A GIS-based assesing of soil heterogeneity

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Graduation thesis

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Content

1. Introduction

To address the increased food demands of a growing global population, it is essential to increase agricultural production to adequate levels. Proper and efficient management of agricultural lands is vital for the conservation of soil and water resources. Excessive use of these resources can cause significant ecological damage. Notably, a decline in soil quality on agricultural lands leads to decreased productivity and a loss of plant diversity (Viana et al., 2022). Soil serves as the fundamental substrate for life and biodiversity, with its quality directly impacting nutrient cycling and consequently human well-being (Bogunović et al., 2017).

According to the FAO, soil fertility is the ability of the soil to supply essential plant nutrients and soil water in adequate amounts and proportions for plant growth and reproduction in the absence of toxic substances that may inhibit plant growth (FAO, 2020).

Assessing the spatial differences in soil properties, such as micronutrients, and creating maps of these variations are highly beneficial techniques for accurately understanding soil behavior fluctuations. These assessments can inform optimal fertilizer recommendations, as proper nutrient management can improve both crop yield and quality, all while ensuring environmental sustainability (Salem et al., 2024).

Spatial variability in soil naturally arises from geological and pedological soil-forming processes, yet it is also significantly influenced by various land uses and management practices, which can degrade soil properties. A key challenge in agriculture, especially under intensified cropping systems, is soil nutrient deficiency, often exacerbated by the heavy use of macronutrients while micronutrients are neglected. To address this issue, continuous assessment and mapping of micronutrient deficiencies across regions using geostatistics are essential. These maps are invaluable tools for policymakers and the fertilizer industry to balance supply and demand in specific areas. Additionally, they are crucial for effective micronutrient management, ensuring that fertilizers are applied in the correct nutrient form, amount, and location, thereby boosting both crop production and soil health (Ali et al., 2020)

Satellite imagery offers precise spatial data swiftly, dependably, and economically, whereas GIS systems gather, alter, store, and exhibit georeferenced data (Abuzaid et al., 2021). The GIS-geostatistical analyst enables the interpretation of spatial variations in soil data and generates continuous layers for incorporation into land resource zoning (Abdellatif et al., 2021).

1.1. Aim of the thesis

The aim of this thesis is to use a GIS-based approach to analyze the significance and share of certain basic soil properties (soil organic matter (SOM), pH, texture, available phosphorus and potassium) in assessing the homogeneity or heterogeneity of two different locations in Pannonian Croatia.

2. Literature review

Currently, most Croatian farmers apply fertilizers without assessing soil fertility, while only a few base their usage on soil analysis, ignoring the spatial differences within their fields (Bogunović et al., 2017). Over the past few decades, improved research methods have increased understanding of both crop and soil science, particularly the variability of soil properties across different areas of a field. However, studies on yield variability have predominantly concentrated on the availability of soil nutrients rather than differences in soil physical properties (Castrignano et al., 2002).

2.1. Soil fertility and the importance of the studied soil properties

Soil fertility should be considered as dynamic concept that evolves with the changing conditions of a region. This necessitates continuous reassessment, particularly as new high-yield plant varieties with greater nutritional demands are introduced (Black, 1993). Overall, soil fertility is a complex attribute linked to the soil's inherent capacity to supply nutrients to plants. This capacity results from biological, chemical, and physical processes that involve the ongoing cycling of nutrients between organic and inorganic forms.

The pH of the soil regulates the solubility, mobility, and bioavailability of macronutrients and trace elements, ultimately dictating their movement within plants. This process primarily relies on the distribution of elements between the solid and liquid phases of the soil, governed by precipitation-dissolution reactions (Forstner, 1995).

Soil organic matter comprises various fractions, from simple molecules like amino acids and monomeric sugars to complex polymeric molecules such as cellulose, proteins, and lignin. These fractions coexist with undecomposed and partially decomposed plant and microbial residues (Baldock, 2007). The content of dissolved organic matter increases with soil pH, leading to higher levels of mineralizable carbon and nitrogen.

In soil, H^+ ions gradually replace other positively charged ions, known as exchangeable cations, such as Ca^{2+}, Mg^{2+}, and K^+, which are held on the soil surface. These cations, termed base cations, are vital for plant growth. The H^+ ions integrate into the soil's solid phase, while an equal number of base cations are released into the soil solution and may be lost through leaching. Soils saturated with protons are not stable and undergo further weathering, transforming into more stable minerals, eventually forming oxides and hydroxides of aluminum, iron, manganese, and titanium (Strawn et al., 2020). Indeed, in acidic environments, minerals like kaolinite or even gibbsite have the potential to dissolve, resulting in the production of soluble Al^{3+} ions (Robarge, 2008). An additional origin of protons stems from the oxidation of soil organic matter (SOM). SOM originates from the microbial breakdown of forest litter and deceased plant and animal matter within soils. While the chemical composition of SOM is intricate, it comprises numerous acidic functional groups, including carboxylic, phenolic, and ketonic groups (Stevenson, 1982).

Phosphorus is essential for cell division and growth, photosynthesis, sugar and starch formation, energy transfer, and carbohydrate movement within plants, especially in the growing parts. Its deficiency significantly reduces the growth of plant tops and roots, making early root development reliant on a readily available phosphorus source. The phosphorus pool in soil includes several interacting sources, with the soil solution being the immediate source for plant roots. Diffusion from bulk soil replenishes depleted phosphorus at the root zone. Since plants absorb phosphorus in the orthophosphate form, organic phosphorus must be mineralized by microorganisms using the phosphatase enzyme before uptake can occur (Hamza, 2008).

Being an indispensable macronutrient, potassium (K) plays crucial roles in various physiological processes such as photosynthesis, translocation, cellulose formation, enzyme activities, cation-anion balance, and stomatal control (Marschner, 2012). Crops have high demands for potassium, which must be obtained from the soil. Potassium is abundant in soil and its presence is influenced by factors like parent material, weathering and leaching of soil minerals, types of soil minerals, organic matter content, and potassium fertilizers. Generally, the total potassium content in soil rises with increasing clay content, highlighting the significant influence of soil texture on both total and exchangeable potassium levels (Hamza, 2008).

Cation exchange capacity (CEC) is a crucial chemical property of soil, widely regarded as a key indicator of soil quality (Huang et al., 2015). It represents the total amount of exchangeable cations (such as magnesium, calcium, sodium, and potassium) that can be adsorbed at a specific pH (Juhosz et al., 2021). In pH-dependent soils, soil pH can also greatly influence the CEC value. Different types of clay play a significant role in regulating CEC in soils. Clay types such as kaolinite and montmorillonite represent opposite extremes that can result in low and high CEC values in soils (Sufian, 2021).

Soil texture is a fundamental property that is not easily altered. It refers to the size of individual soil particles and is categorized into three broad groups: sand, silt, and clay. The size differences between these classes result in significant variations in other properties, such as pore size and cation exchange capacity, which are crucial for storing and transporting water, gases, and nutrients in the soil. Among these classes, clay and, to a lesser extent, silt are particularly important because they have much larger surface areas compared to sand. This increased surface area enhances the soil's ability to store nutrients and buffer against sudden chemical changes. Additionally, clay acts as a binding agent, helping to aggregate soil particles and maintain good soil structure. Soil texture is determined by measuring the proportions of sand, silt, and clay in a soil sample (FAO, 2020).

2.2. Spatial heterogeneity of an arable plot - GIS based evaluation

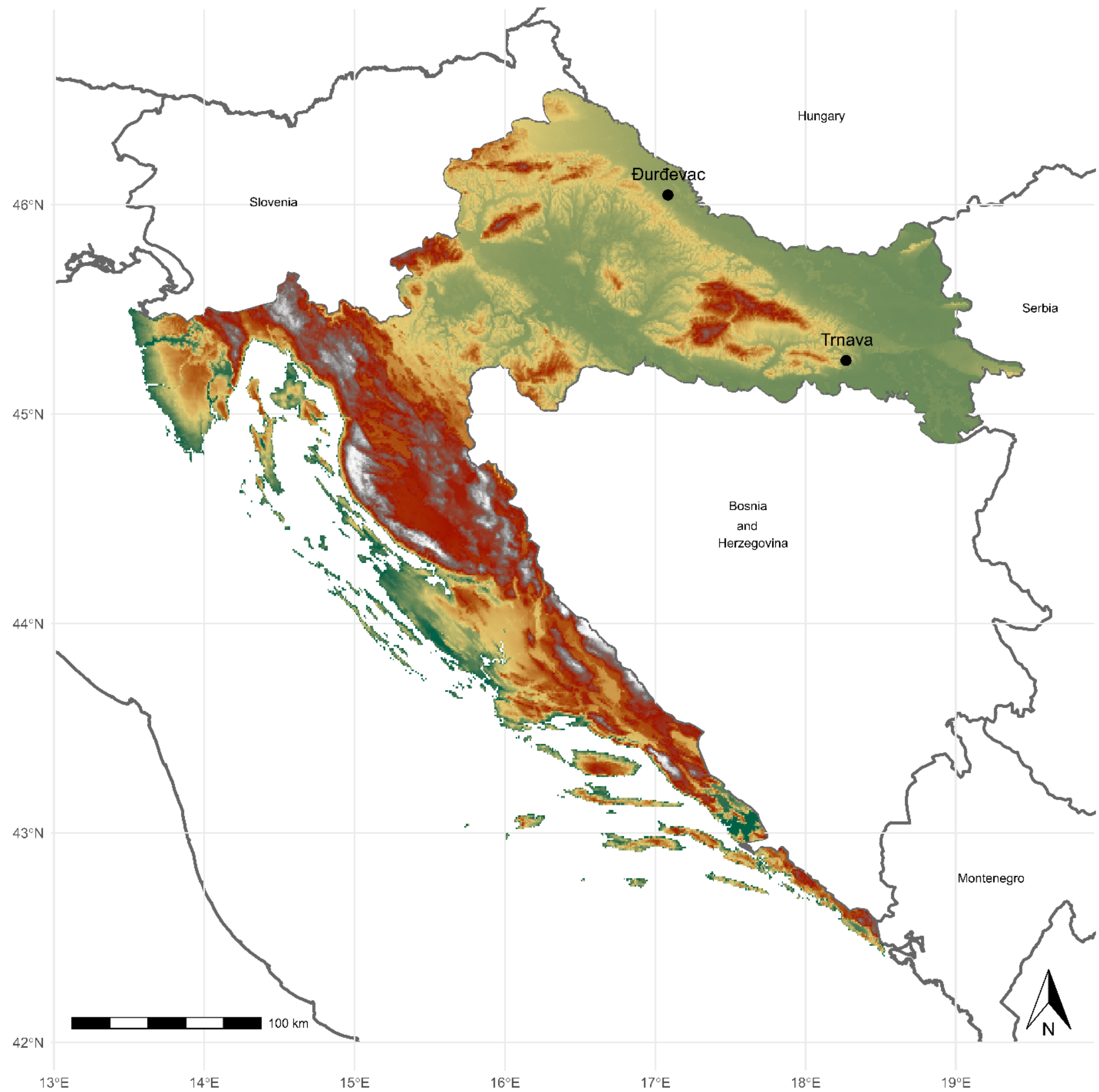
Understanding the spatial variability of soil properties is essential for evaluating soil fertility and refining agricultural practices. While the spatial heterogeneity of soil is naturally influenced by geological and pedological factors, different land uses and management practices significantly impact soil property degradation. Soil nutrient deficiency, exacerbated by crop intensification and the disproportionate application of macronutrients over micronutrients, is a major constraint on crop production. To address this, the widespread deficiency of micronutrients in various regions can be assessed and mapped using geostatistics. These deficiency maps aid policymakers and fertilizer industries in balancing supply and demand for specific areas. They are also instrumental in managing micronutrient application, ensuring the right nutrient is applied in the correct amount, form, and location, thereby enhancing crop production and soil health (Ali et al., 2020).

Geostatistics has proven to be an invaluable tool for assessing the spatial variability of soil properties, playing a crucial role in diagnosing nutrient-related limitations and managing them effectively. Spatial interpolation methods, such as ordinary or co-kriging techniques, enable the prediction of soil variables at unsampled locations using known data points. These techniques develop mathematical models of spatial correlation structures through variogram construction, both isotropic and anisotropic. Variograms and kriging are the most commonly used geostatistical and interpolation techniques, providing the best-unbiased results and a good fit determined by the least squares method. Spatial variance data are characterized and modeled using semi-variograms and cross-semi-variograms, which evaluate data points based on separation distances. Kriging then estimates predicted and observed values between samples based on the modeled variance. These techniques facilitate the generation of highresolution soil maps, which are essential for land use planning and nutrient management in crop production (Arora et al., 2019).

De Zorzi et al. (2008) noted that the layout for soil sampling should be tailored to the size and shape of the agricultural plot. The objective is to obtain the fewest number of samples possible without compromising the precision of spatial interpolation. Typically, this involves initial zoning of the agricultural plots, often by measuring soil electrical conductivity. The selection of sampling depth is crucial and should be based on the crop type and its root system, usually at two levels: 0–30 cm and 30–60 cm.

3. Material and methods

A total of 260 samples of arable soil layer (0-30 cm) were collected for the research, which was sampled from two arable areas: the locality Trnava in Osijek-Baranja County and the locality Đurđevac in Koprivnica-Križevci County (Picture 1).



Picture 1. Study area and sampling localities – Trnava and Đurđevac.

The samples were collected as part of research into the impact of fertilization on crop yields and analyzed in the analytical laboratory of the Department of Agroecology and Environment Protection, Faculty of Agrobiotechnical Sciences Osijek. The analyses included mandatory analyses of soil chemical properties:

1. Soil reaction (pH value of soil suspension in water and in KCl solution)

2. Soil organic matter content (humus content)
3. Hydrolytic soil acidity
4. The content of total carbonates in the soil
5. Phosphorus available to plants (determined by the AL method)
6. Potassium available to plants (determined by the AL method).

In addition to the aforementioned mandatory soil analyses, additional analyses of the physical and chemical properties of the soil were carried out for research:

1. Mechanical composition of the soil
2. Concentration of exchangeable cations on the soil adsorption complex (extraction by the AA method)
3. Total concentration of primary (P and K) and secondary (Ca and Mg) nutrients in the soil (extraction by aqua regia)
4. Total concentration of microelements (Fe, Mn, Zn, Cu, Ni, Mo) in the soil (extraction by with aqua regia)
5. Total concentration of useful elements (Co, Se) in the soil (extraction by aqua regia)
6. Total concentration of harmful elements (Cr, Cd, As, Hg, Pb) in the soil (extraction by aqua regia)

3.1. Collection and preparation of soil samples for analysis

Soil samples were collected from production areas as average samples according to a pre-planned schedule. The locations of the centers of each composite sample were determined using a GPS receiver with ArcPad 7.2 software support.

The collected samples were prepared for laboratory analysis in accordance with the ISO 11464: 2004 protocol, which includes cleaning from impurities, crushing, drying, grinding, sieving and homogenization.

3.2. Laboratory analyses

3.2.1. Soil reaction (pH value)

Soil reaction, represented by its pH value, is a vital measure of soil acidity or alkalinity, expressed as the negative logarithm of hydrogen ion concentration. A slightly acidic to neutral soil pH is optimal for the growth of most plant species. In this study, acidity parameters were assessed in accordance with the ISO 10390: 2005 standard, with pH values determined in soil suspensions using both distilled water and a 1M KCl solution. The pH value serves as a fundamental indicator influencing various agrochemical soil properties essential for plant nutrition (Vukadinović and Lončarić, 1998). Employing an electrometric method with a pH meter (ISO 10390: 2005), soil samples were analyzed, and measurements were taken in a 1:2.5 soil suspension with distilled water to represent actual acidity and in 1 M KCl to denote exchangeable acidity, using a Metrel MA 5750 pH meter.

3.2.2. Soil organic matter content (humus content)

Humus is one of the most important factors of soil fertility, which affects the physical, chemical and biological properties of the soil and the plant-nutritive capacity of the soil.
The humus content in the soil underwent assessment through the bichromate method (ISO 14235: 2004), involving the wet oxidation of soil organic matter utilizing potassium bichromate. Subsequently, the organic carbon concentration within the samples was quantified via spectrophotometric analysis using a Varian Cary 50 spectrophotometer. This measured organic carbon concentration was then converted to humus content using a conversion coefficient of 1.724.

3.2.3. Hydrolytic soil acidity

Hydrolytic acidity in soil was assessed in all samples of acid soils. This parameter, representing the part of total potential acidity of the soil, involves extracting 20 g of soil with 50 ml of 1 M sodium acetate. During this process, the acidic H^+ and Al^{3+} ions in the soil's adsorption complex are replaced by the alkaline Na^+ ion from the acetate (ISO 10693: 1994). The reaction produces acetic acid, the amount of which corresponds to the hydrogen ions on the adsorption complex of the soil. This quantity is determined by titration or neutralizing the resultant acid with 0.1 M sodium hydroxide. Hydrolytic acidity is quantified in cmol(+) kg^{-1} of unsaturation of the soil's adsorption complex with alkaline ions. These measurements are crucial for calculating the soil’s cation adsorption capacity and degree of CEC saturation with alkaline ions, and are particularly important for determining the need for liming. The evaluation of hydrolytic acidity, which also aids in estimating the degree of acidification of the soil's adsorption complex and the need for liming, was conducted using the Kapen method.

3.2.4. Content of total carbonates in the soil

Total carbonates in the soil, which reduce acidity and serve as a source of calcium and magnesium, significantly influence soil structure along with other physical and chemical characteristics. The level of carbonates was assessed using the Galet method, adhering to the ISO 10693: 2004 standard. In samples where substitution acidity values exceeded 5.5 pH units, the carbonate content was determined using a Scheibler calcimeter.

This volumetric method measures the volume of CO_2 released from soil carbonates when reacted with 10% hydrochloric acid. The percentage of $CaCO_3$ is calculated using the formula: % $CaCO_3$= (ml CO_2 × F × 2.274 × 100) / mg soil, where 2.274 is the conversion factor for CO_2 to $CaCO_3$, and F is the weight factor of 1 ml of CO_2 at the analysis temperature and pressure, sourced from relevant tables (Lončarić, 2005). This comprehensive approach allows for accurate measurement and analysis of soil carbonate levels, critical for understanding soil health and managing soil treatment processes.

3.2.5. Plant available P and K extracted using ammonium-lactate method

The determination of available P_2O_5 and K_2O in the soil was carried out using the AL method, involving extraction with ammonium lactate solution (Egner et al., 1960). This method targets phosphorus and potassium fractions soluble in water and weak acids. Specifically, 5 g of air-dried soil was extracted with 100 ml of ammonium lactate (pH 3.75), shaken for 2 hours on a rotary shaker, and then filtered. Phosphorus concentration in the extract was measured spectrophotometrically using the blue method, which involves developing a blue complex through a series of chemical reactions and heating, used for the accurate determination of phosphorus levels. A series of standard solutions were prepared and measured alongside the samples at 680 nm using a Varian Cary 50 spectrophotometer, and phosphorus amounts in the soil samples were calculated with WinLAB software, expressed in mg P_2O_5 per 100g of soil. Concentrations of potassium were determined using an emission technique on an atomic absorption spectrophotometer (AAS). The concentrations of plant available potassium were expressed in mg K_2O per 100g of soil. This comprehensive analysis helps assess the phosphorus and potassium status of soils for better management of fertilization practices.

3.2.6. Determination of the soil texture

The texture, or granulometric composition, of soil is determined by the quantitative relationship of its mechanical elements, such as coarse and fine sand, coarse and fine silt, and clay. This research utilized the ISO method (ISO 11277: 2004), which combines sieving and sedimentation in water. Initially, 10 g of air-dried soil was treated with a 0.4 n $Na_4P_2O_7$ x 10 H_2O solution, left overnight, and then shaken with water for 6 hours. The suspension was sieved to separate sand particles, which were then dried and weighed to calculate the percentages of coarse and fine sand. The remaining suspension was transferred to a sedimentation cylinder, diluted, homogenized, and left to settle. By pipetting and weighing the settled particles, the percentages of silt and clay were determined using Stokes' law. For instance, particles with a diameter of 20 µm settle in 4 minutes and 48 seconds at 20°C. The percentage of clay was calculated after further sedimentation. The content of fine silt was found by subtracting the clay percentage from the total percentage of silt and clay. Finally, the percentage of coarse silt was determined by subtracting the sum of the other particle percentages from 100%. Soil texture was classified using the FAO triangle (2006) textural classes, which is crucial for understanding the soil's water-air regime and overall suitability for plant growth.

3.2.7. Determination of concentrations of exchangeable cations in the soil

The concentration of exchangeable cations on the adsorption complex was determined by extracting the soil with 1M ammonium acetate (AA) followed by triple centrifugation, according to the method described by Jones (2001). This process involved substituting the alkaline cations (Ca, Mg, K, and Na) with NH_4^+ from the ammonium acetate solution. The resulting concentrations of these cations in the solution were then measured using a Perkin Elmer Analyst 200 atomic absorption spectrophotometer. Specifically, K and Na concentrations were measured using the emission technique at wavelengths of 404.4 nm and 589.0 nm, respectively, while Ca and Mg concentrations were determined using the absorption technique at wavelengths of 422.7 nm and 202.6 nm, respectively. The concentrations of the alkaline cations were reported in mg kg^{-1} of soil.

3.2.8. Determination of total content of essential, useful, and toxic elements in soil

The content of individual elements in the soil is determined by soil digestion with aqua regia according to the ISO method (ISO 11466: 2004). The extract of soil samples is used to determine the total concentrations of essential, beneficial, and toxic elements in the soil. 1 g of soil is weighed into teflon digestion tube and 12 ml of a mixture of concentrated HCl and HNO_3 in a ratio of 1:3 were added (aqua regia). Teflon tube with soil samples and aqua regia (acid mixture) are transferred to a microwave oven (CEM Mars 6) for digestion for 45 minutes. After cooling, the contents of the teflon tube (digested soil samples) are quantitatively transferred into measuring flasks and topped up with deionized water. The concentrations of the total amounts of elements in the extract are measured using the inductively coupled plasma emission technique (ICP-OES). The results are expressed in mg kg^{-1}, for most of the analyzed elements, while smaller concentration values are expressed in µg kg^{-1} (eg for Mo, Se, As, Cd, Hg).

