

Table.1 Locations of soil samples with geographic latitude, geographic longitude, elevation and terrain exposure data

No	Settlement	Municipality	Aspect degree	Aspect	elevation	longitude	latitude
1	Donji Vratari	Aleksandrovac	60	SW	604	21.011367	43.452827
2	Vitkovo	Aleksandrovac	60	SW	349	21.102209	43.464038
3	Gornji Stupanj	Aleksandrovac	30	E	253	21.16811	43.482837
4	Drenča	Aleksandrovac	50	S	514	21.040432	43.473998
5	Drenča	Aleksandrovac	30	E	549	21.037855	43.475946
6	Donji Krčin	Varvarin	60	SW	308	21.188746	43.740878
7	Marenovo	Varvarin	30	E	355	21.224257	43.712177
8	Veluće	Trstenik	50	S	284	21.068412	43.553514
9	Ljubinci	Aleksandrovac	20	NE	363	21.096732	43.439543
10	Riljac	Trstenik	60	SW	378	21.050018	43.736615
11	Bobote	Aleksandrovac	60	SW	352	21.110351	43.443249
12	Vitkovo	Aleksandrovac	20	NE	344	21.089909	43.450293
13	Donja Zleginja	Aleksandrovac	90	N	272	21.171764	43.451976
14	Ćelije	Kruševac	60	SW	370	21.167968	43.420431
15	Bačina	Varvarin	30	E	275	21.279639	43.704444
16	Bačina	Varvarin	80	NW	275	21.279923	43.704764
17	Bačina	Varvarin	90	N	251	21.295204	43.706727
18	Obrež	Varvarin	20	NE	326	21.28085	43.777814
19	Lučina	Ćićevac	60	SW	242	21.466496	43.689648
20	Maćija	Ražanj	70	W	264	21.481539	43.696271
21	Grad Stalać	Ćićevac	70	W	275	21.400758	43.661839
22	Medveđa	Trstenik	40	SE	239	21.057558	43.635075
23	Rujišnik	Trstenik	70	W	316	21.079482	43.659751
24	Stalać	Ćićevac	50	S	296	21.456429	43.668273
25	Botunja	Brus	20	NE	449	21.06476	43.417768
26	Tržac	Aleksandrovac	30	E	413	21.071051	43.480932
27	Gornje Rataje	Aleksandrovac	40	SE	322	21.096429	43.478557
28	Gornji Ribnik	Trstenik	50	S	302	21.025069	43.583791
29	Lopaš	Trstenik	50	S	328	21.049709	43.569498
30	Donja Omašnica	Trstenik	40	SE	308	21.134736	43.518393
31	Mala Sugubina	Trstenik	20	NE	305	21.079616	43.704422
32	Božurevac	Trstenik	10	N	347	21.057778	43.706948
33	Božurevac	Trstenik	60	SW	361	21.057379	43.705745
34	Donja Pakašnica	Kruševac	80	NW	212	21.305674	43.568663
35	Bela Voda	Kruševac	60	SW	256	21.203782	43.629653

Figure 5. Soil compactness examination with a penetrometer.

Figure 6. Samples from various soil types in the preparation phase for analysis.

Laboratory analyses were conducted to determine the soil structure coefficient through the analysis of samples in a semi-undisturbed state. Subsequently, the mechanical composition of the soil was examined, along with basic chemical parameters: pH value (in H2O and KCl), humus content, total nitrogen, percentage of calcium carbonate (total lime), active lime percentage, content of easily accessible forms of phosphorus and potassium.

The list of laboratory methods used in the investigations for the purposes of this project is provided in Appendix No. 1 of this study.

Figure 7. Determining soil structure using the dry sieving method on an electromagnetic shaker with a series of sieves.

Figure 8. Determining the percentage representation of particles using the pipette method.