3.2.9. Calculation of cation exchange capacity (CEC) in soil

Cation exchange capacity was calculated as the sum of equivalent amounts of exchangeable fractions of alkaline (K and Na) and alkaline earth cations (Ca and Mg) on the soil complex. Equivalent amounts of individual cations represent the quotient of the measured amount of cations (in mg 100 g^{-1} of soil) and the equivalent atomic mass (atomic mass/valence of the cation).

Hydrolytic acidity (mmol H^+ 100 g^{-1} soil) is added to the sum of equivalent amounts of cations using formula:

$$KIK(cmol(+)kg^{-1} = \frac{Ca(mg100\ \ g^{-1})}{40{,}08/2} + \frac{Mg(mg100\,g^{-1})}{24{,}305/2} + \frac{K(mg100\,g^{-1})}{39{,}098} + \frac{Na(mg100\,g^{-1})}{22{,}99} + \frac{Hk(mg100\,g^{-1})}{1}$$

3.2.10. Calculation of required fertilization and liming

The results of soil analyzes were used to calculate needs in soil liming and the necessary fertilization with N, P and K in the cultivation of wheat, corn and sunflower. For calculation of needs in liming and fertilization, the DSS software (Lončarić et al., 2023, 2022, 2020, 2016) were used.

3.3. Data analyses

All collected data were analyzed in MS Excel for descriptive statistics, correlation, and multiregression analyses and using SAS Enterprise Guide, version 8.1 Update 1 (8.1.1.4580), Copyright 2019, SAS Institute Inc., Cary, NC, USA. The data was visualized using the R environment, version 4.2.2. , Copyright 2016, The R Foundation, Indianapolis, Indiana, United States.

3.4. Regression models

Collected data, i.e. the results of laboratory and statistical analyses were used to create regression models for assessing the value of certain chemical properties of the soil.

4. Results

4.1. Basic chemical and physical properties of the studied soil samples

4.1.1. Basic agrochemical properties of soil

Analysis of actual acidity (pH_{H2O}) of the 116 samples taken on the Trnava location shows that the values range from a minimum of 4.49 to a maximum of 6.33 (Table 1., Appendix table 1). The average pH_{H2O} value is 5.31. The variance of the measurements is 0.18, and the standard deviation is 0.43. The coefficient of variation (CV) was calculated to be 8.10%.
On the other hand, the analysis of the exchangeable acidity (pH_{KCl}) shows that the values range from a minimum of 3.48 to a maximum of 5.45. The average pH_{KCl} is 4.13. The variance of the measurements is 0.18, and the standard deviation is 0.43. The coefficient of variation was also calculated to be 10.42%.
Furthermore, the analysis of soil organic matter content (humus content) shows that the values range from a minimum of 1.03% to a maximum of 2.00%. The average humus content is 1.40%. The variance of the measurements is 0.05, and the standard deviation is 0.22. The coefficient of variation was calculated to be 15.49%.
The hydrolytic soil acidity analysis on the Trnava location shows that the values range from a minimum of 2.05 cmol(+)kg^{-1} to a maximum of 6.91 cmol(+)kg^{-1}. The average hydrolytic soil acidity is 4.59 cmol(+)kg^{-1}. The variance of the measurements is 1.24, and the standard deviation is 1.11. The coefficient of variation was also calculated to be 24.25%.
The values of phosphorus (P_2O_5) available to plants range from a minimum of 6.06 mg /100g soil to a maximum of 40.94 mg /100g. The average available phosphorus is 15.58 mg /100g. The variance of the measurements is 48.32, and the standard deviation is 6.95. The coefficient of variation was calculated to be 44.61%.
As for the analysis of potassium (K_2O) available to plants, the values range from a minimum of 10.19 mg /100g to a maximum of 28.32 mg /100g. The average available potassium is 15.42 mg /100g. The variance of the measurements is 10.12, and the standard deviation is 3.18. The coefficient of variation was calculated to be 20.63%.

Table 1. Summary of descriptive statistics and variability of basic agrochemical soil properties in soil samples from the Trnava location.

	pH_{H_2O}	pH_{KCl}	Humus	Hy	P_2O_5	K_2O
			(%)	$cmol(+)kg^{-1}$	mg /100g soil	
Var	0.18	0.18	0.05	1.24	48.32	10.12
Min	4.49	3.48	1.03	2.05	6.06	10.19
Max	6.33	5.45	2.00	6.91	40.94	28.32
Average	5.31	4.13	1.40	4.59	15.58	15.42
StDev	0.43	0.43	0.22	1.11	6.95	3.18
CV (%)	8.10	10.42	15.67	24.25	44.61	20.63

Further data analysis of actual acidity (pH_{H2O}) of the 144 samples taken on the Đurđevac location shows (Table 2., Appendix table 7) that the values range from a minimum of 4.63 to a maximum of 6.98. The average active acidity value is 5.37. The variance of the measurements is 0.15, and the standard deviation is 0.38. The coefficient of variation was calculated to be 7.15%.

On the other hand, the analysis of the exchangeable acidity (pH_{KCl}) shows that the values range from a minimum of 3.57 to a maximum of 5.61. The average exchangeable acidity is 4.30. The variance of the measurements is 0.12, and the standard deviation is 0.35. The coefficient of variation (CV) was also calculated to be 8.10%.

Furthermore, the analysis of soil organic matter content (humus content) shows that the values range from a minimum of 1.39% to a maximum of 2.22%. The average humus content is 1.72%. The variance of the measurements is 0.03, and the standard deviation is 0.18. The coefficient of variation was calculated to be 10.75%.

The hydrolytic soil acidity analysis on the Đurđevac location shows that the values range from a minimum of 1.79 $cmol(+)kg^{-1}$ to a maximum of 6.62 $cmol(+)kg^{-1}$. The average hydrolytic soil acidity is 4.14 $cmol(+)kg^{-1}$. The variance of the measurements is 0.74, and the standard deviation is 0.86. The coefficient of variation was also calculated to be 20.81%.

The values of phosphorus (P_2O_5) available to plants range from a minimum of 7.38 mg /100g soil to a maximum of 40.62 mg /100g. The average available phosphorus is 17.41 mg /100g. The variance of the measurements is 32.89, and the standard deviation is 5.74. The coefficient of variation was calculated to be 32.94%.

As for the analysis of potassium (K_2O) available to plants, the values range from a minimum of 11.58 mg /100g to a maximum of 39.46 mg /100g. The average available potassium is

19.48 mg /100g. The variance of the measurements is 26.62, and the standard deviation is 5.44. The coefficient of variation was calculated to be 27.94%.

Table 2. Summary of descriptive statistics and variability of basic agrochemical soil properties in soil samples from the Đurđevac location.

	pH_{H_2O}	pH_{KCl}	Humus	Hy	P_2O_5	K_2O
			(%)	cmol$^{(+)}$kg^{-1}	mg /100g soil	
Var	0.15	0.12	0.03	0.74	32.89	29.62
Min	4.63	3.57	1.39	1.79	7.38	11.58
Max	6.98	5.61	2.22	6.62	40.62	39.46
Average	5.37	4.30	1.72	4.14	17.41	19.48
StDev	0.38	0.35	0.18	0.86	5.74	5.44
CV (%)	7.15	8.10	10.75	20.81	32.94	27.94

4.1.2. Cation exchange capacity (CEC) and concentrations of exchangeable cations on the soil adsorption complex

Cation exchange capacity (CEC) of the 116 samples taken at the Trnava location shows (Table 3., Appendix table 2) that the values range from a minimum of 9.82 cmol(+)kg^{-1} to a maximum of 30.58 cmol(+)kg^{-1}. The average value of cation exchange capacity is 14.19 cmol(+)kg^{-1}. The variance of the measurements is 7.36, and the standard deviation is 2.71. The coefficient of variation (CV) was calculated to be 19.13%.

The analysis of concentrations of exchangeable cations on the soil adsorption complex shows that the values for calcium (Ca) concentrations range from a minimum of 817.58 mg/kg to a maximum of 3,564.12 mg kg^{-1}. The average calcium concentrations is 1,370.35 mg kg^{-1}. The variance of the measurements is 169,841.45, and the standard deviation is 412.12. The coefficient of variation was also calculated to be 30.07%.

The analysis of concentrations of exchangeable cations on the soil adsorption complex shows that the values for magnesium (Mg) concentrations range from a minimum of 134.13 mg kg^{-1} to a maximum of 918.79 mg kg^{-1}. The average for magnesium concentrations is 291.85 mg kg^{-1}. The variance of the measurements is 12,370.71, and the standard deviation is 111.22. The coefficient of variation was also calculated to be 38.11%.

Furthermore, the analysis of concentrations of exchangeable cations on the soil adsorption complex shows that the values for potassium (K) concentrations range from a minimum of 54.34 mg kg^{-1} to a maximum of 271.87 mg kg^{-1}. The average for potassium concentrations is 116.83 mg kg^{-1}. The variance of the measurements is 1,082.02, and the standard deviation is 32.89. The coefficient of variation was also calculated to be 28.16%.

Additionally, the analysis of concentrations of exchangeable cations on the soil adsorption complex shows that the values for sodium (Na) concentrations range from a minimum of 6.38 mg kg^{-1} to a maximum of 30.87 mg kg^{-1}. The average for sodium concentrations is 12.57 mg kg^{-1}. The variance of the measurements is 20.27, and the standard deviation is 4.50. The coefficient of variation was also calculated to be 35.82%.

Table 3. Summary of descriptive statistics and variability of cation exchange capacity (CEC) and concentrations of exchangeable cations on the soil adsorption complex in soil samples from the Trnava location.

	Ca	Mg	K	Na	CEC
	(mg kg^{-1})				(cmol(+)kg^{-1})
Var	169,841.45	12,370.71	1,082.02	20.27	7.36
Min	817.58	134.13	54.34	6.38	9.82
Max	3,564.12	918.79	271.87	30.87	30.58
Average	1,370.35	291.85	116.83	12.57	14.19
StDev	412.12	111.22	32.89	4.50	2.71
CV (%)	30.07	38.11	28.16	35.82	19.13

Cation exchange capacity (CEC) of the 144 samples taken on the Đurđevac location shows (Table 4., Appendix table 8) that the values range from a minimum of 5.30 cmol(+)kg^{-1} to a maximum of 11.23 cmol(+)kg^{-1}. The average value of CEC is 8.65 cmol(+)kg^{-1}. The variance of the measurements is 0.72, and the standard deviation is 0.85. The coefficient of variation (CV) was calculated to be 9.82%.

The analysis of concentrations of exchangeable cations on the soil adsorption complex shows that the values for calcium (Ca) concentrations range from a minimum of 223.38 mg kg^{-1} to a maximum of 1,334.77 mg kg^{-1}. The average for Calcium concentrations is 615.70 mg kg^{-1}. The variance of the measurements is 32,887.34, and the standard deviation is 181.35. The coefficient of variation was also calculated to be 29.45%.

The analysis of concentrations of exchangeable cations on the soil adsorption complex shows that the values for magnesium (Mg) concentrations range from a minimum of 40.06 mg kg^{-1} to a maximum of 342.69 mg kg^{-1}. The average for magnesium concentrations is 120.68 mg kg^{-1}. The variance of the measurements is 1,783.08, and the standard deviation is 42.23. The coefficient of variation was also calculated to be 34.99%.

Furthermore, the analysis of concentrations of exchangeable cations on the soil adsorption complex shows that the values for potassium (K) concentrations range from a minimum of 79.92 mg kg^{-1} to a maximum of 299.00 mg kg^{-1}. The average for potassium concentrations is 149.81 mg kg^{-1}. The variance of the measurements is 1,818.12, and the standard deviation is 42.64. The coefficient of variation was also calculated to be 28.46%.
Additionally, the analysis of concentrations of exchangeable cations on the soil adsorption complex shows that the values for sodium (Na) concentrations range from a minimum of 2.31 mg kg^{-1} to a maximum of 57.09 mg kg^{-1}. The average for sodium concentrations is 13.19 mg kg^{-1}. The variance of the measurements is 87.32, and the standard deviation is 9.34. The coefficient of variation was also calculated to be 70.84%.

Table 4. Summary of descriptive statistics and variability of cation exchange capacity (CEC) and concentrations of exchangeable cations on the soil adsorption complex in soil samples from the Đurđevac location.

	Ca	**Mg**	**K**	**Na**	**CEC**
	(mg kg^{-1})				(cmol(+)kg^{-1})
Var	32,887.34	1,783.08	1,818.12	87.32	0.72
Min	223.38	40.06	79.92	2.31	5.30
Max	1,334.77	342.69	299.00	57.09	11.23
Average	615.70	120.68	149.81	13.19	8.65
StDev	181.35	42.23	42.64	9.34	0.85
CV (%)	29.45	34.99	28.46	70.84	9.82

4.1.3. Determination of the soil texture

Coarse sand content of the 116 samples taken at the Trnava location shows (Table 5., Appendix table 3) that the values range from a minimum of 0.69% to a maximum of 2.91%. The average value of coarse sand content is 1.78%. The variance of the measurements is 0.35, and the standard deviation is 0.59. The coefficient of variation (CV) was calculated to be 33.08%.

In the Table 5. is shown that the fine sand content ranges from a minimum of 1.88% to a maximum of 3.15%. The average value of fine sand content is 2.26%. The variance of the measurements is 0.05, and the standard deviation is 0.23. The coefficient of variation (CV) was calculated to be 10.04%.

Furthermore, the analysis of coarse silt content shows that the values range from a minimum of 36.85% to a maximum of 47.88%. The average for coarse silt content is 40.34%. The variance of the measurements is 5.21, and the standard deviation is 2.28. The coefficient of variation was also calculated to be 5.66%.

Additionally, the analysis of fine silt content shows that the values range from a minimum of 28.93% to a maximum of 34.67%. The average for fine silt content is 32.13%. The variance of the measurements is 1.42, and the standard deviation is 1.19. The coefficient of variation was also calculated to be 3.71%.

Moreover, the analysis of clay content shows that the values range from a minimum of 17.58% to a maximum of 27.74%. The average for clay content is 23.50%. The variance of the measurements is 6.37, and the standard deviation is 2.52. The coefficient of variation was also calculated to be 10.74%.

Table 5. Summary of descriptive statistics and variability of the soil texture components in soil samples from the Trnava location.

	Coarse sand	**Fine sand**	**Coarse silt**	**Fine silt**	**Clay**
	(%)				
Var	0.35	0.05	5.21	1.42	6.37
Min	0.69	1.88	36.85	28.93	17.58
Max	2.91	3.15	47.88	34.67	27.74
Average	1.78	2.26	40.34	32.13	23.50
StDev	0.59	0.23	2.28	1.19	2.52
CV (%)	33.08	10.04	5.66	3.71	10.74

Coarse sand content of the 144 samples taken on the Đurđevac location shows (Table 6., Appendix table 9) that the values range from a minimum of 2.19% to a maximum of 8.83%. The average value of coarse sand content is 4.27%. The variance of the measurements is 1.78, and the standard deviation is 1.33. The coefficient of variation (CV) was calculated to be 31.22%.

In the Table 6. is also shown that the fine sand content ranges from a minimum of 10.37% to a maximum of 31.16%. The average value of fine sand content is 18.20%. The variance of the measurements is 28.50, and the standard deviation is 5.34. The coefficient of variation was calculated to be 29.34%.

Furthermore, the analysis of coarse silt content shows that the values range from a minimum of 34.38% to a maximum of 57.29%. The average for coarse silt content is 47.26%. The variance of the measurements is 32.13, and the standard deviation is 5.67. The coefficient of variation was also calculated to be 11.99%.

Additionally, the analysis of fine silt content shows that the values range from a minimum of 14.57% to a maximum of 27.05%. The average for fine silt content is 19.40%. The variance of the measurements is 6.53, and the standard deviation is 2.56. The coefficient of variation was calculated to be 13.17%.

Moreover, the analysis of clay content shows that the values range from a minimum of 8.20% to a maximum of 14.15%. The average for clay content is 10.87%. The variance of the measurements is 1.66, and the standard deviation is 1.29. The coefficient of variation was also calculated to be 11.86%.

Table 6. Summary of descriptive statistics and variability of the soil texture components in soil samples from the Đurđevac location.

	Coarse sand	Fine sand	Coarse silt	Fine silt	Clay
	(%)				
Var	1.78	28.50	32.13	6.53	1.66
Min	2.19	10.37	34.38	14.57	8.20
Max	8.83	31.16	57.29	27.05	14.15
Average	4.27	18.20	47.26	19.40	10.87
StDev	1.33	5.34	5.67	2.56	1.29
CV (%)	31.22	29.34	11.99	13.17	11.86

4.1.4. Total concentrations of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg)

Total phosphorus (P) concentrations of the 116 samples taken on the Trnava location show (Table 7., Appendix table 4) that the values range from a minimum of 462.00 mg kg^{-1} to a maximum of 1,039.00 mg kg^{-1}. The average value of total phosphorus concentrations is 703.26 mg kg^{-1}. The variance of the measurements is 15,625.95, and the standard deviation is 125.00. The coefficient of variation (CV) was calculated to be 17.77%.

In the Table 7. is also shown that the total potassium (K) concentrations range from a minimum of 1,305.00 mg kg^{-1} to a maximum of 4,881.00 mg kg^{-1}. The average value of total potassium concentrations is 2,030.16 mg kg^{-1}. The variance of the measurements is

409,759.51, and the standard deviation is 640.12. The coefficient of variation was calculated to be 31.53%.

Furthermore, the total calcium (Ca) concentrations analysis shows that the values range from a minimum of 1,890.00 mg kg^{-1} to a maximum of 4,499.00 mg kg^{-1}. The total calcium concentration average is 2,934.70 mg kg^{-1}. The variance of the measurements is 144,960.42, and the standard deviation is 380.74. The coefficient of variation was also calculated to be 12.97%.

Moreover, the total magnesium (Mg) concentrations analysis shows that the values range from a minimum of 2,467.00 mg kg^{-1} to a maximum of 4,271.00 mg kg^{-1}. The total magnesium concentration average is 3,201.21 mg kg^{-1}. The variance of the measurements is 154,166.91, and the standard deviation is 392.64. The coefficient of variation was also calculated to be 12.27%.

Table 7. Summary of descriptive statistics and variability of total concentrations of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) in soil samples from the Trnava location.

	P	**K**	**Ca**	**Mg**
	(mg kg^{-1})			
Var	15,625.95	409,759.51	144,960.42	154,166.91
Min	462.00	1,305.00	1,890.00	2,467.00
Max	1,039.00	4,881.00	4,499.00	4,271.00
Average	703.26	2,030.16	2,934.70	3,201.21
StDev	125.00	640.12	380.74	392.64
CV (%)	17.77	31.53	12.97	12.27

Total phosphorus (P) concentrations of the 144 samples taken on the Đurđevac location show (Table 8., Appendix table 10) that the values range from a minimum of 306.70 mg kg^{-1} to a maximum of 977.40 mg kg^{-1}. The average value of total phosphorus concentrations is 612.47 mg kg^{-1}. The variance of the measurements is 7,284.70, and the standard deviation is 85.35. The coefficient of variation (CV) was calculated to be 13.94%.

In the Table 8. is also shown that the total potassium (K) concentrations range from a minimum of 945.80 mg kg^{-1} to a maximum of 3,887.00 mg kg^{-1}. The average value of total potassium concentrations is 1,649.06 mg kg^{-1}. The variance of the measurements is 683,632.67, and the standard deviation is 826.82. The coefficient of variation was calculated to be 50.14%.

Furthermore, the total calcium (Ca) concentrations analysis shows that the values range from a minimum of 1,099.00 mg kg^{-1} to a maximum of 4,004.00 mg kg^{-1}. The total calcium concentration average is 2,010.35 mg kg^{-1}. The variance of the measurements is 672,249.31, and the standard deviation is 819.91. The coefficient of variation was also calculated to be 40.78%.

Moreover, the total magnesium (Mg) concentrations analysis shows that the values range from a minimum of 1,835.00 mg kg^{-1} to a maximum of 4,242.00 mg kg^{-1}. The total magnesium concentration average is 2,844.97 mg kg^{-1}. The variance of the measurements is 2,844.97, and the standard deviation is 527.59. The coefficient of variation was also calculated to be 18.54%.

Table 8. Summary of descriptive statistics and variability of total concentrations of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) in soil samples from the Đurđevac location.

	P	**K**	**Ca**	**Mg**
	(mg kg^{-1})			
Var	7,284.70	683,632.67	672,249.31	c
Min	306.70	945.80	1,099.00	1,835.00
Max	977.40	3,887.00	4,004.00	4,242.00
Average	612.47	1,649.06	2,010.35	2,844.97
StDev	85.35	826.82	819.91	527.59
CV (%)	13.94	50.14	40.78	18.54

4.1.5. Total concentrations of microelements: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), molybdenum (Mo)

The total iron (Fe) concentrations of the 116 samples taken at the Trnava location show (Table 9., Appendix table 5) that the values range from a minimum of 13,080.00 mg kg^{-1} to a maximum of 20,120.00 mg kg^{-1}. The average value of total Iron concentration is 16,403.53 mg kg^{-1}. The variance of the measurements is 2,056,050.88, and the standard deviation is 1,433.89. The coefficient of variation (CV) was calculated to be 8.74%.

In the Table 9. is also shown that the total manganese (Mn) concentrations range from a minimum of 398.10 mg kg^{-1} to a maximum of 1,198.00 mg kg^{-1}. The average value of total manganese concentrations is 573.63 mg kg^{-1}. The variance of the measurements is

12,768.55, and the standard deviation is 113.00. The coefficient of variation was calculated to be 19.70%.

Furthermore, the total zinc (Zn) concentrations analysis shows that the values range from a minimum of 35.95 mg kg^{-1} to a maximum of 59.07 mg kg^{-1}. The total zinc concentration average is 46.29 mg kg^{-1}. The variance of the measurements is 26.02, and the standard deviation is 5.10. The coefficient of variation was also calculated to be 11.02%.

Moreover, the total copper (Cu) concentrations analysis shows that the values range from a minimum of 10.64 mg kg^{-1} to a maximum of 20.24 mg kg^{-1}. The total copper concentration average is 16.35 mg kg^{-1}. The variance of the measurements is 3.79, and the standard deviation is 1.95. The coefficient of variation was also calculated to be 11.90%.

The analysis of total nickel (Ni) concentrations reveals values ranging from a minimum of 16.18 mg kg^{-1} to a maximum of 30.18 mg kg^{-1}. The average concentration of nickel is 23.04 mg kg^{-1}. The variance of the measurements is 7.41, with a standard deviation of 2.72. Additionally, the coefficient of variation is 11.81%.

The analysis of total molybdenum (Mo) concentrations shows values ranging from a minimum of 140.83 µg kg^{-1} to a maximum of 375.36 µg kg^{-1}. The average concentration of molybdenum is 267.27 µg kg^{-1}. The variance of the measurements is 2,146.56, with a standard deviation of 46.33. The coefficient of variation is 17.34%.

Table 9. Summary of descriptive statistics and variability of total concentrations of microelements: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), molybdenum (Mo) in soil samples from the Trnava location.

	Fe	Mn	Zn	Cu	Ni	Mo
	(mg kg^{-1})					(µg kg^{-1})
Var	2,056,050.88	12,768.55	26.02	3.79	7.41	2,146.56
Min	13,080.00	398.10	35.95	10.64	16.18	140.83
Max	20,120.00	1,198.00	59.07	20.24	30.18	375.36
Average	16,403.53	573.63	46.29	16.35	23.04	267.27
StDev	1,433.89	113.00	5.10	1.95	2.72	46.33
CV (%)	8.74	19.70	11.02	11.90	11.81	17.34

The total iron (Fe) concentrations of the 144 samples taken at the Đurđevac location show (Table 10., Appendix table 11) that the values range from a minimum of 10,530.00 mg kg^{-1} to a maximum of 24,130.00 mg kg^{-1}. The average value of total Iron concentration is

17,989.10 mg kg^{-1}. The variance of the measurements is 5,950,251.63, and the standard deviation is 2,439.31. The coefficient of variation (CV) was calculated to be 13.56%.

In the Table 10 is also shown that the total manganese (Mn) concentrations range from a minimum of 207.80 mg kg^{-1} to a maximum of 754.90 mg kg^{-1}. The average value of total manganese concentrations is 485.19 mg kg^{-1}. The variance of the measurements is 5,938.81, and the standard deviation is 77.06. The coefficient of variation was calculated to be 15.88%.

Furthermore, the total zinc (Zn) concentrations analysis shows that the values range from a minimum of 21.70 mg kg^{-1} to a maximum of 56.01 mg kg^{-1}. The total zinc concentration average is 40.06 mg kg^{-1}. The variance of the measurements is 26.75, and the standard deviation is 5.17. The coefficient of variation was also calculated to be 12.91%.

Moreover, the total copper (Cu) concentrations analysis shows that the values range from a minimum of 5.80 mg kg^{-1} to a maximum of 14.16 mg kg^{-1}. The total copper concentration average is 10.31 mg kg^{-1}. The variance of the measurements is 1.85, and the standard deviation is 1.36. The coefficient of variation was also calculated to be 13.21%.

The analysis of total nickel (Ni) concentrations reveals values ranging from a minimum of 8.20 mg kg^{-1} to a maximum of 20.58 mg kg^{-1}. The average concentration of nickel is 15.62 mg kg^{-1}. The variance of the measurements is 5.62, with a standard deviation of 2.37. Additionally, the coefficient of variation is 15.18%.

The analysis of total molybdenum (Mo) concentrations shows values ranging from a minimum of 175.40 µg kg^{-1} to a maximum of 439.91 µg kg^{-1}. The average concentration of molybdenum is 317.69 µg kg^{-1}. The variance of the measurements is 1,734.89, with a standard deviation of 41.65. The coefficient of variation is 13.11%.

Table 10. Summary of descriptive statistics and variability of total concentrations of microelements: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), and molybdenum (Mo) in soil samples from the Đurđevac location.

	Fe	**Mn**	**Zn**	**Cu**	**Ni**	**Mo**
	(mg kg^{-1})					(µg kg^{-1})
Var	5,950,251.63	5,938.81	26.75	1.85	5.62	1,734.89
Min	10,530.00	207.80	21.70	5.80	8.20	175.40
Max	24,130.00	754.90	56.01	14.16	20.58	439.91
Average	17,989.10	485.19	40.06	10.31	15.62	317.69
StDev	2,439.31	77.06	5.17	1.36	2.37	41.65
CV (%)	13.56	15.88	12.91	13.21	15.18	13.11

4.1.6. Total concentrations of beneficial elements cobalt (Co), selenium (Se), and toxic elements chromium (Cr), cadmium (Cd), arsenic (As), mercury (Hg), lead (Pb) in the soil

The total cobalt (Co) concentrations of the 116 samples taken at the Trnava location show (Table 11., Appendix table 6) that the values range from a minimum of 8.28 mg kg^{-1} to a maximum of 20.56 mg kg^{-1}. The average value of total cobalt concentration is 11.43 mg kg^{-1}. The variance of the measurements is 2.88, and the standard deviation is 1.70. The coefficient of variation (CV) was calculated to be 14.84%.

In the Table 11. is also shown that the total selenium (Se) concentrations range from a minimum of 899.40 µg kg^{-1} to a maximum of 1,603.00 µg kg^{-1}. The average value of total selenium concentrations is 1,190.04 µg kg^{-1}. The variance of the measurements is 17,561.71, and the standard deviation is 132.52. The coefficient of variation was calculated to be 11.14%.

Furthermore, the total chromium (Cr) concentrations analysis shows that the values range from a minimum of 12.79 mg kg^{-1} to a maximum of 45.49 mg kg^{-1}. The total chromium concentration average is 28.81 mg kg^{-1}. The variance of the measurements is 88.11, and the standard deviation is 9.39. The coefficient of variation was also calculated to be 32.58%.

Moreover, the total cadmium (Cd) concentrations analysis shows that the values range from a minimum of 99.19 µg kg^{-1} to a maximum of 210.80 µg kg^{-1}. The total cadmium concentration average is 136.93 µg kg^{-1}. The variance of the measurements is 254.38, and the standard deviation is 15.95. The coefficient of variation was also calculated to be 11.65%.

The analysis of total arsenic (As) concentrations reveals values ranging from a minimum of 4,950.00 µg kg^{-1} to a maximum of 13,070.00 µg kg^{-1}. The average concentration of arsenic is 8,735.94 µg kg^{-1}. The variance of the measurements is 3,006,483.55, with a standard deviation of 1,733.92. Additionally, the coefficient of variation is 19.85%.

The analysis of total mercury (Hg) concentrations shows values ranging from a minimum of 1.98 µg kg^{-1} to a maximum of 21.42 µg kg^{-1}. The average concentration of mercury is 5.78 µg kg^{-1}. The variance of the measurements is 11.39, with a standard deviation of 3.38 µg kg^{-1}. The coefficient of variation is 58.40%.

Additionally, the analysis of total lead (Pb) concentrations reveals values ranging from a minimum of 10.23 mg kg^{-1}g to a maximum of 20.01 mg kg^{-1}. The average concentration of lead is 14.82 mg kg^{-1}. The variance of the measurements is 1.19, with a standard deviation of 1.09 mg kg^{-1}. The coefficient of variation is 7.36%.

Table 11. Summary of descriptive statistics and variability of total concentrations of beneficial elements cobalt (Co), selenium (Se), and toxic elements chromium (Cr), cadmium (Cd), arsenic (As), mercury (Hg), lead (Pb) in soil samples from the Trnava location.

	Co	Se	Cr	Cd	As	Hg	Pb
	(mg kg^{-1})	(µg kg^{-1})	(mg kg^{-1})	(µg kg^{-1})			(mg kg^{-1})
Var	2.88	17,561.71	88.11	254.38	3,006,483.55	11.39	1.19
Min	8.28	899.40	12.79	99.19	4,950.00	1.98	10.23
Max	20.56	1,603.00	45.49	210.80	13,070.00	21.42	20.01
Average	11.43	1,190.04	28.81	136.93	8,735.94	5.78	14.82
StDev	1.70	132.52	9.39	15.95	1,733.92	3.38	1.09
CV (%)	14.84	11.14	32.58	11.65	19.85	58.40	7.36

The total cobalt (Co) concentrations of the 144 samples taken at the Đurđevac location show (Table 12., Appendix table 12) that the values range from a minimum of 3.86 mg kg^{-1} to a maximum of 10.98 mg kg^{-1}. The average value of total cobalt concentration is 7.29 mg kg^{-1}. The variance of the measurements is 0.87, and the standard deviation is 0.93. The coefficient of variation (CV) was calculated to be 12.78%.

In the Table 12. is also shown that the total selenium (Se) concentrations range from a minimum 449.60 µg kg^{-1} to a maximum of 1,137.00 µg kg^{-1}. The average value of total selenium concentrations is 809.05 µg kg^{-1}. The variance of the measurements is 21,261.21, and the standard deviation is 0.93. The coefficient of variation was calculated to be 12.78%.

Furthermore, the total chromium (Cr) concentrations analysis shows that the values range from a minimum of 13.41 mg kg^{-1} to a maximum of 32.10 mg kg^{-1}. The total chromium concentration average is 21.14 mg kg^{-1}. The variance of the measurements is 26.51, and the standard deviation is 5.15. The coefficient of variation was also calculated to be 24.35%.

Moreover, the total cadmium (Cd) concentrations analysis shows that the values range from a minimum of 55.00 µg kg^{-1} to a maximum of 169.15 µg kg^{-1}. The total cadmium concentration average is 110.44 µg kg^{-1}. The variance of the measurements is 243.66, and the standard deviation is 15.61. The coefficient of variation was also calculated to be 14.13%.

The analysis of total arsenic (As) concentrations reveals values ranging from a minimum of 2,840.00 µg kg^{-1} to a maximum of 7,284.00 µg kg^{-1}. The average concentration of arsenic is 5,096.15 µg kg^{-1}. The variance of the measurements is 625,365.86, with a standard deviation of 790.80. Additionally, the coefficient of variation is 15.52%.

The analysis of total mercury (Hg) concentrations shows values ranging from a minimum of 0.09 µg kg^{-1} to a maximum of 6.36 µg kg^{-1}. The average concentration of mercury is 1.64

μg kg^{-1}. The variance of the measurements is 1.28, with a standard deviation of 1.13 μg kg^{-1}. The coefficient of variation is 68.96%.

Additionally, the analysis of total lead (Pb) concentrations reveals values ranging from a minimum of 6.60 mg kg^{-1} to a maximum of 19.00 mg kg^{-1}. The average concentration of lead is 13.39 mg kg^{-1}. The variance of the measurements is 3.85, with a standard deviation of 1.96 mg kg^{-1}. The coefficient of variation is 14.66%.

Table 12. Summary of descriptive statistics and variability of total concentrations of beneficial elements cobalt (Co), selenium (Se), and toxic elements chromium (Cr), cadmium (Cd), arsenic (As), mercury (Hg), lead (Pb) in soil samples from the Đurđevac location.

	Co	**Se**	**Cr**	**Cd**	**As**	**Hg**	**Pb**
	(mg kg^{-1})	(μg kg^{-1})	(mg kg^{-1})	(μg kg^{-1})			(mg kg^{-1})
Var	0.87	21,261.21	26.51	243.66	625,365.86	1.28	3.85
Min	3.86	449.60	13.41	55.00	2,840.00	0.09	6.60
Max	10.98	1,137.00	32.10	169.15	7,284.00	6.36	19.00
Average	7.29	809.05	21.14	110.44	5,096.15	1.64	13.39
StDev	0.93	145.81	5.15	15.61	790.80	1.13	1.96
CV (%)	12.78	18.02	24.35	14.13	15.52	68.96	14.66

4.2. Variability of soil properties

The coefficient of variation CV is the most important measure for defining the variability in soil parameters. A CV value of ≤ 20% is categorized under the low variability class, a value of 21% < CV ≤ 50% is categorized as moderate variability, a value of 51% < CV ≤ 100% is categorized as high variability, and CV > 100% indicates very high variability. Figure 1. displays the CV values for various measured soil properties at the Trnava location. These properties include basic agrochemical properties, cation exchange capacity (CEC), exchangeable cations on the soil adsorption complex, and soil texture components. Among these, the coefficient of variation for available phosphorus (P_2O_5) is the highest being 44.61%, whereas the coefficient of variation for fine silt content is the lowest being 3.71%.

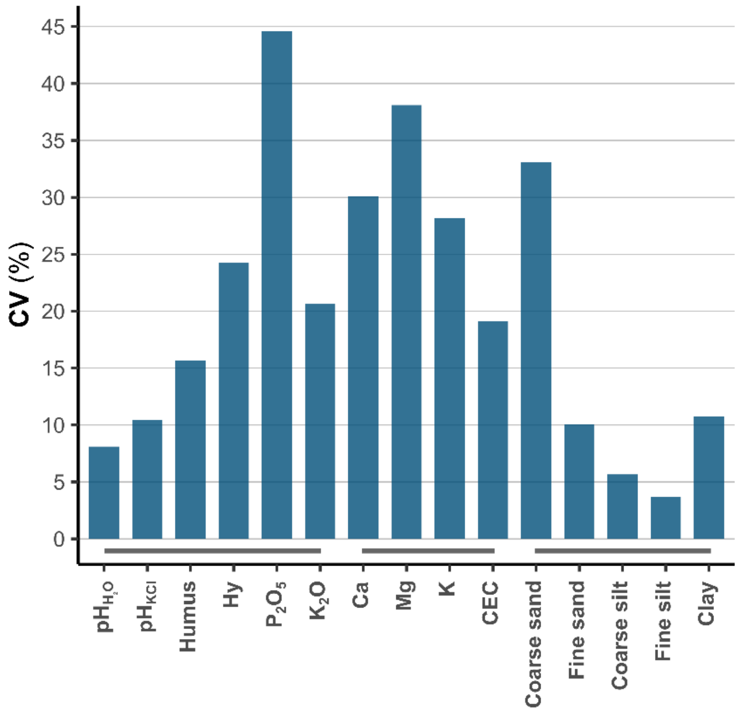


Figure 1. The coefficient of variation (CV) of basic agrochemical properties, exchangeable cations within the soil adsorption complex, cation exchange capacity (CEC), and soil texture components at the Trnava location.

Figure 2. presents the coefficients of variation for measured soil properties at the Trnava location, including total concentrations of macronutrients (phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg)), micronutrients (iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), and molybdenum (Mo)), as well as beneficial elements (cobalt (Co), selenium (Se)) and toxic elements (chromium (Cr), cadmium (Cd), arsenic (As), lead

(Pb)). Among these, the coefficient of variation is highest for the toxic element chromium (Cr) being 32.58% indicating significant variability, while it is lowest for another toxic element, lead (Pb) being 7.36%.

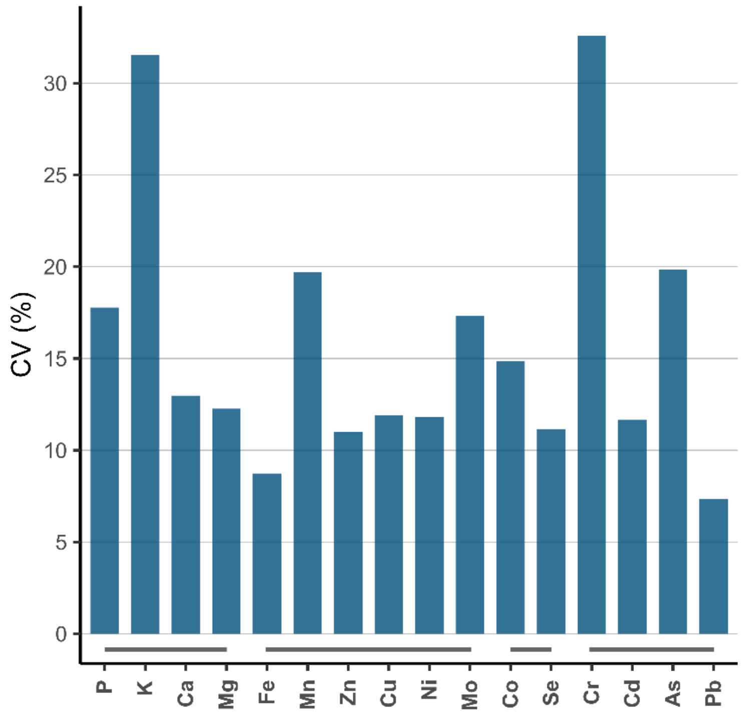


Figure 2. The coefficients of variation for measured total concentrations of macronutrients (P, K, Ca, Mg), micronutrients (Fe, Mn, Zn, Cu, Ni, Mo), beneficial elements (Co, Se) and toxic elements (Cr, Cd, As, Pb) at the Trnava location.

Figure 3. illustrates the coefficient of variation (CV) for a range of soil properties measured at the Đurđevac location. These soil properties include basic agrochemical properties, cation exchange capacity (CEC), exchangeable cations within the soil adsorption complex, and soil texture components. Notably, the CV is highest for the exchangeable cation magnesium (Mg) being 34.99%, while it is lowest for actual acidity 8.10%. Figure 4. presents the coefficients of variation for measured soil properties at the Đurđevac location, including total concentrations of macronutrients (phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg)), micronutrients (iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), and molybdenum (Mo)), as well as beneficial elements (cobalt (Co), selenium (Se)) and toxic elements (chromium (Cr), cadmium (Cd), arsenic (As), lead (Pb)). Among these, the coefficient of variation is highest for the macronutrient potassium (K) being 50.14%, and it is the lowest for the beneficial element, cobalt (Co) being 14.84%.

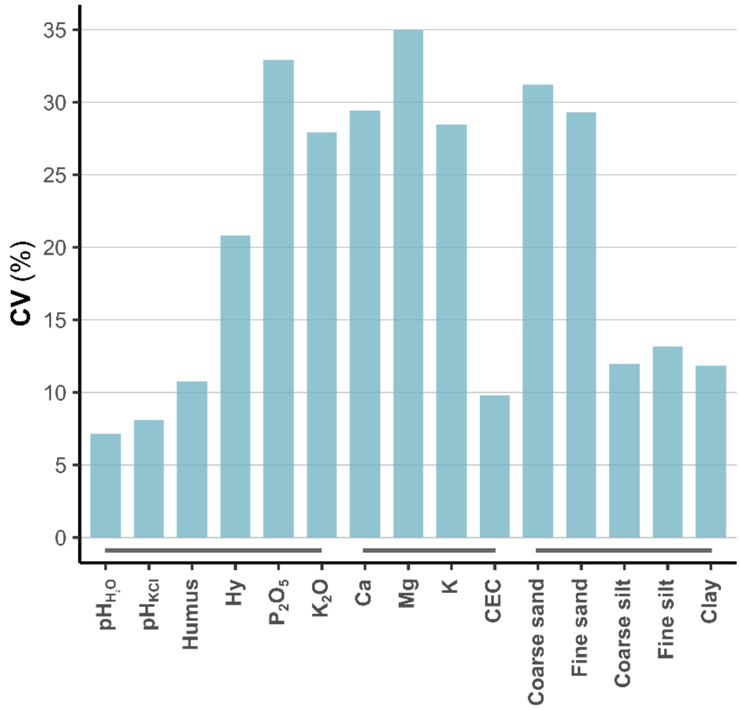


Figure 3. The coefficient of variation (CV) of basic agrochemical properties, exchangeable cations within the soil adsorption complex, cation exchange capacity (CEC), and soil texture components at the Đurđevac location.

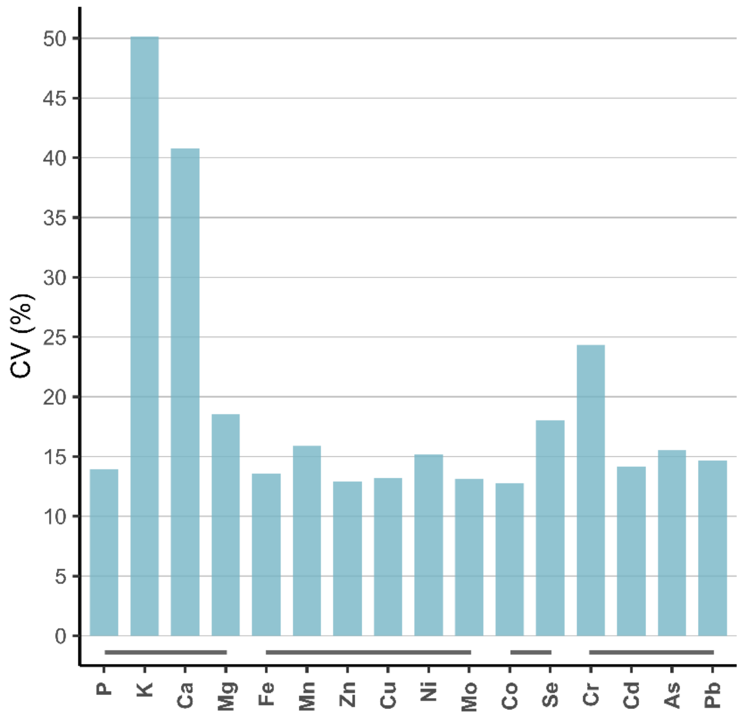


Figure 4. The coefficients of variation for measured total concentrations of macronutrients (P, K, Ca, Mg), micronutrients (Fe, Mn, Zn, Cu, Ni, Mo), beneficial elements (Co, Se) and toxic elements (Cr, Cd, As, Pb) at the Đurđevac location.

4.3. Comparison of Trnava and Đurđevac sites

The boxplots illustrate the mean distribution of basic agrochemical soil properties, including pH, humus content, hydrolytic acidity (Hy), phosphorus (P_2O_5), and potassium (K_2O) in Trnava and Đurđevac (Figure 5). Significant differences between Trnava and Đurđevac were found in pH_{KCl}, humus, Hy, P_2O_5 and K_2O (Tukey HSD; p value < 0.001).