Figure 9. Vineyard on the hillside in the town of Stalac

3. RESULTS OF THE INVESTIGATION

3.1. *Survey Results*

Through a survey conducted among grape growers cultivating wine grape varieties, we determined the percentage participation of various rootstocks most commonly used in the Rasina District. Graphs 1 and 2, illustrating the survey results, show the almost complete dominance of the Kober 5 BB rootstock, especially on smaller vineyard areas. The survey revealed an average age of vineyards of approximately 17 years (ranging from 3 to 88 years, with the youngest being 3 years and the oldest 88 years). Additionally, the survey indicated the percentage of vacant spaces and replaced vines in the vineyards, with an average value of around 10% (ranging from 1% to as much as 50% vacant spaces). One of the numerous factors that can influence the shorter lifespan of vines is the inadequate choice of rootstock for the specific soil and climate conditions.

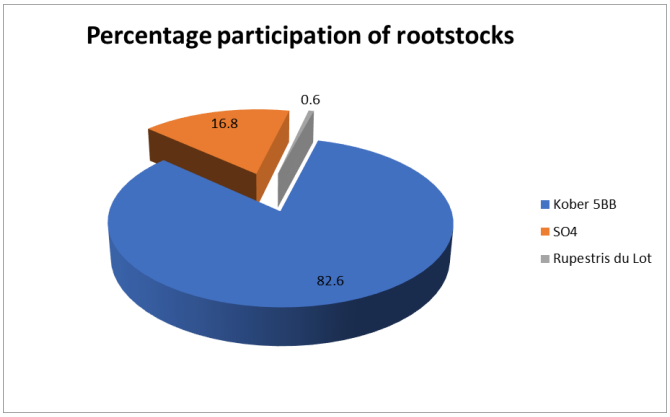


Figure 10. Percentage participation of rootstocks (all surveyed households).

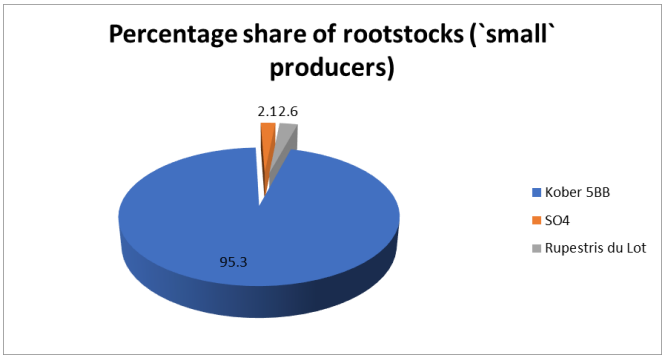


Figure 11. Percentage participation of rootstocks among `small`producers.

3.2. *Results of Field Research and Laboratory Analyses*

In the viticultural area of the Raška District, two main types of soil dominate: Vertisols (locally known as `smolnica`) and EutricCambisols (brown soils known as `gajnjace`), along with their complexes that significantly differ from each other. Out of 35 sampled locations, slightly more than half of the sampled soil belongs to the Vertisols group, while the rest, based on the newer classification, falls into the group of EutricCambisols.

In the following section, the results of field and laboratory research are presented in tabular form and arranged in the order of sampling, corresponding to GIS (Geographic Information System) codes from 1 to 35. The positions of sampled locations are shown on Map No. 1. At some locations, due to the presence of a hard-to-penetrate soil layer (parent material), sampling was conducted at two depths: 0-30 cm and 30-60 cm. Along with basic location data (municipality, cadastral municipality, detailed location description), the code (number) of the cartographic unit belonging to the soil type according to the used pedological map (Map in the attachment) is indicated, as well as the name of the soil type according to the newer classification.

4. DISCUSSION WITH COMMENTS AND RECOMMENDATIONS

The mechanical composition of soil (granulometric composition, texture) involves the percentage representation of particles (mechanical fractions) of various dimensions in the soil. The water, air, and thermal regimes of the soil depend on its mechanical composition, influencing numerous chemical and biogenic properties of the soil. The mechanical composition of the soil also determines the suitability range for soil cultivation. Mechanical fractions are divided into two major groups: the skeleton (particles larger than 2 mm, gravel and stone fractions) and fine earth - silt (particles smaller than 2 mm, sand, silt, and clay fractions). From an agronomic standpoint, the ideal soil is considered to have a sand: silt: clay ratio of 40%:40%:20%. Sandy soils are easy to cultivate, well-aerated, stimulating root growth. However, they quickly dry out after irrigation due to poor water retention capacity, leading to the leaching of water-soluble nutrients from the active rhizosphere (root system).