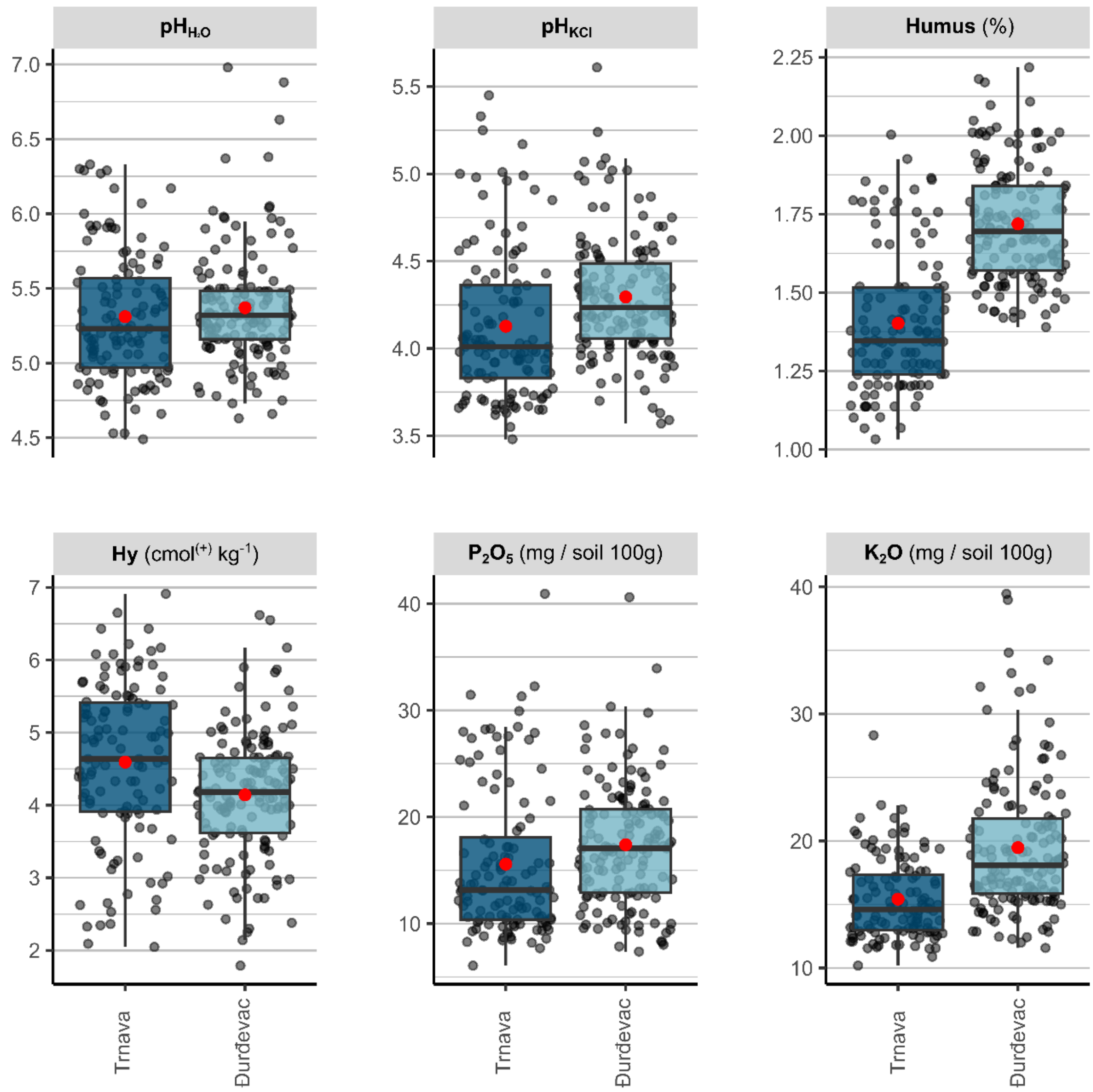


Figure 5. Comparison of basic agrochemical soil properties, including pH, humus content, hydrolytic acidity (Hy), phosphorus (P_2O_5), and potassium (K_2O) between Trnava and Đurđevac. Each boxplot displays the first and third quartiles, with the median marked by a line within the box. The individual points represent the observed data points. Red point on each plot indicates the average value for each property per each studied location.

In Figure 6. the boxplots illustrate the distribution of cation exchange capacity (CEC) and exchangeable cations on the soil adsorption complex in Trnava and Đurđevac. Significant differences between Trnava and Đurđevac were found in Ca, Mg, K and CEC (Tukey HSD; p value < 0.001).

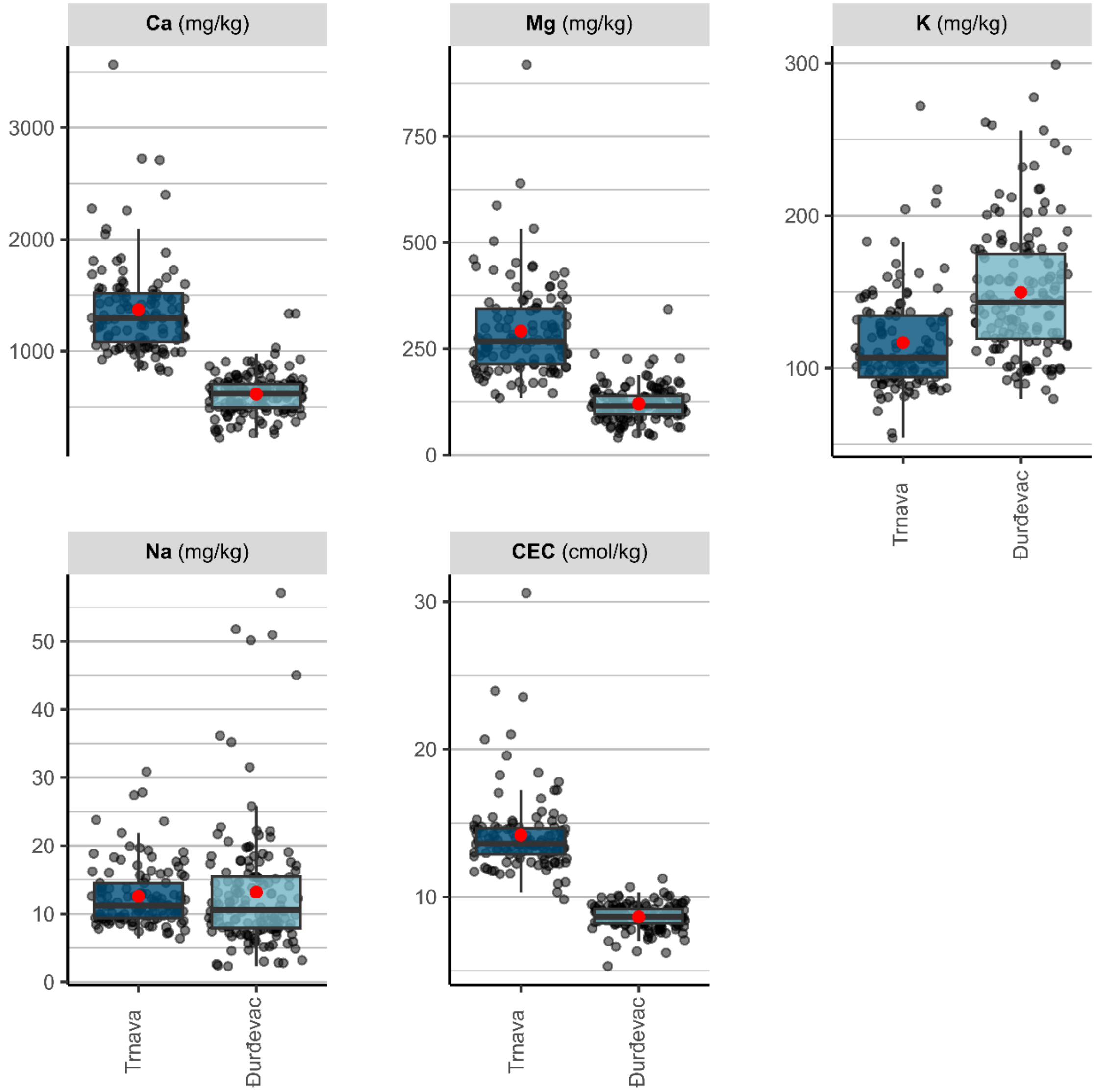


Figure 6. Comparison of cation exchange capacity (CEC) and exchangeable cations on the soil adsorption complex between Trnava and Đurđevac. Each boxplot displays the first and third quartiles, with the median marked by a line within the box. The individual points represent the observed data points. Red point on each plot indicates the average value for each property per each studied location.

In Figure 7. the boxplots illustrate the distribution of soil texture components in Trnava and Đurđevac. Significant differences between Trnava and Đurđevac were found in coarse sand, fine sand, fine silt and clay (Tukey HSD; p value < 0.001).

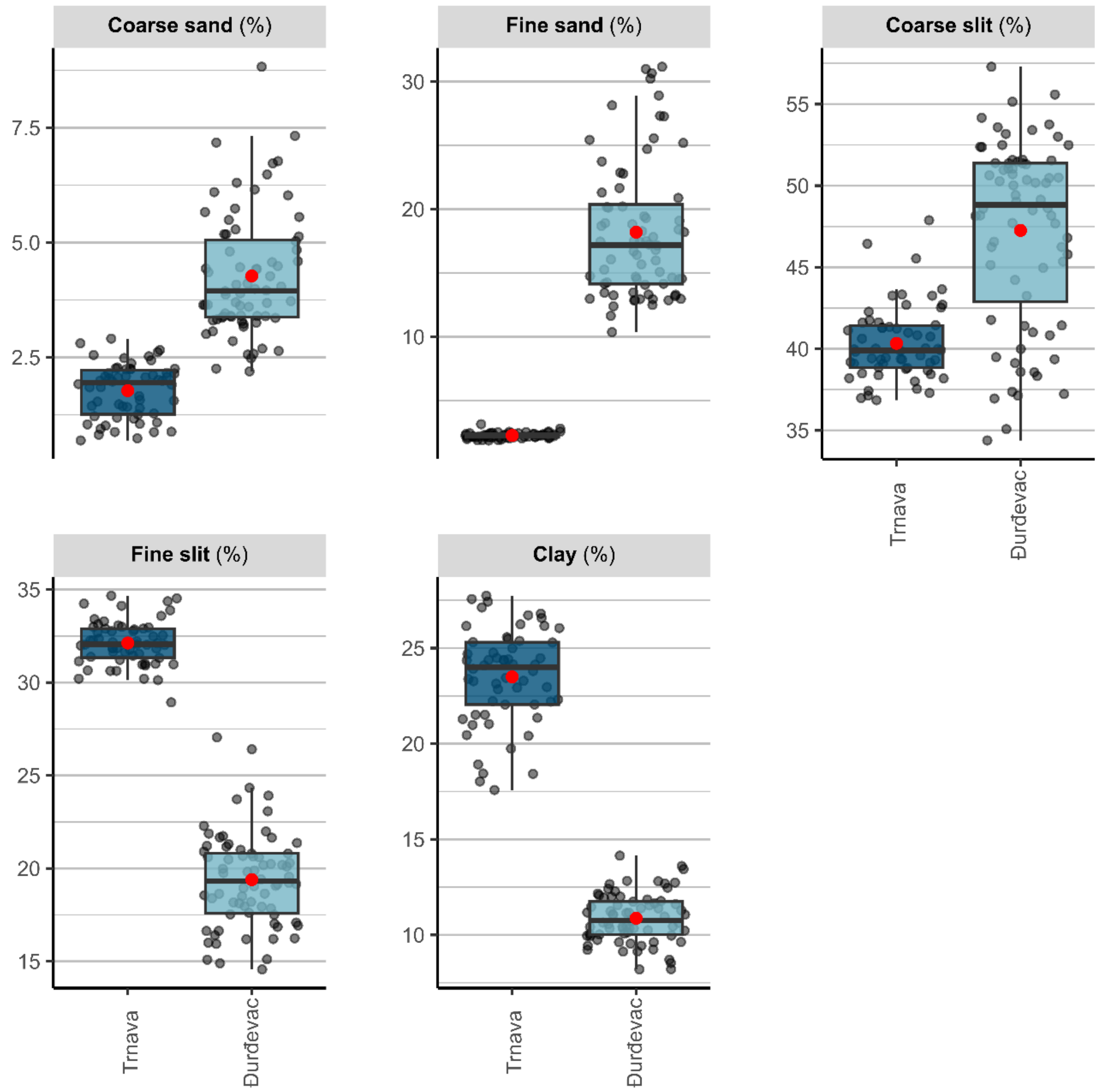


Figure 7. Comparison of soil texture components between Trnava and Đurđevac. Each boxplot displays the first and third quartiles, with the median marked by a line within the box. The individual points represent the observed data points. Red point on each plot indicates the average value for each property per each studied location.

In Figure 8. the boxplots illustrate the distribution of total concentrations of macronutrients (phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) in Trnava and Đurđevac. Significant differences between Trnava and Đurđevac were found in P, K, Ca and Mg (Tukey HSD; p value < 0.001).

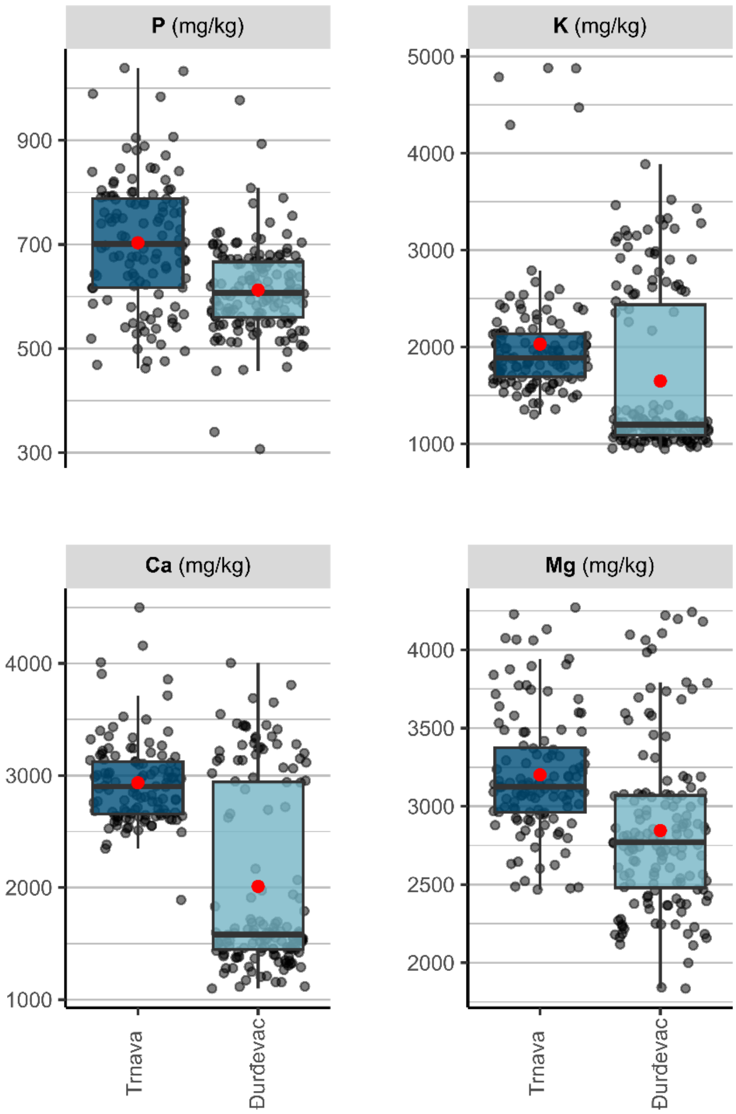


Figure 8. Comparison of total concentrations of macronutrients (phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) between Trnava and Đurđevac. Each boxplot displays the first and third quartiles, with the median marked by a line within the box. The individual points represent the observed data points. Red point on each plot indicates the average value for each property per each studied location.

In Figure 9. the boxplots illustrate the distribution of total concentrations of micronutrients (iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), and molybdenum (Mo) in Trnava and Đurđevac. Significant differences between Trnava and Đurđevac were found in Fe, Mn, Zn, Cu, Ni and Mo (Tukey HSD; p value < 0.001).

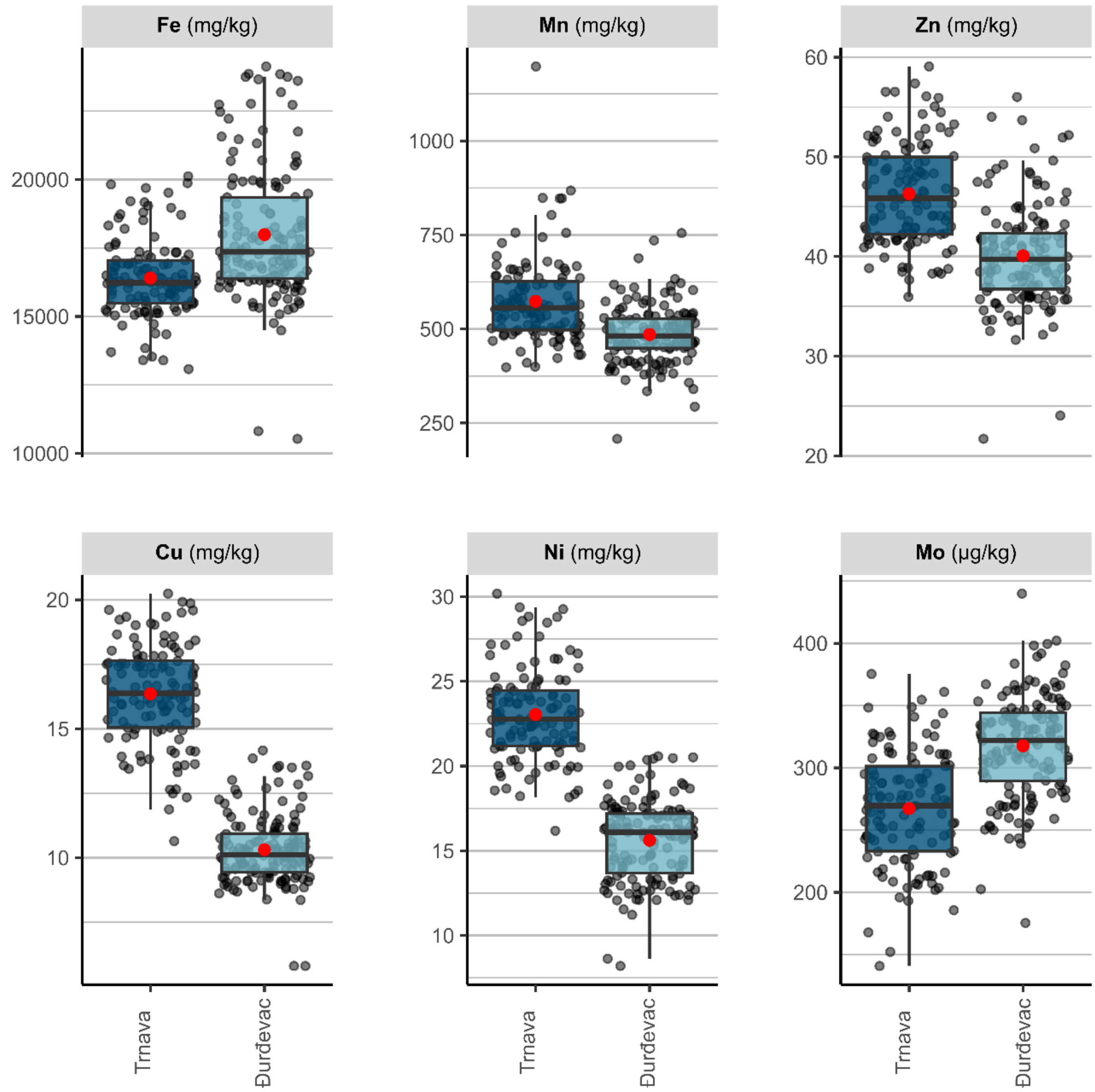


Figure 9. Comparison of total concentrations of micronutrients (iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), and molybdenum (Mo) between Trnava and Đurđevac. Each boxplot displays the first and third quartiles, with the median marked by a line within the box. The individual points represent the observed data points. Red point on each plot indicates the average value for each property per each studied location.

In Figure 10. the boxplots illustrate the distribution of total concentrations of beneficial elements (cobalt (Co), selenium (Se)) and toxic elements (chromium (Cr), cadmium (Cd), arsenic (As), lead (Pb) in Trnava and Đurđevac. Significant differences between Trnava and Đurđevac were found in Co, Se, Cr, Cd, As and Hg (Tukey HSD; p value < 0.001).