Loamy soils contain sufficient air and water, are not cold, absorb water well, conduct it through the soil, are easy to cultivate, exhibit intense microbiological activity, and provide a good habitat for plants. Clayey soils are heavy, with a short period of favorable moisture for soil cultivation. Draining excess water and soil aeration are challenging. In spring, they remain moist and cold for an extended period, affecting the shortening of the vegetative period for perennial plantings.

In the following paragraphs, a brief description of the results obtained through the cartographic analysis of relief, exposure and terrain slope is provided. An analysis of mechanical and chemical parameters of sampled soil is also presented, organized by soil types - cartographic units marked with numbers in parentheses. The examined locations are identified by the cadastral municipality name and the geoposition number, and their overview is displayed on Map No. 1.

The selection of an adequate rootstock is an exceptionally complex task, and in addition to physio-chemical parameters, the quality of the soil also depends on the choice of grape variety, terrain exposure, slope, and other ecological factors. Due to the existence of a large number of rootstocks adaptable to different agro-pedological conditions, the recommendations listed below each described soil type include possible limitations in selecting rootstocks that can be used in soils with similar characteristics. For easier interpretation of results and recommendations, a table with comparative characteristics of some rootstocks has been prepared (Table 1 is located in the section dedicated to rootstocks).

Normal Vertisol (1)

Examined location: Vitkovo (12)

The physio-geographical characteristics of the location are suitable for growing grapevines, as the terrain is gently undulating, with a southwest exposure, a slight slope, and an elevation of 341m. Soil properties: In terms of texture, it belongs to clayey soils (heavy clay loam), with the percentage of sand decreasing with depth while the clay fraction increases. Structural characteristics are satisfactory in the surface layer but unsatisfactory at depth. The soil is moderately compacted. Fraction ratio (sand:silt:clay) - 16:33:51. Chemical properties: Highly humus soil (4.8%), weak to moderately carbonate, with a low content of active lime. The pH is neutral, poorly supplied with available phosphorus, and well-supplied with available potassium (around 30 mg/100 g). Recommendation: Avoid genotypes highly sensitive to excess moisture on such soils. Due to its fertility, caution is advised when using vigorous or very vigorous rootstocks.

Vertisol in Eutric Cambisol (2)

Examined locations: Bučje (8), Jasikovica (29), Mala Sugubina (31)

The physio-geographical characteristics of the Bučje location are suitable for grapevine cultivation, as the terrain gently slopes southward, with a southern exposure and an elevation of 284m. The Jasikovica location in the Lopaš region is suitable for grapevine cultivation due to its hilly nature, an elevation of 326m, and a southern exposure. In the case of Mala Sugubina, the exposure is northeast, the elevation is 303m, and the terrain is gently sloped. Soil properties: Structurally, it is clayey loam, with the percentage of clay increasing with depth. The structure is satisfactory in the surface layer but unsatisfactory at depth, and the soil is weak to moderately compacted. Fraction ratio (sand:silt:clay) - 25:30:45. Chemical properties: Humus soil (3-4%), moderately to highly carbonate (especially in deeper layers), with an active lime content ranging from 3.9 to 10.5. The pH is slightly alkaline, poorly supplied with available phosphorus (<5 mg/100 g), and moderately supplied with available potassium (15-20 mg/100 g). Recommendation: A wide range of rootstocks can be used on such soils, with caution when selecting genotypes sensitive to high lime and clay content.

Ogajnjačena Vertisol (3)

Examined locations: Donje Zleginje (13), Bačina (15, 16, 17), Lucina (19, 20), Donji Krčin (6), Božurevac (32)

The physio-geographical characteristics of the location Donje Zleginje are suitable for grapevine cultivation, as the terrain is hilly, the slope is small, and the elevation is 269m. The terrain exposure is north. In locations 15, 16, and 17 in the village of Bačina, the terrain is gently sloping, with elevations ranging from 252 to 274m. The exposure is east at location 15, northwest at location 16, and north at location 17. On the stretch Lucina (19), the terrain is gently sloping to the southwest, with an elevation of 241m. The location Macija has favorable physio-geographical characteristics, with the terrain gently sloping to the west and an elevation of 266m. Location DonjiKrčin (6) is situated at an elevation of 306m, on the southwest slope of the elevation where grapevines are already cultivated. The sample from the Božurevac stretch (32) was taken at an elevation of 360m, with a southwest exposure and a slight slope.

Physical properties: In terms of texture, they belong to clays and clayey loams (medium clayey), with satisfactory structure in the surface layer and cloddy structure at depth. The soil is weak to moderately compacted.

Fraction ratio (sand:silt:clay) - 33:27:40.

Chemical properties: Weakly humus to humus soil (1.5-2.5%), weakly carbonate, with an active lime content of about 3%. The soil is acidic (pH around or below 5), poorly supplied with available phosphorus, except in the case of vineyards in operation where regular fertilization with mineral fertilizers has been performed. Moderately to optimally supplied with available potassium (about 20 mg/100 g), except in the case of vineyards under intensive cultivation where it is above 40 mg/100 g.

Recommendation: With adequate ameliorative measures to correct acidity and overall fertility, there are no significant restrictions on the use of most available grapevine rootstocks on soils of this type.

Eroded (shallow) Vertisol (4)

Surveyed locations: Ljubinci (9), Bobote - Brdo Varina (11), Crvena Jabuka (25), Donja Crnišava (28), Bela Voda (35)

The physical-geographic characteristics of the locations are suitable for growing grapevines because the terrain is hilly, the slope is not steep, and the altitude is Ljubinci (363m), Bobote - Brdo Varina (351m), Crvena Jabuka (447m), Donja Crnišava (301m), Bela Voda (255m). The exposure of the terrain is suitable for growing grapevines at locations 9, 11, 28, and 35, while at location 25, the exposure is northeast. Physical characteristics: In terms of texture, they belong to clayey loams, occasionally sandy loams, mostly with good or satisfactory structures, especially in the surface layer. The soils are weak to moderately compacted. The parent rock is often limestone at depths greater than 50-60 cm.

Fraction ratio (sand:silt:clay) - 40:30:30

Chemical properties: Slightly humic to humic soils (1.5-3%), highly carbonate (>20% CaCO3), with active lime content up to 13%. Slightly alkaline soils (pH 7-8), with low accessibility to phosphorus, except in the case of actively cultivated vineyards (17 mg/100). Potassium is optimally provided only in the surface layer, while the easily accessible potassium content decreases sharply with depth, except in the case of intensively cultivated vineyards where it is above 20 mg/100 g of soil in deeper profile layers.

Recommendation: Rootstocks that require deep soils with fewer carbonates and rootstocks prone to chlorosis are not suitable choices for these types of soils.

Eroded (in the process of podzolization) Vertisol (5,6)

Surveyed locations: Božurevac (32), Rujisnik (23), Medvedja (22), Marenovo (7)

The physical-geographic characteristics of the locations are suitable for growing grapevines because the terrain is hilly, the slope is not steep, and the altitude is appropriate at Božurevac (344m), Rujishnik (315m), Medvedja (236m), and Marenovo (355m). The exposure of the terrain is suitable for

growing grapevines at locations 32 (southwest), 23 (west), 22 (southeast), and 7 (east). Physical characteristics: In terms of texture, they belong to sandy-clay loams, with a somewhat lighter mechanical composition, mostly with good or satisfactory structures, especially in the surface layer. The soils are weak to moderately compacted.

Fraction ratio (sand:silt:clay) - 47:20:33

Chemical properties: They are generally slightly humus soils (<2%), weakly carbonate, with a low active lime content up to 3%. These are weakly acidic or acidic soils with an average pH of 5.5. These soils are weakly supplied with easily accessible phosphorus and moderately supplied with easily accessible potassium (15-20 mg/100 g).