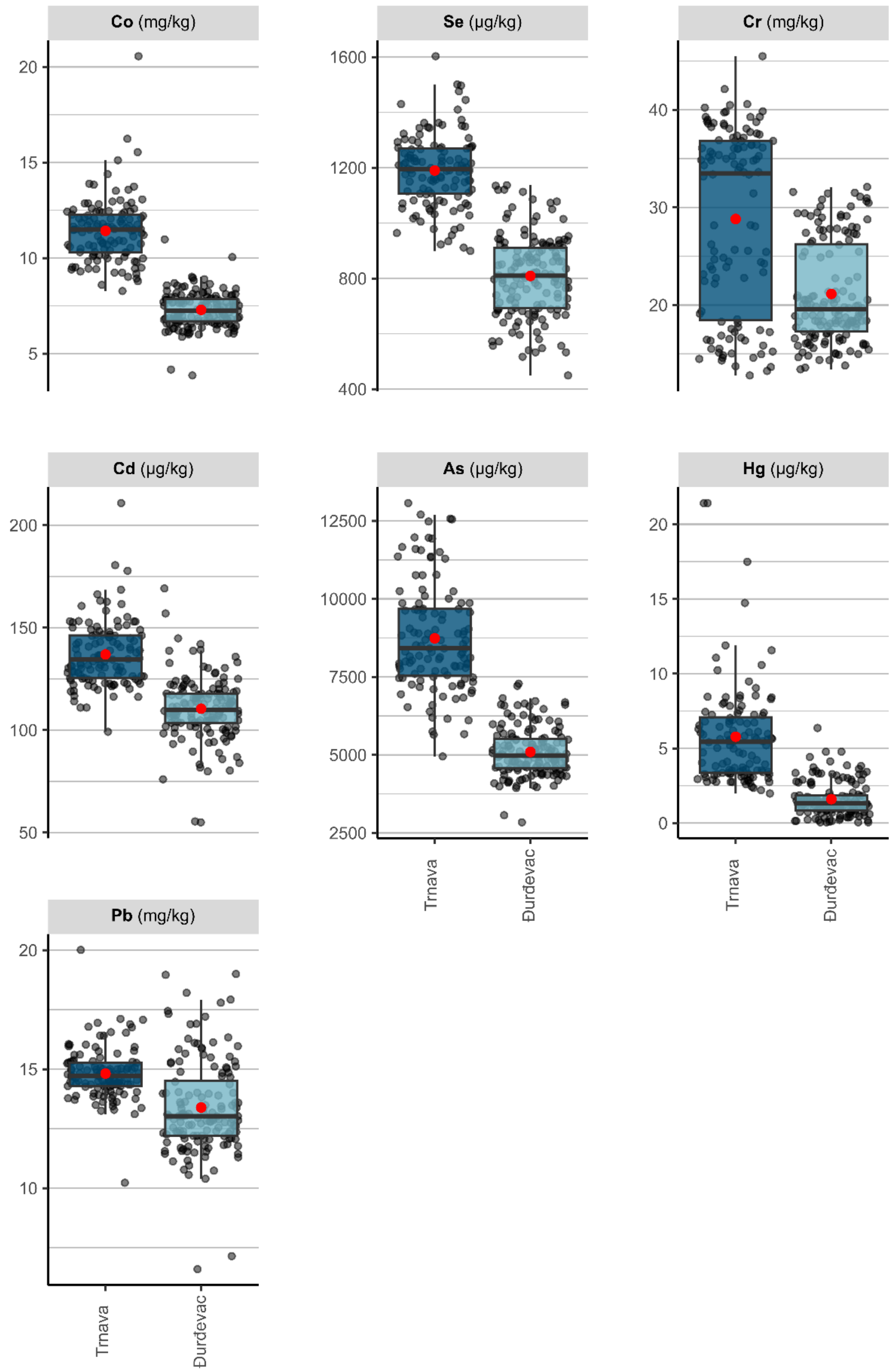


Figure 10. Comparison of total concentrations of beneficial elements (cobalt (Co), selenium (Se)) and toxic elements (chromium (Cr), cadmium (Cd), arsenic (As), lead (Pb) between Trnava and Đurđevac. Each boxplot displays the first and third quartiles, with the median marked by a line within the box. The individual points represent the observed data points.

Red point on each plot indicates the average value for each property per each studied location.

4.4. Regression models

The regression analysis of soil samples from the Trnava and Đurđevac regions demonstrate the benefit of multiple linear regression in predicting the cation exchange capacity (CEC) based on various soil properties, including humus content, clay content, pH, modified cation exchange capacity, and silt content. Table 3 shows the results of multiple linear regression analyses for CEC in Trnava and Đurđevac. In the Trnava content, six models were constructed using 58 samples, yielding R values ranging from 0.9795 to 0.9936 and R^2 values between 0.9592 and 0.9873. The standard errors of the estimate (SEE) for Trnava models vary from 3.0036 to 4.0488, reflecting the average deviation of observed values from the predicted values. The predicted values for all Trnava models are below 0.05, confirming the statistical significance of the independent variables. While the Đurđevac dataset, constructed using 72 samples, produced six regression models with even stronger correlations, as the R values between 0.9945 and 0.9965 and R^2 range from 0.9889 to 0.9935. The SEE values for Đurđevac models are particularly lower, between 0.6034 and 0.9324, indicating higher precision in predictions (Table 13).

The analysis of Model 6 of the Trnava dataset gives an insight into the relationship between soil properties and cation exchange capacity (CEC). Based on 58 samples, this linear regression model demonstrates a high coefficient of determination (R^2) of 0.9936. Additionally, the adjusted R^2 of 0.9873 accounts for the number of predictors in the model. The extremely low standard error of the estimate (SEE) of 0.4808 and statistically significant p-value of 2.55E-51 underscore the model's effectiveness in capturing the variance in CEC. The model equation, CEC = -0.019 × Humus (%) + 0.152 × silt - 0.00043 × clay, explains the specific contributions of each predictor variable. Humus (%), silt, and clay are significant predictors of CEC, with varying magnitudes of influence. For the Đurđevac dataset, Model 4 and Model 2 have identical R^2 values of 0.9956, indicating that they explain the same amount of variability in the dependent variable (CEC) using the independent variables included in the regression analysis. However, Model 4 has a higher adjusted R^2 value (0.9912) than Model 2 (0.8301). The adjusted R^2 value accounts for the number of predictors in the model. Additionally, the p-value for Model 4 (5.14E-70) is lower than that of Model 2 (2.67E-68), indicating greater statistical significance.

Table 13. Performance indices for the models with their equations.

	Model	Training subset	Regression method	R (Multiple R)	R^2	SEE (Standard error of the estimate)	P-value	Equation	Average difference (CEC - CECmod)
Trnava	M1	58	Linear	0.9795	0.9595	3.0440	9.05E-38	**CEC** = -0.524 * **pH$_{KCl}$** + 4.111 * **SOM (%)** + 0.456 * **Clay (%)**	1.58
	M2	58	Linear	0.9805	0.9613	3.0036	6.19E-37	**CEC** = -0.616 * **pH$_{KCl}$** + 3.700 * **pH$_{Diff}$** + 4.149 * **SOM (%)** + 0.286 * **Clay (%)**	1.62
	M3	58	Linear	0.9795	0.9595	3.0440	8.19E-40	**CEC** = -0.524 * **pH$_{KCl}$** + 0* **SOM (%)** - 0.572 * **Clay (%)** + 2.056 * **CEC$_{Mod}$**	1.58
	M4	58	Linear	0.9805	0.9613	3.0036	2.80E-38	**CEC** = -0.616 * **pH$_{KCl}$** + 3.700 * **pH$_{Diff}$** + 0 * **SOM (%)** - 0.752 * **Clay (%)** + 2.075 * **CEC$_{Mod}$**	1.62
	M5	58	Linear	0.9795	0.9594	3.0211	3.38E-39	**CEC** = 3.454 * **SOM (%)** + 0.404 * **Clay (%)**	1.57
	M6	58	Linear	0.9936	0.9873	0.4808	2.55E-51	**CEC** = -0.019 * **SOM (%)** + 0.152 * **Fine silt (%)** - 0.00043 * **Clay (%)**	0.36
Đurđevac	M1	72	Linear	0.9956	0.9911	0.8280	6.71E-70	**CEC** = 0.973 * **PH$_{KCl}$** + 0.949 * **SOM (%)** + 0.255 * **Clay (%)**	0.69
	M2	72	Linear	0.9956	0.9912	0.8301	2.67E-68	**CEC** = 0.965 * **pH$_{KCl}$** -0.362 * **pH$_{Diff}$** + 1.134 * **SOM (%)** + 0.266 * **Clay (%)**	0.68
	M3	72	Linear	0.9956	0.9911	0.8280	1.59E-72	**CEC** = 0.973 * **pH$_{KCl}$** + 0* **SOM (%)** + 0.018 * **Clay (%)** + 0.475 * **CEC$_{Mod}$**	0.69
	M4	72	Linear	0.9956	0.9912	0.8301	5.14E-70	**CEC** = 0.965 * **pH$_{KCl}$** - 0.362 * **pH$_{Diff}$** + 0* **SOM (%)** -0.017 * **Clay (%)** + 0.567 * **CEC$_{Mod}$**	0.68
	M5	72	Linear	0.9944	0.9888	0.9249	3.23E-68	**CEC** = 2.688 * **SOM (%)** + 0.367 * **Clay (%)**	0.76
	M6	72	Linear	0.9945	0.9890	0.9213	9.48E-67	**CEC** = 2.310 * **SOM (%)** + 0.054 * **Fine silt (%)** + 0.331 * **Clay (%)**	0.77

4.5. Spatial variability of parameters in Trnava

The spatial analysis revealed spatial variability of soil fertility parameters in Trnava. The eastern parts had relatively higher pH_{KCl}, soil organic matter, and CEC than other part (Figure 11. – Figure 13). The percentage of clay in soil was higher in western parts of the studied area in Trnava (Figure 14).

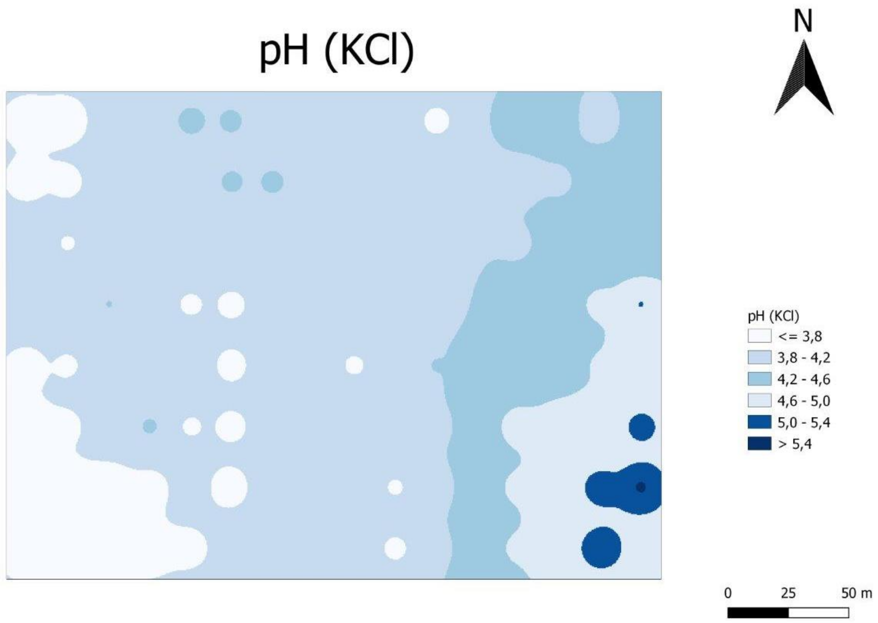


Figure 11. Spatial distribution of pH (KCl) in Trnava. Lower values are associated with lighter colors, and higher values with darker colors.

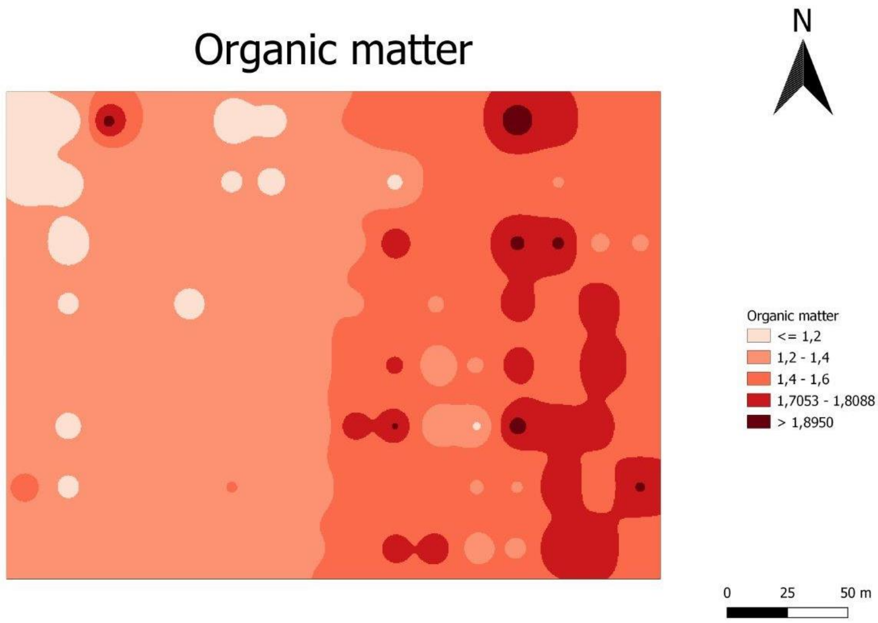


Figure 12. Spatial distribution of soil organic matter in Trnava. Lower values are associated with lighter colors, and higher values with darker colors.

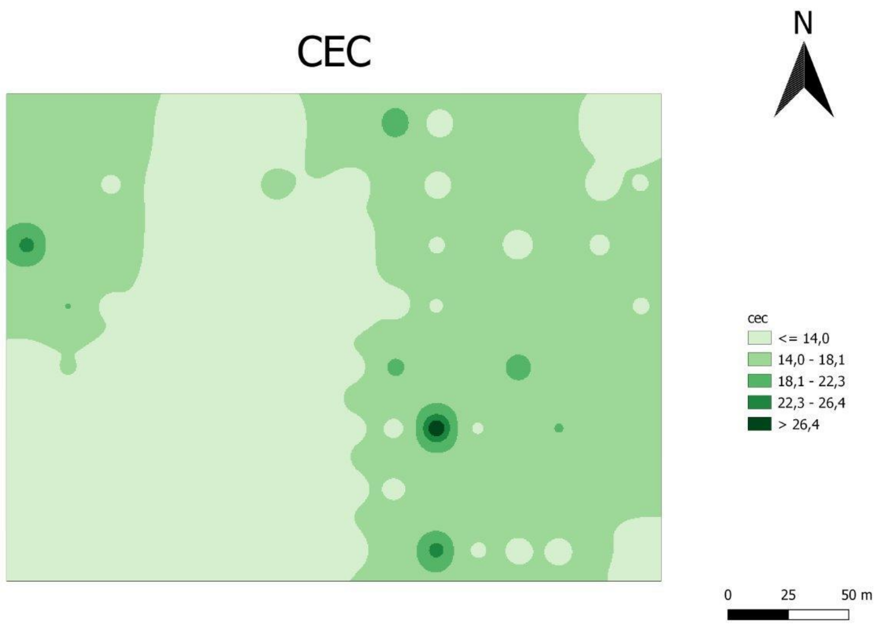


Figure 13. Spatial distribution of CEC in Trnava. Lower values are associated with lighter colors, and higher values with darker colors.

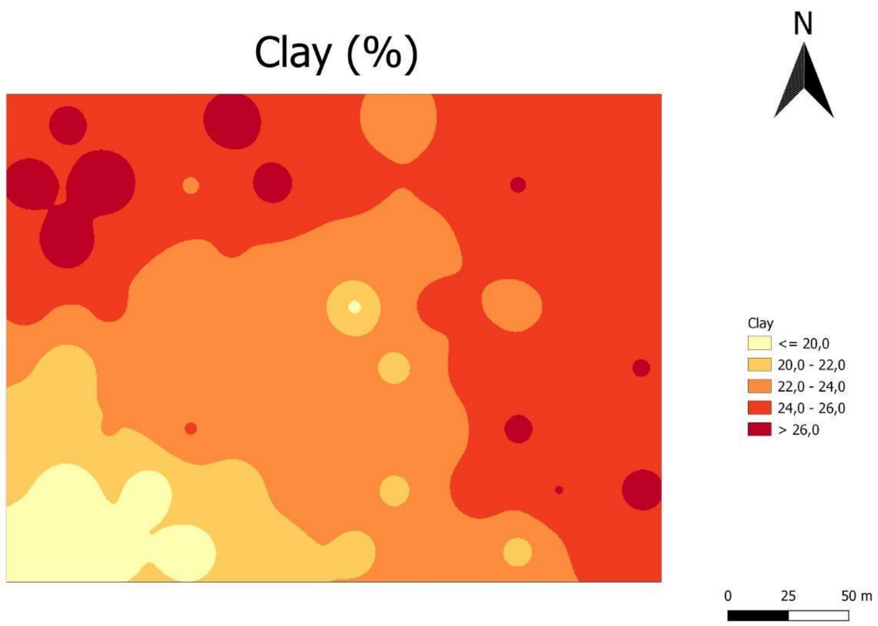


Figure 14. Spatial distribution of clay (%) in Trnava. Lower values are associated with lighter colors, and higher values with darker colors.

4.6. Liming and fertilization needs

The results of soil analyzes were used to calculate needs in soil liming and the necessary fertilization with N, P and K in the cultivation of wheat, corn and sunflower using DSS software and research results (Lončarić et al., 2023, 2022, 2020, 2016).

4.6.1. Liming needs for neutralization of exessive soil acidity

In the soils of both localities, there is a significant need for liming, as excessive soil acidity has been determined. In the Trnava locality, the need for liming was determined from 0 to 13.0 t ha^{-1} of pure finely ground limestone (calcium carbonate equivalent 100%) with an average of 7.76 t ha^{-1} (Table 14). The variance of the calculated needs is 7.56, and the standard deviation is 2.75 with the coefficient of variation 35.42%.

Table 14. Liming needs in Trnava and Đurđevac localities

	Liming needs in Trnava	**Liming needs in Đurđevac**
	(t ha^{-1} lime)	(t ha^{-1} lime)
Var	7.56	4.27
Min	0.00	0.00
Max	13.00	12.00
Average	7.76	6.59
StDev	2.75	2.07
CV (%)	35.42	31.32

In the locality of Trnava, a slightly smaller need for liming was determined, from 0 to 12.0 t ha^{-1} of pure finely ground limestone with an average of 6.59 t ha^{-1} (Table 14). The variance of the calculated needs is 4.27, and the standard deviation is 2.07 with the coefficient of variation 31.32%.

4.6.2. Need for fertilization with N, P and K in wheat, maize and sunflower growing

Using DSS software and models, the required fertilization was determined with the aim of determining the agrotechnical significance of precise fertilizer application. Fertilization needs were determined for nitrogen, phosphorus and potassium fertilization in the cultivation of wheat, corn and sunflower in both researched locations.

In the Trnava locality, the needs for fertilization with nitrogen was determined from 155-165 kg ha^{-1} for wheat growing, 185-200 kg ha^{-1} for maize and 145-160 kg ha^{-1} for sunflower

(Table 15). The variance of the calculated needs is 6.20 for wheat and 18.37 for maize and sunflower, the standard deviation is 2.49 and 4.29 with the coefficient of variation 1.56% for winter wheat and 2.73% for maize and sunflower.

Table 15. The fertilization needs in Trnava site for wheat, maize and sunflower gowing

	Fertilization needs for wheat (in kg ha^{-1})			Fertilization needs for maize (in kg ha^{-1})			Fertilization needs for sunflower (in kg ha^{-1})		
	(N)	(P_2O_5)	(K_2O)	(N)	(P_2O_5)	(K_2O)	(N)	(P_2O_5)	(K_2O)
Var	6.2	860.6	477.1	18.37	576.9	852.6	18.4	418.9	462.2
Min	155.0	0.0	25.0	185.0	0.0	30.0	145.0	0.0	25.0
Max	165.0	95.0	155.0	200.0	80.0	210.0	160.0	65.0	155.0
Average	159.3	60.2	131.5	196.8	48.06	177.9	156.8	39.0	129.6
StDev	2.49	29.34	21.84	4.29	24.02	29.20	4.29	20.47	21.50
CV (%)	1.56	48.72	16.61	2.18	49.97	16.41	2.73	52.53	16.59

The needs for fertilization with phosphorus was determined from 0-95 kg ha^{-1} for wheat growing, 0-80 kg ha^{-1} for maize and 0-65 kg ha^{-1} for sunflower (Table 15). The variance of the calculated needs is 860.6 for wheat and 576.9 and 418.9 for maize and sunflower, the standard deviation is 29.34, 24.02 and 20.47 for wheat, maize and sunflower, respectively. The coefficient of variation was 48.72% for winter wheat, 49.97% for maize and 52.53% for sunflower.

The needs for fertilization with potassium was determined from 25-155 kg ha^{-1} for wheat growing, 30-210 kg ha^{-1} for maize and 25-155 kg ha^{-1} for sunflower (Table 15). The variance of the calculated needs is 477.1 for wheat and 852.6 and 462.2 for maize and sunflower, the standard deviation is 21.84, 29.20 and 21.50 for wheat, maize and sunflower, respectively. The coefficient of variation was 16.61% for winter wheat, 16.41% for maize and 16.59% for sunflower.

In the Đurđevac locality, the needs for fertilization with nitrogen was determined from 155-160 kg ha^{-1} for wheat growing, 190-195 kg ha^{-1} for maize and 150-155 kg ha^{-1} for sunflower (Table 16). The variance of the calculated needs is 7.69 for wheat and 13.54 for maize and sunflower, the standard deviation is 2.77 (wheat) and 3.68 (maize and sunflower) with the coefficient of variation 1.76% for winter wheat, 1.91% for maize and 2.41% for sunflower.

Table 16. The fertilization needs in Đurđevac site for wheat, maize and sunflower growing

	Fertilization needs for wheat (in kg ha^{-1})			Fertilization needs for maize (in kg ha^{-1})			Fertilization needs for sunflower (in kg ha^{-1})		
	(N)	(P_2O_5)	(K_2O)	(N)	(P_2O_5)	(K_2O)	(N)	(P_2O_5)	(K_2O)
Var	7.7	489.3	1,313	13.5	395.0	2,426	13.5	294.1	1,274
Min	150.0	0.0	0.0	180.0	0.0	0.0	140.0	0.0	0.0
Max	160.0	85.0	140.0	200.0	70.0	190.0	160.0	60.0	135.0
Average	157.5	51.4	92.5	192.8	41.3	125.7	152.8	33.7	91.2
StDev	2.77	22.12	36.24	3.68	19.88	49.25	3.68	17.15	35.70
CV (%)	1.76	43.05	39.20	1.91	48.14	39.19	2.41	50.97	39.13

The needs for fertilization with phosphorus in Đurđevac locality was determined from 0-85 kg ha^{-1} for wheat growing, 0-70 kg ha^{-1} for maize and 0-60 kg ha^{-1} for sunflower (Table 16). The variance of the calculated needs is 489.3 for wheat and 395.0 and 294.1 for maize and sunflower, the standard deviation is 22.12, 19.88 and 17.15 for wheat, maize and sunflower, respectively. The coefficient of variation was 43.05% for winter wheat, 48.14% for maize and 50.97% for sunflower.

The needs for fertilization with potassium in Đurđevac locality was determined from 0-140 kg ha^{-1} for wheat growing, 0-190 kg ha^{-1} for maize and 0-135 kg ha^{-1} for sunflower (Table 16). The variance of the calculated needs is 1,313.6 for wheat and 2,425.6 and 1,274.2 for maize and sunflower, the standard deviation is 36.24, 49.25 and 35.70 for wheat, maize and sunflower, respectively. The coefficient of variation was 39.20% for winter wheat, 39.19% for maize and 39.13% for sunflower.