Recommendation: With adequate ameliorative measures to correct acidity and overall fertility, soils of this type do not have significant limitations in using most available grapevine rootstocks.

Normal vineyard soil (Eutericcambisol) (7)

Surveyed location: Suvaja (18)

The physical-geographic characteristics of the location are suitable for growing grapevines because the terrain is hilly, the slope is not steep, and the altitude is appropriate at 325m. The exposure of the terrain is northeast. Physical characteristics: The soil, in terms of texture, belongs to clay (medium clay), with satisfactory structures in the surface layer and unsatisfactory structures in the depth of the profile. The soil is moderately compacted.

Fraction ratio (sand:silt:clay) - 30:25:45

Chemical properties: Humus soil (2-3%), weakly carbonate in the profile up to 60 cm and strongly carbonate in the profile from 60 to 90 cm (7% CaCO3), with an active lime content up to 2.5-6%. The soil is strongly acidic throughout most of the profile (pH 4 to 4.8), poorly supplied with easily accessible phosphorus, and optimally supplied with potassium (>20 mg/100 g).

Recommendation: With adequate ameliorative measures to correct acidity and overall fertility, for soils of this type, extra caution is needed when using rootstocks that are sensitive to strongly acidic and compacted soils.

Eroded vineyard soil (Eutericcambisol) (8)

Surveyed locations: Riljac (10), the city ofStalać (21)

The physical-geographic characteristics of the locations are suitable for growing grapevines because the slope of the terrain is gentle, and the altitude is appropriate - Riljac (378m), the city ofStalać (276m). The exposure of the terrain is suitable for growing grapevines at location 10 (southwest) and at location 21 (west). Physical characteristics: These soils, in terms of texture, belong to clayey loams (medium clay), with satisfactory structures. The soils are weak to moderately compacted.

Fraction ratio (sand:silt:clay) - 40:30:30

Chemical properties: Slightly to humus soils (1.1-3.5% humus), weakly carbonate (0.2-2% CaCO3), with an active lime content up to 1.3-8.3%. The soil has a weakly acidic to neutral reaction (average pH 6.2), is poorly supplied with easily accessible phosphorus (<5 mg/100 g throughout the entire profile depth), and has a medium content of easily accessible potassium (average 17 mg/100 g). The content of easily accessible potassium slightly decreases under the plow.

Recommendation: With adequate ameliorative measures to improve overall fertility, there are no significant limitations in using most available grapevine rootstocks on soils of this type.

Leached vineyard soil (Eutericcambisol) (9)

Surveyed locations: Stalać (24), Tržac (26), Rataje (27)

The physical-geographic characteristics of the locations are suitable for growing grapevines because the slope of the terrain is gentle, and the altitude is appropriate - Stalać (295m), Tržac (409m), and Rataje (320m). The exposure of the terrain is suitable for growing grapevines - at location 24, it is south-facing, while at locations 26 and 27, it is east and southeast. Physical characteristics: These soils, in terms of texture, belong to clays (medium clay), where the clay content increases with depth in the examined profile, except in the case of terraced soil (Rataje), where profiles are mixed. Despite the heavier mechanical composition, the soils are weakly compacted with satisfactory structures.

Fraction ratio (sand:silt:clay) - 34:24:42

Chemical properties: Slightly to humus soils (1.5-2% humus), weakly carbonate (<1% CaCO3, except at the Svračak locality where carbonates are above 2%, and they increase to above 20% with depth). The content of active lime is low, except at the mentioned locality. The soil has a weakly acidic to neutral reaction (average pH 6.4), is poorly supplied with easily accessible phosphorus (<5 mg/100 g throughout the entire profile depth), and has a low content of easily accessible potassium (average 14 mg/100 g). The content of easily accessible potassium slightly decreases under the plow.

Recommendation: With adequate ameliorative measures to improve overall fertility, there are no significant limitations in using most available grapevine rootstocks on soils of this type.

Cultivation in Podzolized Soil (EutericCambisol) (10)

Examined locations: Pakašnica (34), Vitkovo (2), Gornji Stupanj (3)

The physio-geographical characteristics of the locations are suitable for growing grapevines because the terrain slope is small, and the altitude is appropriate - Pakašnica (210m), Vitkovo (349m), and Gornji Stupanj (252m). The terrain exposure is suitable for growing grapevines - the location 34 has a northwest exposure, while the location 2 has a southwest exposure, and the location 3 has an eastern exposure of the terrain relief. Physical characteristics: these soils, based on texture, belong to loams (medium loam), where the clay content increases with depth in the examined profile, except in cases of plowed land. The soils have satisfactory structure, weak to moderately compacted.

Fraction ratio (sand:silt:clay) - 31:26:43

Chemical properties: the soils are weakly humus (<2% humus), weakly carbonate (mostly below 1% CaCO3), with low active lime content. The soil is acidic with a pH value below 5. These soils are characterized by very low easily accessible phosphorus content (<5 mg/100 g throughout the profile depth) and low easily accessible potassium content, except in plots that were fertilized before vine planting (Vitkovo and GornjiStupanj), where the potassium level in the examined profile is at a moderate or optimal level.

Recommendation: On soils with such characteristics, in addition to appropriate ameliorative measures, it is possible to use a greater number of available rootstocks with caution when using genotypes sensitive to increased soil acidity.

Podzolized Soil, Podzol (11, 12)

Examined location: Donja Omašnica (30)

The physio-geographical conditions of the location are suitable for grapevine cultivation because the terrain slope is small, and the altitude is appropriate - Donja Omašnica (306m). The terrain exposure is suitable - at location 30, it is southeast. Physical characteristics: the soil, based on texture, belongs to sandy loam (light loam) with a very high percentage of coarse sand (35%). The soil has unsatisfactory structure, especially in the deeper layers of the profile where the sand content increases. At the surface, the soil is loosely compacted, but penetrometer readings are significantly high in the deeper layers due to the presence of coarse sand.

Fraction ratio (sand:silt:clay) - 73:14:13

Chemical properties: the soil is weakly humus (about 1% humus), weakly carbonate (below 1% CaCO3), with low active lime content. The soil is slightly acidic with a pH value around 6.5. These soils are characterized by very low easily accessible phosphorus content (<5 mg/100 g throughout the profile depth) and very low easily accessible potassium content (potassium content in layers below 30cm is less than 5 mg/100 grams).

Recommendation: Considering the low percentage of humus and clay in podzolized soils, it is advisable to prefer vigorous rootstocks adapted to poor, dry, and compacted soils.

Euteric Brown Soil on Flint (EutericCambisol/Litosol) (30)

Examined locations: Drenča - Lukarevina (4, 5)

The physio-geographical characteristics of the location are suitable for grapevine cultivation because the terrain slope is appropriate, although the altitude is slightly higher - Drenča (510m) and Lukarevina (547m). However, the terrain exposure is suitable for grapevine cultivation, with a southern exposure at location 4 and an eastern exposure at location 5. Physical characteristics: these soils, based on texture, belong to the group of sandy-clay loams (medium or heavy loams), where the clay content decreases with depth in the examined profile. The soils show low values of penetration resistance at optimal moisture, but with a low structural coefficient due to a very high percentage of fine sand (>40%).

Fraction ratio (sand:silt:clay) - 58:20:22

Chemical properties: the soil is humus (2-3% humus), weak to moderately carbonate (up to 6.5% CaCO3), with low active lime content (up to 5%). The soil is neutral (average pH 6.8), poorly supplied with easily accessible phosphorus (<5 mg/100 g throughout the profile depth), and with low to moderate levels of easily accessible potassium (10-17 mg/100 g).

Recommendation: With adequate ameliorative measures and improvements in general fertility, there are no significant limitations in using most available grapevine rootstocks on soils of this type.