5. Discussion

The spatial variability or heterogeneity of soil properties plays a crucial role in understanding and managing soil health and fertility. This study analyzed 116 soil samples from the Trnava location and 144 from the Đurđevac location. The spatial variability of key soil properties was analyzed, coefficients of variation were calculated, multiple linear regression models were developed, and GIS spatial variability for four soil properties was created to visualize these patterns.

5.1. Spatial variability and coefficient of variation

In analyzing the presented statistical data, the coefficient of variation (CV) emerges as a critical factor for characterizing data variability (Bogunovic et al., 2014). The lowest CV was determined for the actual soil acidity (pH_{H2O}) of the soil at both locations (Trnava 8.1% and Đurđevac 7.15%), which means that the lowest heterogeneity of both production areas was determined precisely for the acidity of the soil solution. The fact that the average values of the acidity of the soil solution are almost the same in both localities (5.31 Trnava and 5.37 Đurđevac) adds additional significance to the findings, but with a slightly narrower range in Đurđevac (4.63-6.98) than in Trnava (4.49-6,33).

It was very similar determined for the exchangeable acidity (pH_{KCl}), although a slightly higher CV (10.42%) was determined at the Trnava site than at the Đurđevac site (8.1%) and on average a slightly higher CV than for the acidity of the soil solution (pH_{H2O}). A very similar range of exchangeable acidity was determined at both locations (3.48-5.45 Trnava and 3.57-5.62 Đurđevac). Slightly higher variability of exchangeable acidity than soil solution acidity is expected due to higher influence of SOM and CEC on exchangeable than actual acidity.

It is realistic to expect the same for hydrolytic acidity, which is an indicator of the acidity of an even wider range of ions than exchangeable acidity, and especially of the acidity of the soil solution. Therefore, it is not surprising that, despite the similar average (4.59 and 4.14) and range (2.05-6.91 and 1.79-6.62) for Trnava and Đurđevac, the variability of hydrolytic acidity is still greater in the Trnava locality (24.25%) than in the locality Đurđevac (20.8%).

The significance of the influence of SOM and CEC content on the variability of soil acidity is also shown by the different variability of SOM and CEC in the studied localities. Comparing the variability of the different acidity of the soil (pH_{H2O}, pH_{KCl} and hydrolytic acidity), at both localities the variability of the acidity of the soil solution is the lowest, and the variability of the hydrolytic acidity is the highest. Likewise, the variability of all three acidity is higher at the Trnava locality than at the Đurđevac locality, which can easily be linked to the higher variability of SOM and CEC in Trnava (15.67% and 19.13%) than in Đurđevac (10.72% and 9.85%). This is supported by the significantly higher average CEC in the Trnava locality (19.13) than in the Đurđevac locality (9.82), and it is interesting that the average lower SOM of the Trnava locality (1.40%) has higher variability (15.67%) than the higher SOM content (1.72%) of the Đurđevac locality, where the CV of SOM was 10.75%.

It is similar with the average and variability of the clay content. A significantly higher average clay content (23.5%) than in Đurđevac (10.87%) was found at the Trnava location, but with slightly greater variability in Đurđevac (CV 11.86%) than in Trnava (CV 10.74%).

The mentioned comparisons show that the variability of different soil properties may not result in same or the similar variability of their associated properties since it depends not only on the variability, but also on the intensity of the associated properties.

Mishra et al. (2019) concluded in their study that the soil pH values ranged from 5.02 to 5.18, indicating acidity. Sand content varied slightly between 43.87% and 49.98%, with the lowest in forest areas and the highest in cash crop areas. Silt content ranged from 26.46% to 27.88%, while clay content showed more variation, from 22.15% to 29.67%, due to weathering, erosion, and deposition processes. Bulk density was highest in cash crop areas (1.06 kg m^{-3}) and lowest in jhum areas (0.87 kg m^{-3}), generally remaining low across all land uses. Soil organic carbon content was high, ranging from 1.47% to 2.00%, with the highest in forest soils and the lowest in jhum soils. Cation exchange capacity (CEC) varied widely from 13.60 to 20.19 cmol(+)kg^{-1}, with forest soils having the highest CEC and jhum soils the lowest.

The highest variability of all analyzed soil properties was determined for the total potassium content in samples from the Đurđevac locality, as much as 50.14%, which is the only variability in the range of high variability (>50%). Although it is significantly less (31.53%) than in Đurđevac, the variability of the total content between all elements was highest for potassium in the Trnava locality also. However, for the sustainability of agricultural production, the variability of potassium concentrations available to plants is more significant than its total concentration in the soil. In this respect, the variability is significantly lower, but still in the range of moderate variability in the Đurđevac site (27.94%), and almost in the range of low variability (20.63%) in the Trnava site. At the same time, the concentration (as well as the variability) of potassium available to plants is on average higher in Đurđevac (17.41) than in Trnava (15.42).

Correlations of total and plant-available amounts of potassium were determined at the locality of Trnava (R=0.655) and Đurđevac (R=0.927). Simultaneously, at the Đurđevac site, no correlations between potassium and clay content were established (R=0.12 and 0.16), and at the Trnava site only the correlation with plant-available fraction (R=0.606) was established, with a weak correlation between clay and total potassium content (R= 0.334). We assume that the reason is the almost 2.2 times lower content of clay at the Đurđevac site than at the Trnava site with a slightly higher content of available potassium in Đurđevac. This example also shows that the possibility of connecting the variability of different soil properties also depends on the intensities of these properties.

The highest variability of soil properties, which are directly related to the needs of crop fertilization, was determined for the content of plant-available phosphorus (CV=44,61%) in the Trnava locality. Significant variability for the same property was also found at the Đurđevac site (CV=32,94%).

Since there were no correlations between the content of phosphorus available to plants, neither with the content of total phosphorus (CV= 17.77% Trnava, 13.94% Đurđevac), nor with the content of SOM (CV= 24.25 and 20.8%), nor with soil pH (CV=10.42 and 8.10%), and the variability is significantly higher than the variability of all the mentioned properties, the assumption is that the variability of phosphorus available to plants is a consequence of anthropogenic influence, i.e. the same fertilization and agricultural techniques on the entire arable plot despite the variability of soil properties.

The study by Vasu et al. (2017) was conducted in the semi-arid tropical Deccan plateau region of India to assess the spatial variability of soil pH, organic carbon (OC), and available nutrients including nitrogen (N), phosphorus (P), potassium (K), and sulfur (S). A total of 1508 composite soil samples (0–15 cm depth) were collected using a 325 × 325 m grid interval, covering one sample per 10 ha. Analysis showed that OC, N, P, K, and S exhibited high heterogeneity, with coefficients of variation (CV) greater than 35% (Vasu et al., 2017).

The lowest variability of total macroelements content, comparing Ca, Mg, K and P, was determined for total magnesium (12.27 and 18.54%) and total phosphorus (17.77 and 13.94%).

The lowest variability of the total content of microelements was determined for iron (8.74 and 13.56%), although the total concentrations of Fe are very high (16.4 18.0 g kg^{-1}). It is very significant to note that the variability of all microelements and beneficial elements (Co and Se) in both localities was low (all values <20%), mostly in the range 11-15%, and only Mn in the range 15-20%. The same applies to toxic elements (Cr, As, Cd, Pb) whose total concentrations are very low, but also the coefficient of variability.

Based on the above, we can conclude that there are indications of increased heterogeneity of the analyzed arable plots, which mostly refers to the available fractions of macronutrients (P, K, Ca, Mg), and to a very small extent to the SOM, CEC and clay content. The variability of the total content of microelements and toxic elements was low and almost not determined at the analyzed sites.

5.2. Regression models

Regression models are straightforward and practical tools that can generate new insights. Their accuracy significantly improves when additional soil properties, particularly pH and organic matter content, are included. Further precision can be achieved by incorporating other soil characteristics, such as cation exchange capacity. To ensure its reliability and applicability, the developed model must be validated using datasets with known analytically determined values from field experiments. The analysis of Model 6 of the Trnava dataset gives an insight into the relationship between soil properties and cation exchange capacity (CEC). Based on 58 samples, this linear regression model demonstrates a remarkably high coefficient of determination (R^2) of 0.9936, indicating that the independent variables explain approximately 99.36% of the variability in CEC. Additionally, the adjusted R^2 of 0.9873 accounts for the number of predictors in the model, further validating its robustness. The extremely low root mean square error (SEE) of 0.4808 and statistically significant p-value of 2.55E-51 underscore the model's effectiveness in capturing the variance in CEC. The model equation, CEC = -0.019 * Humus (%) + 0.152 * silt - 0.00043 * clay, explains the specific contributions of each predictor variable. Humus (%), silt, and clay are significant predictors of CEC, with varying magnitudes of influence. Overall, Model 6 is a highly reliable tool for predicting CEC based on the included soil properties, offering valuable insights for soil management and agricultural practices. For the Đurđevac dataset, Model 4 and Model 2 have identical R^2 values of 0.9956, indicating that they explain the same amount of variability in the dependent variable (CEC) using the independent variables included in the regression analysis.

However, Model 4 has a higher adjusted R^2 value (0.9912) than Model 2 (0.8301). The adjusted R^2 value accounts for the number of predictors in the model, providing a more accurate assessment of the model's goodness of fit. Additionally, the p-value for Model 4 (5.14E-70) is lower than that of Model 2 (2.67E-68), indicating greater statistical significance. Based on the adjusted R^2 value and the lower p-value, Model 4 appears to be a better-fitting model than Model 2.

5.3. Liming and fertilization needs

A moderate variability of the need for liming was determined, 35.42% for the Trnava (range 0-13 t ha^{-1}, average 7.8) and 31.32% for Đurđevac site (range of need 0-12 t ha^{-1}, average 6.6). However, although the variability is statistically only moderate, the heterogeneity in terms of the required application of lime materials is very large, and therefore it is very important to precisely calculate the needs for liming. A uniform application of the average required amount over the entire arable plot is not acceptable, but a precise application of lime material is necessary.

Regarding fertilization with phosphorus and potassium, the need for precise fertilization is even more emphasized because the variability of the required potassium fertilization is 39.2% in both sites (amounts of 0-190 kg ha^{-1}), and the variability of the required phosphorus fertilization is even higher. The required phosphorus fertilization at the Đurđevac site is 0-85 kg ha^{-1} with a coefficient of variability of 43.05-50.97 % (depending on the crop), and at the Trnava site it is 0-95 kg ha^{-1} with a variability of 48.72-52.53%.

The variability of the nitrogen fertilization plan is very small (1.56-2.73%), which is a consequence of the low humus content of the soil (< 2% SOM) and the high need for fertilization, often maximal from the aspect of enviornmental acceptability of mineral fertilization. This means that, based on the analyzed soil properties the nitrogen fertilization plan includes almost maximum fertilization and precise application of nitrogen fertilizers is not necessary, but uniform autumn fertilization with nitrogen is acceptable. However, this paper did not analyze the amount of mineral N in the soil, which often has a high variability and must certainly be included in the calculation of planned nitrogen fertilization. In this case, with the expected variability of mineral N in the soil of 30-50%, variable nitrogen fertilization would also be required. Likewise, uniform autumn fertilization with nitrogen should include a plan for precise determination of the spring nitrogen requirement (N_{min} analysis in the soil and crop analysis with sensors and/or in the laboratory) and precise nitrogen supplementation.

6. Conclusions

This thesis employed a GIS-based approach to assess the significance and distribution of basic soil properties, including soil organic matter, pH, texture, available phosphorus, and potassium, in determining the homogeneity or heterogeneity of two arable plots in Trnava and Đurđevac. A total of 116 soil samples from Trnava and 144 from Đurđevac were analyzed for both mandatory and additional soil physical and chemical properties. The data underwent descriptive statistics, correlation, and multi-regression analyses. These analyses were base in determining the soil liming and fertilization requirements for wheat, corn, and sunflower using the DSS software.

The coefficient of variation for available phosphorus was the highest at 44.61%, indicating significant heterogeneity, while fine silt content exhibited the lowest variation at 3.71% in Trnava. In Đurđevac, content of total potassium showed the highest variation, and actual acidity the lowest at 8.10%. However, the variability of different soil properties may not result in same or the similar variability of their associated properties since it depends also on the intensity of the associated properties. On the analyzed arable plots, the most significant indicators of possible soil heterogeneity and required variable fertilization are soil hydrolytic acidity and plant-available phosphorus, and to a lesser extent, plant-available potassium.

Regression analysis demonstrated the efficacy of multiple linear regression models in predicting cation exchange capacity based on various soil properties. In Trnava, six models with high R values (0.9795 to 0.9936) and R^2 values (0.9592 to 0.9873) were developed, with standard errors of the estimate ranging from 3.0036 to 4.0488. The Đurđevac models, constructed with 72 samples, exhibited even stronger correlations, with R values between 0.9945 and 0.9965, R^2 values from 0.9889 to 0.9935, and lower SEE values (0.6034 to 0.9324), indicating higher prediction precision.

Geo-statistical results revealed diverse spatial distribution patterns of soil properties and plant available nutrients, indicating strong, moderate, and weak spatial dependence. These spatial distribution maps are valuable for devising location-specific soil management strategies and identifying optimal sites for future experiments. This comprehensive analysis underscores the importance of detailed soil property assessment in enhancing agricultural productivity and soil management practices.

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8. Summary

This thesis aims to use a GIS-based approach to analyze the significance and share of certain basic soil properties (soil organic matter, pH, texture, available phosphorus, and potassium) in assessing the homogeneity or heterogeneity of two individual arable plots, Trnava and Đurđevac. During the study, 116 soil samples were collected and analyzed from the Trnava location and 144 from the Đurđevac location. The analyses included mandatory analyses of soil chemical properties and additional analyses of the soil's physical and chemical properties. All collected data were analyzed for descriptive statistics, correlation, and multi-regression analyses. The results of the soil analyses were utilized to determine the requirements for soil liming and the necessary fertilization with nitrogen (N), phosphorus (P), and potassium (K) for the cultivation of wheat, corn, and sunflower. These calculations were performed using the DSS software.

The coefficient of variation is the highest for available P at 44.61%, indicating significant heterogeneity. The lowest coefficient of variation is the lowest for fine silt content at 3.71% in the Trnava site. The second site, Đurđevac, had the highest coefficient of variation of the potassium total content and the lowest coefficient of variation for acual acidity, 8.10%. On the analyzed plots, the most significant indicators of soil heterogeneity and needs for variable fertilization are soil hydrolytic acidity and plant-available P, and to a lesser extent, plant-available K, which means that variable liming and fertilization with P and K are needed.

The regression analysis of soil samples from the Trnava and Đurđevac regions demonstrates the effectiveness of multiple linear regression in predicting cation exchange capacity based on soil properties like humus content, clay content, pH, and silt content. In Trnava, six models using 58 samples yielded high R values (0.9795 to 0.9936) and R^2 values (0.9592 to 0.9873), with standard errors of the estimate (SEE) ranging from 3.0036 to 4.0488. The p-values for all models were below 0.05, confirming statistical significance. The Đurđevac dataset, with 72 samples, produced even stronger models, with R values between 0.9945 and 0.9965, R^2 values from 0.9889 to 0.9935, and lower SEE values (0.6034 to 0.9324), indicating higher prediction precision.

Geo-statistical results revealed diverse distribution patterns of soil properties and phyto-available nutrients, exhibiting strong, moderate, and weak spatial dependence. These spatial distribution maps can be utilized to develop location-specific soil management strategies.

9. Sažetak

Cilj ovog diplomskog rada je analiza značaja i udjela pojedinih osnovnih svojstava tla (organska tvar tla, pH, tekstura, biljkama dostupni fosfor i kalij) u procjeni homogenosti ili heterogenosti dviju pojedinačnih obradivih parcela uz upotrebu GIS alata. Tijekom istraživanja prikupljeno je i analizirano 116 uzoraka tla s lokacije Trnava i 144 s lokacije Đurđevac. Analize su uključivale osnovne analize kemijskih svojstava tla i dodatne analize fizikalno-kemijskih svojstava tla. Svi prikupljeni podaci analizirani su uz pomoć deskriptivne statistike, korelacijske i multiregresijske analize. Rezultati analize tla korišteni su za utvrđivanje zahtjeva za kalcizacijom i potrebnom gnojidbom dušikom (N), fosforom (P) i kalijem (K) za uzgoj pšenice, kukuruza i suncokreta pomoću DSS softvera.

Koeficijent varijacije je najveći za biljkama raspoloživi fosfor (44,61%), što ukazuje na značajnu heterogenost. Najniži koeficijent varijacije je za sadržaj sitnog praha (3,71%) na lokaciji Trnava. Druga lokacija, Đurđevac, imala je najveći koeficijent varijacije za ukupni sadržaj kalija, a najmanji koeficijent varijacije za aktualnu kiselost, 8,10%. Na analiziranim oranicama najznačajniji pokazatelji heterogenosti tla i potrebe za varijabilnom gnojidbom su hidrolitička kiselost tla i biljkama dostupni P, a u manjoj mjeri biljkama dostupni K, što znači da su potrebni varijabilna kalcizacija i gnojidba s P i K.

Regresijska analiza uzoraka tla s područja Trnave i Đurđevca pokazuje učinkovitost višestruke linearne regresije u predviđanju kationskog izmjenjivačkog kapaciteta tla na temelju svojstava tla kao što su sadržaj humusa, sadržaj gline, pH, i sadržaj praha. Za lokalitet Trnava šest je različitih modela rezultiralo visokim R (0,9795 do 0,9936) i R^2 vrijednostima (0,9592 do 0,9873), sa standardnim pogreškama procjene (SEE) u rasponu od 3,0036 do 4,0488. P-vrijednosti za sve modele bile su ispod 0,05, potvrđujući statističku značajnost. Skup podataka Đurđevac, sa 72 uzorka, rezultirao je još preciznijim modelima, s R vrijednostima između 0,9945 i 0,9965, R^2 vrijednostima od 0,9889 do 0,9935 i nižim SEE vrijednostima (0,6034 do 0,9324), što ukazuje na veću točnost predviđanja.

Geostatistički rezultati otkrili su različite obrasce distribucije svojstava tla i biljkama raspoloživih hranjivih tvari, pokazujući jaku, umjerenu i slabu prostornu ovisnost. Ove karte prostorne distribucije mogu se koristiti za razvoj strategija upravljanja tlom specifičnih za određenu lokaciju, tj. za preciznu varijabilnu gnojidbu i kondicioniranje tala.

10. Appendices

Appendix table 1. Basic agrochemical soil properties in soil samples from the Trnava location.

Lab number	pH_{H_2O}	pH_{KCl}	Humus	Hy	P_2O_5	K_2O
			(%)	cmol(+)kg^{-1}	mg 100g^{-1} soil	
11137	5.91	4.37	1.48	4.33	15.67	17.62
11139	6.00	4.58	1.41	3.68	18.70	17.85
11141	5.84	4.43	1.38	3.98	17.55	19.48
11143	6.27	5.01	1.52	3.02	26.27	21.07
11145	5.94	5.00	1.59	2.77	16.27	18.56
11147	6.29	5.17	1.45	2.35	14.55	16.61
11149	6.29	5.45	1.83	2.05	17.17	15.51
11151	6.30	4.98	1.41	2.92	10.62	15.01
11153	5.16	3.97	1.45	5.62	21.07	18.71
11155	5.55	4.37	1.44	4.19	24.52	17.27
11157	5.54	4.56	1.34	3.83	27.54	19.91
11159	5.90	4.70	1.76	3.28	32.26	19.25
11161	5.74	4.62	1.76	3.92	24.00	19.18
11163	5.92	4.85	1.66	2.70	16.31	15.99
11165	6.17	5.25	1.52	2.36	13.14	17.21
11167	6.33	5.33	1.76	2.09	13.75	15.96
11169	5.63	4.33	1.79	4.55	28.23	21.83
11171	5.47	4.12	1.38	4.52	19.87	17.01
11173	5.66	4.56	1.85	3.51	27.26	17.04
11175	5.75	4.56	1.51	3.53	27.59	17.68
11177	5.51	4.46	1.45	3.89	15.32	15.43
11179	5.92	4.88	1.66	2.53	9.40	15.44
11181	6.07	4.96	1.79	2.56	11.65	17.93
11183	5.73	4.99	1.79	2.33	12.11	13.78
11185	5.60	4.43	2.00	4.17	28.46	28.32
11187	5.21	4.01	1.52	4.62	12.90	17.55
11189	5.20	4.06	1.87	4.76	12.17	16.42
11191	5.36	4.34	1.69	3.94	11.66	13.74
11193	5.62	4.39	1.72	3.89	12.17	14.16
11195	5.91	4.91	1.93	2.63	9.37	14.69
11197	5.89	4.71	1.38	2.93	6.06	13.82
11199	5.82	4.66	1.35	2.65	11.93	13.29
11201	5.67	4.36	1.37	3.69	8.83	13.72
11203	5.70	4.45	1.17	3.12	8.52	13.20
11205	5.78	4.54	1.38	3.19	11.10	13.36
11207	6.17	4.60	1.30	3.24	10.32	12.90
11209	4.87	3.65	1.45	6.22	29.94	21.82
11211	5.24	4.01	1.41	4.92	23.31	19.38
11213	5.45	4.03	1.49	4.47	15.34	16.41
11215	5.51	4.08	1.38	4.39	13.97	13.63
11217	5.38	4.21	1.25	3.89	10.34	13.58
11219	5.47	4.05	1.24	4.59	8.59	12.36
11221	5.12	3.94	1.42	5.05	9.76	13.04
11223	5.17	4.02	1.72	4.58	11.31	12.79
11225	5.15	4.05	1.55	5.38	40.94	22.83
11227	5.46	4.07	1.14	4.78	28.01	20.54