Rocky Skeletal Soil (EutericCambisol/Regosol/Litosol) (32)

Examined location: Starci (1)

The physio-geographical predispositions of the location for grapevine cultivation are as follows: high altitude of 602m, southwest exposure, and a slight terrain slope. Physical characteristics: the soil, based on texture, belongs to sandy loam (medium loam) with a high percentage of coarse sand (35%) and rock fragments. The soil has good structure in the surface layer but unsatisfactory structure at depth due to the presence of abundant rock fragments. The soil is shallow, with the parent rock appearing at a depth of 40-50 cm.

In the layer up to the parent substrate, the soil is loosely compacted.

Fraction ratio (sand:silt:clay) - 55:30:15

Chemical properties: the soil is humus in the layer up to 30 cm (over 3% humus), weakly carbonate (below 1% CaCO3), and with low active lime content (up to 1%). The soil is highly acidic with a pH value below 4.5. The soil is characterized by very low easily accessible phosphorus content (<5 mg/100 g) throughout the profile depth, as well as very low easily accessible potassium content.

Recommendation: On soils of this type, it is advisable to prefer grapevine rootstocks that easily adapt to shallow, dry, rocky, and acidic soils.

The recommendations and other information provided in this text take into account solely pedological and agrochemical properties of the analyzed soil samples. For each specific situation, before selecting planting material for grape cultivation, it is advisable, in addition to a comprehensive soil analysis to determine agro-pedological characteristics, to consider other factors such as the microclimate of the area, compatibility of grape variety and rootstock, the influence of the rootstock on grape and wine quality, grape ripening time, and more.

5. GUIDANCE FOR CHOOSING GRAPEVINE ROOTSTOCKS

When selecting grapevine varieties, especially in relation to grapevine rootstocks, preference is given to noble varieties. Regions, soils, and technologies are carefully chosen for these varieties. Grapevine rootstocks form the basis for adapting or sustaining a particular noble variety to a specific location. In viticulture, the noble grape variety contributes to yield and grape quality, while the grapevine rootstock should enhance the expression of genetic and agrobiological characteristics of the variety. Therefore, when choosing grapevine varieties, rootstocks are tailored to noble varieties to meet the biological requirements of the variety and the production-economic interests of the vine grower. To achieve this, each grapevine rootstock should, to a satisfactory extent, exhibit certain properties, including:

1. Resistance to Phylloxera
2. Compatibility with Noble Varieties
3. Adaptability to Pedological and Agrochemical Properties of Vineyard Soil
4. Resistance to Drought and Excess Moisture
5. Resistance to Nematodes
6. Possession of Appropriate Growth Vigor.

While a universal rootstock that fulfills all these requirements hasn't been created, significant progress has been made through over a century of selection and crossbreeding of different genotypes within the Vitis genus. A large number of grapevine rootstocks adapted to various growing conditions have been developed, capable of meeting the specific demands of viticulture.

Due to their pronounced resistance to phylloxera, rootstocks derived from American Vitis species, such as Vitis riparia, Vitis berlandieri, and Vitis rupestris, or hybrids resulting from their crosses, are commonly used. Additionally, hybrids resulting from crosses between Vitis vinifera and American species have been developed. Through the breeding of these species, grapevine rootstocks have been created and are now utilized in almost all vine-growing regions worldwide.

Overview of Rootstocks by Origin

Rootstocks derived from V. riparia selection:Riparia portalis (Riparia Gloire de Montpellier)

Rootstocks derived from V. rupestris selection:Rupestris du Lot (Montikola)

Rootstocks resulting from crosses between V. berlandieri x V. riparia:SO4, Kober 5BB, 420A, 161 - 49 Couderc, Teleki 5C, Teleki 8 B

Rootstocks resulting from crosses between V. rupestris x V. berlandieri:Richter 110, Richter 99, Paulsen 1103, Ruggeri 140

Rootstocks resulting from crosses between V. riparia x V. rupestris:3309 C, Schwarzmann

Rootstock resulting from crosses between V. vinifera (cv.Chasselas) x V. berlandieri:41B

Complex hybrids resulting from crosses between multiple parents (American species and noble varieties):Fercal, Gravesac

It should be noted that in global production, there is a significant number of clones created to enhance specific characteristics of the original rootstocks, such as improved rooting, varying growth vigor, better adaptability to environmental conditions, and influencing grape and wine characteristics, grape ripening time, among others. A comparative overview of the basic characteristics of some grapevine rootstocks is provided in Table 2.

Table 2. Characteristics of grapevine rootstocks

Rootstock	Force of growth	Tolerates limestone % (CaCO3) in the soil		Drought resistance	Resistance to excess moisture in spring	Adaptability to soil conditions	Possible limitations	Nutrient uptake good (+++) average (++) poor (+)		
		Active	Total					P	K	Mg
Riparia portalis	Weakly exuberant	6	15	Low	high	It suits sandy soils with little clay	Not suitable for compacted soils with a high clay content; irrigation is required	+	+	+
Rupestris du lot (Montikola)	exuberant	14	25	High (in deepsoils)	low	For poor, light, deep soils with little lime	Not suitable for shallow and compacted soils	+	+++	-
Kober 5BB	exuberant	20	35	Low-medium	medium	For soils of moderate fertility and less dry positions."	On fertile soils, it is very exuberant	+++	++	++
420A	Weaklyexuberant	20	35	low	Low-medium	For fertile, deep, clayey-limestone soils	Not suitable for overly compacted and moist soils.	++	+	++
SO4	Medium exuberant	17	35	Medium-low	high	For sandy, acidic, or clayey-limestone soils, but not overly fertile	Not suitable for shallow and dry, nor compacted soils.	+++	++	+
161-49 C	Medium exuberant	25	40	Medium-high	low	Limestone-clay soils, sufficiently deep and with a lighter texture	Not suitable for overly compacted and wet soils.	-	++	-
Teleki 5 C	exuberant	20	35	medium	low	It suits clayey soils with finer texture	It does not tolerate excess water or highly acidic soils.	++	++	++
3309 C	Medium exuberant	11	20	Very low	low	For acidic, deep, sandy-clay soils with little lime	Extremely sensitive to salinized soils.	+	+	++
Richter 110	exuberant	17	-	high	low	Very suitable for dry, rocky soils without lime	High risk of chlorosis depending on the grafted variety	+++	+++	+
Ruggeri 140	Medium exuberant to exuberant	20	50	high	medium	Very suitable for dry, poor, rocky, and calcareous soils	Not suitable for fertile, deep, and moist soils	++	+	+++
Paulsen 1103	exuberant	17	30	Medium to high	medium	Well adapts to dry conditions and compacted soils	Not suitable for excessively wet soils	+++	++	+++
Šasla 41 B	Medium exuberant	40	60	medium	low	For highlycalcareous-soils	Not suitable for compacted soils	+++	+	+++
Gravesac	Medium exuberant to exuberant	6	15	medium		Sandy-gravelly and suitable for soils with clay in depth, acidic	Not suitable for overly acidic soils	+	++	++
Fercal	Medium exuberant to exuberant	40	60	Medium – high (in deeper soils)	high	Adaptable to different conditions, especially suitable for highly calcareous soils	Substrate has difficulty absorbing magnesium in the presence of high levels of potassium	+++	+++	++

6. CONCLUSION

The paper provides a brief description of the results obtained through cartographic analysis of relief, exposure, and terrain slope. Additionally, an analysis of mechanical and chemical parameters of sampled soil, grouped by soil types indicated by numbers in parentheses, has been conducted. The examined locations are identified by the name of the cadastral municipality and the geo-positioning number, as presented in Map No. 1.

The selection of an appropriate rootstock is an exceptionally complex task. Besides physical and chemical parameters, the quality of the soil depends on the choice of grape variety, terrain exposure, slope, and environmental factors. Due to the existence of a large number of rootstocks adaptable to various agro-pedological conditions, the paper provides recommendations for each type of soil, suggesting suitable rootstocks. Possible limitations in the selection of rootstocks for soils with similar characteristics are also discussed.

For easier interpretation of the results and recommendations, a table with comparative characteristics of some rootstocks has been created (Table 2).

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