Lab number	pH_{H_2O}	pH_{KCl}	Humus	Hy	P_2O_5	K_2O
			(%)	cmol(+)kg^{-1}	mg 100g^{-1} soil	
11229	5.15	3.98	1.79	5.41	25.14	18.69
11231	5.14	3.98	1.48	5.02	27.39	14.98
11233	4.96	3.83	1.65	5.59	15.68	14.35
11235	5.34	4.03	1.83	4.39	9.49	11.56
11237	5.04	3.72	1.48	5.85	10.38	13.47
11239	4.96	3.65	1.69	5.50	13.18	12.10
11241	4.97	3.87	1.41	5.71	31.32	19.76
11243	4.95	3.83	1.34	5.93	28.28	22.49
11245	5.06	3.94	1.34	5.26	22.62	19.40
11247	5.09	3.94	1.38	5.29	31.46	14.79
11249	4.53	3.71	1.59	6.43	23.24	14.52
11251	5.04	3.93	1.76	5.51	16.60	13.87
11253	5.20	4.01	1.41	4.32	8.29	12.54
11255	5.20	4.01	1.52	4.23	10.38	11.52
11257	5.12	3.88	1.27	4.87	12.19	15.08
11259	5.41	3.93	1.20	4.64	9.96	11.76
11261	5.27	3.88	1.34	5.16	10.59	12.79
11263	5.15	3.98	1.38	4.90	12.46	12.37
11265	5.23	3.97	1.14	5.21	25.37	20.66
11267	5.64	4.27	1.14	4.16	14.03	15.99
11269	5.17	3.97	1.20	5.29	15.04	13.20
11271	5.06	3.84	1.37	6.13	17.20	15.23
11273	5.18	3.99	1.21	5.51	15.78	13.11
11275	5.05	3.88	1.24	5.91	13.83	12.60
11277	5.30	4.14	1.34	4.46	21.51	14.21
11279	5.15	3.97	1.31	4.90	17.88	11.72
11281	5.41	4.25	1.07	4.33	17.06	20.07
11283	5.56	4.26	1.17	3.89	13.11	15.52
11285	5.23	4.02	1.24	4.33	10.59	14.08
11287	4.83	3.68	1.27	6.91	13.21	17.12
11289	4.65	3.63	1.24	6.43	10.54	13.74
11291	4.75	3.67	1.21	6.08	10.67	15.18
11293	4.53	3.55	1.41	5.78	13.01	15.35
11295	4.95	3.86	1.38	5.03	14.98	14.11
11297	5.25	4.27	1.31	4.11	25.79	15.83
11299	5.35	4.14	1.20	4.07	16.18	16.83
11301	5.16	4.05	1.27	4.42	12.09	14.49
11303	4.90	3.73	1.10	5.25	11.51	13.11
11305	5.06	3.96	1.20	4.94	8.69	12.73
11307	4.97	3.75	1.27	5.64	8.21	13.00
11309	5.13	3.86	1.21	4.64	13.53	12.86
11311	4.86	3.70	1.27	5.43	13.07	10.19
11313	5.02	3.98	1.34	4.94	11.67	13.18
11315	5.45	4.28	1.27	4.07	12.58	12.36
11317	4.76	3.68	1.27	5.78	9.29	10.89
11319	4.81	3.68	1.34	6.17	11.43	12.91
11321	5.10	3.86	1.86	5.95	19.07	20.59
11323	5.23	3.92	1.24	5.16	21.35	20.78
11325	5.32	4.02	1.20	4.94	14.44	17.07
11327	5.50	4.21	1.20	3.94	10.05	13.51
11329	5.38	4.18	1.34	4.03	11.20	12.57
11331	5.40	4.16	1.21	3.37	9.06	12.24
11333	4.49	3.48	1.31	6.65	10.83	13.13

Lab number	pH_{H_2O}	pH_{KCl}	Humus	Hy	P_2O_5	K_2O
			(%)	cmol(+)kg^{-1}	mg 100g^{-1} soil	
11335	4.82	3.74	1.31	5.03	9.93	11.82
11337	4.82	3.65	1.07	5.91	14.65	17.62
11339	4.93	3.71	1.14	5.99	15.61	18.72
11341	4.94	3.77	1.10	5.60	9.75	16.77
11343	5.32	4.05	1.17	5.21	8.75	14.53
11345	4.94	3.73	1.21	5.34	9.22	12.53
11347	4.82	3.69	1.14	3.33	10.14	11.83
11349	4.66	3.65	1.14	5.38	10.70	11.89
11351	4.69	3.66	1.31	5.29	9.71	11.57
11353	4.85	3.71	1.03	6.08	27.90	19.48
11355	5.08	3.70	1.14	5.91	13.67	14.74
11357	5.32	3.92	1.24	4.55	9.42	14.49
11359	5.34	4.05	1.28	4.33	7.70	14.98
11361	4.86	3.66	1.31	5.69	8.43	12.28
11363	4.95	3.62	1.28	5.47	9.93	12.10
11365	4.74	3.67	1.48	5.34	13.45	11.64
11367	4.87	3.74	1.34	4.99	10.20	12.88
	pH_{H_2O}	pH_{KCl}	Humus	Hy	P_2O_5	K_2O
			(%)	cmol(+)kg^{-1}	mg 100g^{-1} soil	
Var	0.18	0.18	0.05	1.24	48.32	10.12
Min	4.49	3.48	1.03	2.05	6.06	10.19
Max	6.33	5.45	2.00	6.91	40.94	28.32
Average	5.31	4.13	1.40	4.59	15.58	15.42
StDev	0.43	0.43	0.22	1.11	6.95	3.18
CV (%)	8.10	10.42	15.67	24.25	44.61	20.63

Appendix table 2. Concentrations of exchangeable cations on the soil adsorption complex and cation exchange capacity (CEC) in soil samples from the Trnava location.

Lab number	Ca	Mg	K	Na	CEC
	(mg kg^{-1})				(cmol(+)kg^{-1})
11137	1,281.24	262.63	124.28	11.03	13.25
11139	1,479.17	305.24	127.52	11.94	13.95
11141	1,484.51	346.55	136.65	12.95	14.65
11143	1,485.87	358.97	148.21	15.21	13.83
11145	1,658.52	442.33	149.83	19.29	15.16
11147	1,807.80	444.23	120.97	17.64	15.41
11149	1,807.18	452.47	104.48	23.82	15.16
11151	945.47	237.78	57.56	17.82	9.82
11153	1,017.11	275.91	54.34	19.04	13.19
11155	1,379.31	272.02	120.08	12.63	13.67
11157	1,442.47	287.12	136.06	12.23	13.79
11159	1,564.37	323.12	134.29	13.94	14.15
11161	1,456.67	305.29	134.99	15.68	14.11
11163	1,610.74	376.26	116.54	18.31	14.21
11165	1,726.28	424.55	117.18	18.36	14.85
11167	1,719.67	429.81	118.58	19.91	14.60
11169	1,375.30	290.56	161.51	13.12	14.27
11171	1,424.71	283.39	123.30	15.53	14.35
11173	1,547.85	306.42	122.26	12.85	14.12
11175	1,519.01	306.23	133.51	9.83	14.01
11177	1,831.18	395.63	126.84	11.26	16.66
11179	2,276.09	503.02	129.47	14.56	18.42
11181	2,091.63	460.76	142.18	17.93	17.23
11183	1,566.29	366.23	106.42	17.12	13.50
11185	1,600.71	349.27	217.23	12.81	15.64
11187	1,373.53	319.06	131.74	9.41	14.48
11189	1,203.16	299.92	106.08	8.41	13.54
11191	1,510.71	298.96	105.92	11.08	14.26
11193	2,399.01	532.68	142.49	13.87	20.66
11195	1,725.33	445.03	107.07	15.87	15.24
11197	1,603.81	421.91	103.81	12.55	14.73
11199	1,524.66	344.16	99.38	11.68	13.40
11201	1,523.47	368.29	103.00	10.61	14.63
11203	1,425.31	363.71	96.42	12.53	13.52
11205	1,556.78	400.69	103.75	11.50	14.57
11207	1,437.08	341.40	96.02	10.32	13.51
11209	971.24	206.45	148.92	6.38	13.18
11211	1,233.56	254.33	146.56	8.20	13.58
11213	1,313.23	298.36	130.31	8.61	13.85
11215	1,338.07	298.86	106.82	9.34	13.84
11217	1,518.21	364.52	105.20	12.08	14.78
11219	3,564.12	918.79	208.38	27.84	30.58
11221	1,379.21	336.84	102.28	11.56	15.01
11223	2,710.19	639.47	182.76	27.43	23.95
11225	2,258.99	435.43	271.87	14.51	21.00
11227	1,458.08	268.20	162.40	10.51	14.72
11229	1,465.68	260.05	145.79	9.14	15.27
11231	1,287.19	204.87	113.18	9.49	13.46
11233	2,045.65	397.34	165.53	15.82	19.56

Lab number	Ca	Mg	K	Na	CEC
	(mg kg^{-1})				(cmol(+)kg^{-1})
11235	1,252.36	256.00	82.87	8.85	13.00
11237	1,041.94	243.73	90.10	8.13	13.32
11239	1,686.41	357.93	116.09	16.09	17.23
11241	1,294.06	270.55	148.68	10.37	14.81
11243	1,034.22	210.30	159.84	8.75	13.27
11245	1,023.63	193.75	137.31	8.54	12.35
11247	1,085.32	155.71	104.91	18.83	12.34
11249	1,025.37	163.43	107.65	16.03	13.24
11251	1,185.94	227.26	93.23	16.97	13.61
11253	1,326.26	285.23	89.27	19.65	13.60
11255	1,230.06	265.34	88.31	16.22	12.84
11257	1,181.98	204.58	101.55	8.17	12.74
11259	1,199.89	240.53	84.46	9.39	12.86
11261	1,142.35	237.49	83.03	9.42	13.07
11263	1,124.43	214.37	81.64	13.70	12.54
11265	1,125.09	202.69	137.08	7.25	12.87
11267	1,475.42	300.37	111.27	8.63	14.31
11269	1,250.05	255.20	94.04	9.31	13.91
11271	1,037.27	206.64	110.25	7.14	13.31
11273	1,098.09	200.50	93.79	7.79	12.92
11275	1,051.14	212.60	89.36	10.67	13.18
11277	1,050.59	196.81	79.99	10.11	11.57
11279	1,135.80	233.25	89.66	13.36	12.77
11281	1,301.12	275.12	130.87	21.87	13.52
11283	1,262.28	258.72	97.97	9.76	12.61
11285	1,097.27	232.02	86.33	8.72	11.97
11287	980.53	193.19	106.25	8.54	13.70
11289	1,037.79	220.31	101.81	8.95	13.72
11291	1,064.48	232.29	107.30	10.33	13.62
11293	882.87	170.29	103.78	9.30	11.89
11295	1,061.02	207.28	98.98	9.61	12.33
11297	1,296.76	251.84	113.17	12.60	13.00
11299	1,185.17	236.77	104.04	8.95	12.24
11301	1,158.26	216.43	89.08	9.93	12.25
11303	1,014.75	197.45	99.06	11.95	12.24
11305	1,284.43	266.34	94.42	12.60	13.84
11307	1,044.07	238.50	92.90	9.17	13.09
11309	980.59	211.62	92.07	9.42	11.55
11311	827.63	134.13	71.77	9.79	10.88
11313	1,231.52	250.53	96.74	9.92	13.44
11315	1,317.86	264.95	96.42	10.87	13.12
11317	870.17	169.72	81.04	9.09	11.76
11319	817.58	142.79	97.13	7.40	11.70
11321	1,230.79	250.64	155.39	9.99	14.60
11323	1,214.56	242.65	150.91	9.19	13.65
11325	1,346.80	281.86	124.50	10.53	14.35
11327	1,403.97	275.41	101.10	13.09	13.53
11329	1,320.49	248.85	92.90	12.82	12.96
11331	1,286.61	270.21	91.13	10.69	12.29
11333	1,009.34	171.20	111.10	16.33	13.45
11335	1,124.82	196.15	107.85	14.55	12.60
11337	1,565.80	345.82	168.60	12.22	17.05
11339	1,629.38	377.05	204.33	11.21	17.79

Lab number	Ca	Mg	K	Na	CEC
	(mg kg^{-1})				(cmol(+)kg^{-1})
11341	1,420.64	326.01	136.82	12.60	15.78
11343	1,880.01	395.46	137.02	12.22	18.25
11345	1,282.11	254.86	105.49	10.43	14.15
11347	1,016.28	200.06	85.43	11.19	10.31
11349	923.53	180.33	87.01	13.77	11.75
11351	852.21	144.88	86.03	10.02	11.00
11353	1,280.11	225.57	152.40	10.86	14.76
11355	1,390.68	268.47	112.82	11.17	15.40
11357	2,723.35	587.32	183.00	23.60	23.54
11359	1,416.05	339.41	108.91	30.87	14.60
11361	973.19	186.66	87.50	8.03	12.34
11363	988.60	173.87	89.35	7.56	12.10
11365	992.25	191.20	90.91	9.99	12.14
11367	989.95	191.57	96.44	9.37	11.79
	Ca	**Mg**	**K**	**Na**	**CEC**
	(mg kg^{-1})				(cmol(+)kg^{-1})
Var	169,841.45	12,370.71	1,082.02	20.27	7.36
Min	817.58	134.13	54.34	6.38	9.82
Max	3,564.12	918.79	271.87	30.87	30.58
Average	1,370.35	291.85	116.83	12.57	14.19
StDev	412.12	111.22	32.89	4.50	2.71
CV (%)	30.07	38.11	28.16	35.82	19.13

Appendix table 3. Soil texture components in soil samples from the Trnava location.

Lab number	Coarse sand	Fine sand	Coarse silt	Fine silt	Clay
	(%)				
11137	1.22	2.80	39.09	32.48	24.41
11141	1.54	2.16	39.82	31.00	25.48
11145	2.01	2.36	38.49	30.98	26.16
11149	2.09	2.55	37.54	31.01	26.80
11155	1.28	2.17	39.34	32.85	24.36
11159	1.98	2.44	40.01	31.22	24.36
11163	2.16	2.28	38.83	32.25	24.47
11167	2.55	2.48	37.30	33.29	24.38
11169	1.01	2.35	39.59	32.06	24.99
11173	1.19	2.28	39.33	31.83	25.38
11177	2.24	2.27	37.43	32.77	25.29
11181	2.26	2.12	38.19	31.38	26.05
11187	0.94	2.10	38.68	32.11	26.16
11191	1.44	2.38	40.00	32.89	23.29
11195	2.15	2.14	37.14	31.86	26.72
11199	2.81	2.52	40.63	32.70	21.35
11201	1.66	2.05	36.85	34.13	25.31
11205	2.25	2.44	36.98	32.76	25.57
11211	1.05	2.57	40.03	32.21	24.13
11215	1.39	2.36	39.46	32.03	24.76
11219	2.24	2.14	40.84	31.64	23.14
11223	2.91	3.15	39.10	32.54	22.31
11225	1.26	2.28	39.89	33.13	23.45
11229	1.08	2.28	39.41	34.37	22.85
11233	1.92	2.09	41.29	33.41	21.29
11237	2.48	1.95	39.39	34.67	21.51
11243	0.88	2.11	40.99	31.32	24.69
11247	1.48	2.38	43.33	33.07	19.74
11251	2.11	2.04	39.92	33.89	22.05
11255	2.16	2.04	42.27	32.02	21.52
11257	2.07	2.17	40.75	32.04	22.96
11261	2.66	2.25	38.38	32.90	23.80
11267	0.69	1.91	38.01	32.26	27.13
11271	1.44	2.16	41.13	32.35	22.93
11275	2.44	2.21	41.28	31.85	22.22
11279	1.85	2.24	42.53	32.97	20.41
11281	0.82	1.90	38.20	31.65	27.43
11285	1.16	2.16	41.61	30.97	24.10
11289	2.52	2.18	38.44	33.58	23.27
11293	2.04	2.24	41.74	33.00	20.98
11299	1.42	2.57	41.45	30.65	23.91
11303	1.56	1.90	41.35	33.00	22.20
11307	2.61	2.35	39.97	30.91	24.16
11311	1.91	2.37	45.54	31.76	18.42
11313	2.08	2.16	41.24	31.14	23.38
11317	2.28	2.47	47.88	28.93	18.44
11323	1.04	2.08	39.19	30.13	27.56
11327	1.57	2.22	41.62	30.20	24.38
11331	2.25	2.38	42.69	30.63	22.05
11335	1.99	2.45	46.44	30.20	18.92
11337	0.74	1.88	39.15	31.99	26.25

Lab number	Coarse sand	Fine sand	Coarse silt	Fine silt	Clay
	(%)				
11341	0.87	1.99	38.77	30.63	27.74
11345	2.37	2.31	42.70	32.17	20.45
11349	2.06	2.12	43.26	34.53	18.03
11355	0.88	2.14	38.86	31.55	26.58
11359	1.85	2.50	39.32	31.85	24.49
11363	2.07	2.20	43.26	31.44	21.03
11367	1.99	2.53	43.65	34.24	17.58
	Coarse sand	**Fine sand**	**Coarse silt**	**Fine silt**	**Clay**
	(%)				
Var	0.35	0.05	5.21	1.42	6.37
Min	0.69	1.88	36.85	28.93	17.58
Max	2.91	3.15	47.88	34.67	27.74
Average	1.78	2.26	40.34	32.13	23.50
StDev	0.59	0.23	2.28	1.19	2.52
CV (%)	33.08	10.04	5.66	3.71	10.74

Appendix table 4. Total concentrations of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) in soil samples from the Trnava location.

Lab number	P	K	Ca	Mg
	(mg kg^{-1})			
11137	668.60	4,877.00	3,857.00	3,320.00
11139	704.50	4,293.00	3,906.00	3,331.00
11141	687.10	4,881.00	4,010.00	3,309.00
11143	750.40	4,472.00	4,159.00	3,247.00
11145	697.60	4,787.00	4,499.00	3,475.00
11147	675.70	1,902.00	3,525.00	3,191.00
11149	759.00	1,847.00	3,714.00	3,125.00
11151	622.80	1,704.00	3,120.00	2,913.00
11153	593.20	1,822.00	2,347.00	2,995.00
11155	657.90	1,816.00	2,552.00	3,052.00
11157	665.00	1,694.00	2,670.00	2,960.00
11159	709.40	1,874.00	2,935.00	2,904.00
11161	462.00	1,642.00	1,890.00	2,476.00
11163	644.10	1,669.00	2,983.00	2,978.00
11165	629.00	1,689.00	3,030.00	2,845.00
11167	670.70	1,880.00	2,660.00	3,138.00
11169	604.20	1,746.00	2,614.00	3,039.00
11171	672.20	1,745.00	2,889.00	3,086.00
11173	670.50	1,692.00	2,647.00	2,990.00
11175	653.80	1,575.00	2,696.00	2,924.00
11177	548.50	1,527.00	2,633.00	2,911.00
11179	580.20	1,534.00	3,137.00	3,144.00
11181	556.90	1,657.00	3,057.00	2,922.00
11183	579.80	1,646.00	3,178.00	2,700.00
11185	620.30	2,017.00	2,551.00	3,099.00
11187	586.00	1,921.00	2,595.00	3,370.00
11189	528.20	1,762.00	2,606.00	3,235.00
11191	541.20	1,812.00	2,802.00	3,013.00
11193	617.00	1,896.00	3,105.00	2,996.00
11195	616.20	1,985.00	3,434.00	3,190.00
11197	507.70	1,848.00	3,323.00	3,048.00
11199	540.50	1,478.00	3,042.00	2,487.00
11201	499.00	1,791.00	3,008.00	3,029.00
11203	519.00	1,551.00	3,000.00	2,890.00
11205	555.80	1,675.00	3,098.00	3,068.00
11207	562.40	1,670.00	2,972.00	2,738.00
11209	635.10	1,973.00	2,383.00	2,948.00
11211	644.10	1,956.00	2,700.00	3,084.00
11213	568.70	1,794.00	2,640.00	3,220.00
11215	543.30	1,586.00	2,685.00	2,962.00
11217	519.10	1,576.00	2,898.00	2,947.00
11219	468.70	1,359.00	2,637.00	2,835.00
11221	475.60	1,417.00	2,661.00	2,797.00
11223	549.50	1,492.00	2,909.00	2,602.00
11225	772.20	1,979.00	2,658.00	2,880.00
11227	662.80	2,146.00	2,942.00	3,152.00
11229	638.70	1,894.00	2,825.00	2,808.00
11231	643.20	1,619.00	2,810.00	2,467.00
11233	538.10	1,353.00	2,605.00	2,625.00

Lab number	P	K	Ca	Mg
	(mg kg^{-1})			
11235	475.60	1,505.00	3,021.00	2,646.00
11237	532.90	1,531.00	2,764.00	2,632.00
11239	494.80	1,305.00	2,696.00	2,482.00
11241	677.10	1,878.00	2,769.00	3,064.00
11243	682.30	1,925.00	2,586.00	3,145.00
11245	639.50	1,780.00	2,757.00	2,829.00
11247	675.80	1,420.00	2,537.00	2,522.00
11249	793.00	1,708.00	2,511.00	3,065.00
11251	736.20	1,641.00	2,633.00	3,118.00
11253	565.60	1,616.00	2,792.00	3,092.00
11255	639.30	1,704.00	2,696.00	3,062.00
11257	697.30	1,904.00	2,585.00	3,269.00
11259	616.50	1,839.00	2,639.00	3,363.00
11261	692.10	1,624.00	2,554.00	3,125.00
11263	693.10	1,603.00	2,642.00	2,963.00
11265	885.30	2,020.00	2,486.00	3,686.00
11267	750.30	2,170.00	3,114.00	3,943.00
11269	678.30	1,933.00	2,526.00	3,639.00
11271	743.70	1,962.00	2,494.00	3,387.00
11273	743.50	1,987.00	2,716.00	3,293.00
11275	714.30	1,796.00	2,603.00	3,136.00
11277	716.60	1,817.00	2,618.00	3,141.00
11279	804.00	1,850.00	2,850.00	2,879.00
11281	983.90	2,790.00	3,338.00	4,271.00
11283	804.70	2,525.00	3,499.00	4,066.00
11285	790.20	2,274.00	3,204.00	3,736.00
11287	823.90	2,412.00	2,885.00	3,599.00
11289	777.40	2,285.00	2,976.00	3,474.00
11291	779.40	2,186.00	2,979.00	3,326.00
11293	762.30	2,068.00	2,781.00	3,076.00
11295	839.70	2,131.00	3,142.00	3,146.00
11297	989.50	2,392.00	3,242.00	3,597.00
11299	888.90	2,335.00	3,248.00	3,580.00
11301	795.40	2,124.00	3,127.00	3,345.00
11303	820.90	2,141.00	2,788.00	3,236.00
11305	750.50	2,137.00	3,175.00	3,488.00
11307	750.20	2,257.00	3,005.00	3,418.00
11309	783.20	2,068.00	2,971.00	3,088.00
11311	806.50	2,044.00	2,935.00	2,982.00
11313	761.90	2,405.00	3,392.00	3,490.00
11315	880.70	2,160.00	3,294.00	3,532.00
11317	847.50	2,022.00	2,988.00	3,194.00
11319	845.70	1,872.00	2,872.00	3,113.00
11321	846.10	2,300.00	2,826.00	3,840.00
11323	1,033.00	2,672.00	3,243.00	4,075.00
11325	905.10	2,115.00	2,911.00	3,896.00
11327	793.10	2,239.00	3,350.00	3,772.00
11329	793.60	2,017.00	3,183.00	3,478.00
11331	740.00	1,966.00	3,014.00	3,275.00
11333	826.10	1,813.00	2,633.00	3,187.00
11335	840.80	1,802.00	2,674.00	3,163.00
11337	870.90	2,540.00	2,981.00	4,228.00
11339	906.80	2,526.00	3,026.00	4,061.00

Lab number	P	K	Ca	Mg
	(mg kg^{-1})			
11341	786.40	2,442.00	3,266.00	4,132.00
11343	780.30	2,025.00	3,195.00	3,746.00
11345	787.70	1,737.00	2,779.00	3,151.00
11347	760.20	1,623.00	2,678.00	3,070.00
11349	728.30	1,768.00	2,607.00	3,089.00
11351	801.30	1,613.00	2,528.00	2,820.00
11353	1,039.00	2,597.00	2,922.00	3,775.00
11355	817.00	2,437.00	3,167.00	3,876.00
11357	781.40	2,384.00	3,220.00	3,907.00
11359	740.60	2,387.00	3,399.00	3,717.00
11361	717.00	1,796.00	2,766.00	3,112.00
11363	777.00	2,032.00	2,905.00	3,177.00
11365	800.10	2,069.00	3,090.00	3,121.00
11367	761.40	1,931.00	3,035.00	2,969.00
	P	K	Ca	Mg
	(mg kg^{-1})			
Var	15,625.95	409,759.51	144,960.42	154,166.91
Min	462.00	1,305.00	1,890.00	2,467.00
Max	1,039.00	4,881.00	4,499.00	4,271.00
Average	703.26	2,030.16	2,934.70	3,201.21
StDev	125.00	640.12	380.74	392.64
CV (%)	17.77	31.53	12.97	12.27

Appendix table 5. Total concentrations of microelements: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), molybdenum (Mo) in soil samples from the Trnava location.

Lab number	Fe	Mn	Zn	Cu	Ni	Mo
	(mg kg^{-1})					(μg kg^{-1})
11137	16,390.00	631.00	51.16	16.78	23.77	277.57
11139	16,890.00	636.30	51.50	17.22	23.62	307.71
11141	16,240.00	558.20	51.79	17.82	24.35	287.50
11143	16,160.00	531.90	51.31	17.35	23.66	262.04
11145	17,340.00	559.30	50.17	18.26	25.26	314.47
11147	16,550.00	555.40	42.32	18.22	24.08	301.16
11149	16,850.00	744.20	47.43	19.02	25.85	289.61
11151	15,650.00	604.40	43.56	15.90	22.59	225.77
11153	15,560.00	439.30	38.75	16.66	20.00	252.64
11155	16,170.00	491.20	44.20	16.20	21.78	243.34
11157	15,840.00	541.00	44.12	16.68	22.52	228.14
11159	15,800.00	667.00	44.07	16.10	21.09	251.03
11161	13,080.00	431.60	35.95	10.64	16.18	140.83
11163	16,430.00	509.80	42.20	16.18	22.67	226.58
11165	14,670.00	398.10	42.94	15.18	19.93	152.16
11167	16,300.00	476.00	42.74	18.24	22.35	290.77
11169	16,080.00	577.00	41.65	17.41	22.49	277.42
11171	16,090.00	510.60	41.24	17.53	22.73	253.24
11173	15,320.00	503.90	41.64	16.58	21.69	255.84
11175	15,170.00	497.20	42.23	17.15	21.47	234.20
11177	15,120.00	485.40	40.68	15.92	21.42	203.67
11179	16,920.00	567.00	41.79	17.51	24.43	253.04
11181	15,300.00	463.50	42.87	15.93	21.91	193.07
11183	15,120.00	501.40	40.33	15.35	19.73	195.95
11185	16,170.00	493.40	42.02	17.88	22.46	287.74
11187	17,160.00	556.40	44.12	17.55	25.09	243.44
11189	17,050.00	527.10	44.07	17.39	23.76	282.84
11191	15,490.00	502.00	42.88	16.17	22.35	247.13
11193	16,200.00	536.20	42.40	17.15	23.90	262.04
11195	17,620.00	592.20	41.48	17.95	25.06	312.74
11197	16,440.00	533.20	41.61	17.04	24.08	218.78
11199	13,400.00	468.40	38.47	13.63	18.56	167.79
11201	16,520.00	542.50	43.59	17.15	24.01	264.25
11203	16,070.00	847.40	43.01	16.89	25.80	310.76
11205	17,380.00	569.60	41.86	17.46	24.43	267.48
11207	16,010.00	615.70	41.94	15.48	22.73	274.28
11209	16,290.00	451.60	41.58	17.14	21.03	279.81
11211	16,230.00	480.90	40.91	18.33	23.15	281.80
11213	17,360.00	495.50	42.19	17.82	23.21	291.12
11215	15,740.00	527.60	42.31	17.81	22.83	275.91
11217	15,940.00	562.20	41.23	17.53	22.80	302.00
11219	15,330.00	453.80	41.36	15.95	22.02	213.80
11221	15,040.00	496.60	38.47	15.70	21.13	206.24
11223	15,410.00	551.90	38.91	16.17	20.99	272.50
11225	16,260.00	515.80	44.06	18.15	21.85	311.46
11227	16,730.00	482.20	45.05	19.35	24.13	304.08
11229	15,180.00	484.90	41.01	17.62	21.17	257.05
11231	13,530.00	465.20	38.87	16.32	18.16	208.59
11233	13,840.00	410.00	37.66	15.66	18.67	185.67

Lab number	Fe	Mn	Zn	Cu	Ni	Mo
	(mg kg^{-1})					(µg kg^{-1})
11235	14,350.00	431.80	38.29	16.25	19.96	203.56
11237	15,500.00	495.10	38.82	16.15	20.31	242.83
11239	13,400.00	399.80	38.28	14.97	18.35	207.19
11241	16,230.00	495.20	43.62	19.92	22.90	320.64
11243	16,660.00	471.60	42.99	19.50	22.75	294.98
11245	15,560.00	494.30	39.91	18.43	21.16	291.47
11247	13,700.00	534.20	42.22	16.33	18.22	231.73
11249	15,190.00	518.10	47.64	15.24	21.18	230.20
11251	17,540.00	495.60	48.52	16.61	23.12	269.48
11253	16,420.00	464.60	43.83	14.78	22.32	232.66
11255	15,240.00	485.80	45.81	13.44	21.78	201.87
11257	16,940.00	611.00	48.20	15.64	23.40	290.21
11259	16,330.00	578.30	47.74	15.05	23.64	256.74
11261	16,750.00	557.60	46.29	14.66	21.91	255.19
11263	15,010.00	422.70	45.20	13.31	20.06	220.60
11265	18,600.00	556.00	52.65	18.66	26.55	343.72
11267	18,970.00	563.70	52.48	20.24	29.37	360.97
11269	17,700.00	509.20	50.69	17.43	25.19	326.42
11271	16,660.00	582.30	48.61	16.67	24.00	327.64
11273	16,190.00	561.50	49.33	15.82	23.00	278.24
11275	15,700.00	540.70	46.35	14.99	21.97	269.68
11277	15,720.00	546.90	44.98	14.59	24.65	275.77
11279	15,810.00	472.00	44.60	13.73	19.98	247.25
11281	19,690.00	641.50	59.07	19.23	30.18	316.93
11283	18,800.00	603.20	53.27	18.58	27.65	308.10
11285	17,910.00	803.10	52.13	17.37	26.32	325.87
11287	17,260.00	639.90	52.05	15.88	23.70	311.04
11289	16,910.00	848.60	48.33	15.80	24.63	274.26
11291	16,540.00	679.40	49.79	14.89	23.42	287.83
11293	14,720.00	533.30	47.56	12.65	19.60	207.02
11295	15,150.00	528.10	48.22	13.57	19.97	241.61
11297	16,960.00	564.50	52.52	16.42	24.13	293.93
11299	17,050.00	693.90	50.74	16.43	25.12	303.40
11301	15,980.00	565.30	48.93	15.03	22.31	245.27
11303	16,640.00	616.10	49.57	14.06	22.12	276.47
11305	16,800.00	663.70	52.13	15.99	25.00	266.04
11307	17,240.00	847.20	50.06	15.50	24.67	297.69
11309	16,030.00	620.60	47.17	13.82	21.48	245.25
11311	15,160.00	586.90	45.30	12.49	19.20	216.12
11313	16,440.00	579.40	48.42	15.97	23.80	250.89
11315	17,340.00	653.90	49.96	16.66	24.59	316.54
11317	16,500.00	755.50	49.56	14.65	22.64	310.99
11319	15,450.00	616.60	46.41	14.16	21.31	245.54
11321	18,710.00	571.20	50.93	18.53	26.33	325.25
11323	19,170.00	624.90	54.30	19.61	28.47	348.74
11325	19,210.00	756.10	54.47	18.03	27.15	324.88
11327	18,320.00	636.20	55.06	17.43	26.16	283.47
11329	17,090.00	675.40	51.38	15.67	24.23	263.21
11331	16,290.00	672.30	46.56	14.94	23.06	256.01
11333	15,690.00	640.70	46.74	14.15	21.47	239.98
11335	16,180.00	728.90	47.99	13.55	21.42	275.99
11337	20,120.00	617.90	56.53	19.86	28.80	348.39
11339	19,820.00	659.10	54.03	19.59	28.83	335.16

Lab number	Fe	Mn	Zn	Cu	Ni	Mo
	(mg kg^{-1})					(µg kg^{-1})
11341	19,870.00	654.30	56.07	19.34	29.26	328.68
11343	18,200.00	657.70	52.81	17.68	26.64	295.45
11345	16,930.00	868.00	48.84	15.27	23.33	354.65
11347	15,820.00	582.80	46.83	13.92	20.81	226.98
11349	15,050.00	500.90	45.85	12.34	19.57	213.16
11351	14,380.00	503.00	43.01	11.87	18.56	215.81
11353	18,510.00	670.20	57.37	19.03	26.84	340.92
11355	19,040.00	661.40	55.92	19.09	27.65	327.51
11357	19,520.00	1,198.00	56.53	18.61	28.57	375.36
11359	18,730.00	635.40	52.95	17.50	27.18	287.12
11361	15,420.00	536.50	46.46	13.96	21.16	212.45
11363	15,880.00	557.40	49.53	14.12	21.17	213.16
11365	15,450.00	552.60	48.50	13.59	20.37	233.13
11367	15,240.00	508.60	45.43	12.64	19.39	210.63
	Fe	**Mn**	**Zn**	**Cu**	**Ni**	**Mo**
	(mg kg^{-1})					(µg kg^{-1})
Var	2,056,050.88	12,768.55	26.02	3.79	7.41	2,146.56
Min	13,080.00	398.10	35.95	10.64	16.18	140.83
Max	20,120.00	1,198.00	59.07	20.24	30.18	375.36
Average	16,403.53	573.63	46.29	16.35	23.04	267.27
StDev	1,433.89	113.00	5.10	1.95	2.72	46.33
CV (%)	8.74	19.70	11.02	11.90	11.81	17.34

Appendix table 6. Total concentrations of beneficial elements: cobalt (Co), selenium (Se), and toxic elements: chromium (Cr), cadmium (Cd), arsenic (As), mercury (Hg), lead (Pb) in soil samples from the Trnava location.

Lab number	Co	Se	Cr	Cd	As	Hg	Pb
	(mg kg^{-1})	(µg kg^{-1})	(mg kg^{-1})	(µg kg^{-1})			(mg kg^{-1})
11137	12.10	1,603.00	40.22	158.29	8,099.00	5.74	16.03
11139	12.42	1,164.00	39.81	145.37	8,673.00	4.72	16.89
11141	11.43	1,373.00	40.58	143.02	8,278.00	3.53	15.75
11143	10.70	1,430.00	37.57	166.26	7,955.00	3.69	15.48
11145	11.52	1,476.00	42.12	161.51	8,826.00	3.73	16.95
11147	12.24	1,267.00	28.20	146.62	8,156.00	3.28	14.70
11149	16.24	1,347.00	28.16	177.75	8,865.00	4.21	16.53
11151	13.07	1,501.00	26.21	152.96	7,434.00	3.81	17.08
11153	9.87	1,410.00	22.79	130.77	6,794.00	4.51	13.11
11155	10.17	911.70	23.15	152.50	7,337.00	4.10	14.42
11157	11.69	1,179.00	23.97	150.51	7,172.00	2.94	15.00
11159	12.58	1,208.00	24.40	180.49	7,380.00	3.28	16.78
11161	9.41	956.20	19.10	99.19	4,950.00	2.69	10.23
11163	10.89	1,026.00	24.67	141.89	7,990.00	3.96	15.27
11165	9.30	1,104.00	23.89	125.39	6,107.00	3.28	13.29
11167	10.81	1,303.00	24.86	140.32	7,481.00	3.53	14.52
11169	12.53	1,497.00	25.66	149.08	7,682.00	3.42	15.77
11171	11.65	1,207.00	25.51	125.07	7,600.00	3.96	14.51
11173	10.29	1,445.00	22.45	163.15	6,869.00	3.07	14.37
11175	10.55	1,044.00	22.77	168.51	6,985.00	3.29	13.94
11177	9.18	1,127.00	22.19	155.18	6,531.00	3.06	13.37
11179	12.60	1,168.00	23.64	150.48	8,219.00	3.53	14.82
11181	10.29	1,213.00	24.24	140.75	6,943.00	4.04	13.88
11183	10.78	1,245.00	23.36	146.54	6,597.00	4.71	15.31
11185	11.49	1,186.00	24.46	136.68	7,503.00	3.36	14.26
11187	12.07	978.50	18.28	143.51	8,549.00	3.42	15.38
11189	12.08	1,110.00	17.73	152.56	8,029.00	3.60	14.51
11191	10.31	1,028.00	17.24	133.50	7,257.00	3.10	14.77
11193	11.51	1,274.00	18.17	147.85	7,684.00	3.93	14.61
11195	13.84	1,106.00	19.36	146.13	8,926.00	3.18	15.32
11197	11.47	1,071.00	18.54	126.79	7,847.00	3.01	14.49
11199	9.50	1,064.00	15.11	131.73	5,667.00	2.75	13.77
11201	12.06	1,076.00	17.42	145.26	7,929.00	3.36	14.85
11203	13.89	1,234.00	16.87	210.80	8,117.00	2.84	15.34
11205	12.90	964.00	17.56	153.13	8,416.00	2.86	15.07
11207	12.13	1,201.00	17.23	162.63	8,070.00	2.74	16.41
11209	10.92	1,005.00	15.03	132.73	7,222.00	3.56	13.60
11211	11.58	1,164.00	16.34	148.32	7,761.00	3.06	14.43
11213	11.71	1,193.00	16.36	134.58	8,132.00	3.33	14.86
11215	12.03	983.60	15.54	146.14	7,788.00	2.88	15.06
11217	12.96	1,032.00	15.51	138.83	7,468.00	2.75	14.69
11219	9.82	934.10	14.32	134.98	7,069.00	4.98	13.62
11221	11.35	1,054.00	14.48	131.83	6,837.00	2.43	14.28
11223	12.39	1,043.00	16.52	151.28	7,856.00	5.21	16.02
11225	12.04	1,320.00	16.45	160.60	7,828.00	3.44	15.61
11227	11.80	1,051.00	16.65	142.05	8,179.00	3.21	14.40
11229	11.58	899.40	14.96	145.93	7,200.00	4.65	14.72

Lab number	Co	Se	Cr	Cd	As	Hg	Pb
	(mg kg^{-1})	(µg kg^{-1})	(mg kg^{-1})	(µg kg^{-1})			(mg kg^{-1})
11231	10.14	1,274.00	13.65	152.97	6,156.00	2.35	15.00
11233	9.53	1,096.00	13.25	139.60	5,746.00	1.98	13.76
11235	10.10	976.40	14.60	119.64	6,391.00	2.74	14.41
11237	11.13	1,121.00	14.86	143.02	7,283.00	2.80	15.66
11239	9.82	1,082.00	13.73	122.63	5,647.00	2.59	14.38
11241	13.52	922.90	15.85	153.34	7,556.00	3.28	14.79
11243	12.82	1,017.00	15.24	153.22	7,846.00	3.51	15.26
11245	12.44	1,155.00	14.60	140.52	7,465.00	2.75	15.93
11247	11.85	1,072.00	12.79	148.90	6,199.00	2.20	15.01
11249	9.53	1,219.00	25.44	144.76	7,103.00	14.73	15.06
11251	9.99	1,162.00	28.06	136.55	9,632.00	8.41	16.40
11253	10.07	1,155.00	25.56	123.28	8,517.00	8.06	15.11
11255	9.02	1,148.00	34.85	126.21	8,297.00	8.45	13.85
11257	11.15	1,292.00	36.88	122.54	9,867.00	8.43	14.95
11259	10.91	1,191.00	37.35	119.09	8,687.00	7.98	14.06
11261	10.59	1,221.00	34.93	137.88	9,862.00	7.03	15.96
11263	8.60	1,082.00	34.61	120.14	8,074.00	21.41	14.73
11265	11.63	1,125.00	36.07	129.09	11,330.00	8.29	14.99
11267	12.21	1,190.00	39.26	124.13	11,600.00	9.48	14.96
11269	10.47	1,131.00	36.81	111.00	10,010.00	8.53	14.36
11271	11.78	1,197.00	36.39	136.25	9,532.00	9.04	16.05
11273	10.91	1,307.00	35.27	138.91	9,049.00	10.58	14.99
11275	10.63	1,115.00	35.15	124.27	8,678.00	7.44	15.12
11277	10.49	1,155.00	33.16	126.32	8,761.00	7.84	14.32
11279	9.24	1,269.00	35.25	135.42	8,957.00	8.36	15.93
11281	12.45	1,224.00	45.49	121.35	13,070.00	11.06	14.48
11283	11.75	1,117.00	40.48	130.04	11,500.00	10.23	14.04
11285	13.58	1,196.00	38.80	142.18	11,290.00	17.49	15.00
11287	11.30	1,210.00	38.40	128.59	9,564.00	6.11	14.54
11289	13.74	1,216.00	38.58	150.01	9,676.00	5.62	14.77
11291	12.27	1,355.00	38.08	124.62	9,627.00	11.89	15.01
11293	9.24	1,062.00	34.99	114.03	7,761.00	5.91	13.45
11295	9.42	1,185.00	35.38	133.44	7,909.00	5.57	13.92
11297	10.32	1,071.00	37.47	122.03	9,867.00	5.83	14.05
11299	11.91	1,272.00	38.64	139.28	10,250.00	6.20	14.63
11301	9.98	1,232.00	36.17	116.73	9,324.00	6.03	13.84
11303	10.40	1,209.00	35.99	116.33	10,090.00	5.48	14.36
11305	11.21	1,300.00	36.13	126.48	9,659.00	5.69	13.62
11307	14.39	1,252.00	37.15	142.84	10,240.00	11.56	16.76
11309	10.76	1,352.00	36.06	129.49	9,635.00	6.08	15.34
11311	9.79	1,237.00	33.83	136.44	8,418.00	6.54	14.82
11313	10.15	1,344.00	37.71	125.28	9,495.00	5.64	13.78
11315	11.79	1,293.00	36.80	134.45	10,770.00	21.42	14.93
11317	13.03	1,362.00	36.03	130.42	10,300.00	6.89	17.11
11319	10.69	1,269.00	34.81	130.53	8,883.00	8.53	14.35
11321	11.47	1,053.00	37.15	110.98	11,360.00	6.67	13.71
11323	12.43	1,157.00	39.26	128.03	11,960.00	7.34	14.56
11325	15.12	1,238.00	36.45	134.56	11,970.00	7.20	14.50
11327	11.65	1,266.00	38.24	121.66	10,760.00	6.28	14.47
11329	11.52	1,279.00	36.40	126.38	9,683.00	5.49	14.53
11331	11.67	1,108.00	34.78	130.26	9,410.00	5.97	13.99
11333	10.75	1,150.00	34.45	128.64	9,006.00	6.80	14.75
11335	12.74	1,272.00	34.14	146.60	9,857.00	6.45	15.60

Lab number	Co	Se	Cr	Cd	As	Hg	Pb
	(mg kg^{-1})	(µg kg^{-1})	(mg kg^{-1})	(µg kg^{-1})			(mg kg^{-1})
11337	12.29	1,349.00	39.72	116.19	12,480.00	7.53	14.27
11339	12.87	1,280.00	38.75	126.74	12,550.00	7.25	15.24
11341	12.86	1,221.00	39.28	131.23	12,700.00	7.24	14.35
11343	11.91	1,151.00	36.81	130.92	11,360.00	6.78	14.06
11345	15.54	1,153.00	33.62	123.99	10,760.00	5.21	16.56
11347	10.68	1,223.00	33.37	124.91	9,030.00	5.60	14.44
11349	8.79	1,235.00	33.38	121.01	7,928.00	5.46	13.26
11351	8.28	1,223.00	31.44	118.84	8,414.00	5.89	13.49
11353	12.46	1,258.00	38.08	128.39	11,560.00	6.82	14.78
11355	12.40	1,362.00	38.98	122.91	11,930.00	6.65	15.03
11357	20.56	1,189.00	39.85	131.84	12,570.00	7.38	20.01
11359	11.48	1,226.00	38.57	128.05	11,660.00	6.73	14.22
11361	9.45	1,199.00	33.61	122.08	8,890.00	7.84	13.90
11363	9.83	1,176.00	35.70	131.36	8,898.00	5.41	14.30
11365	9.45	1,323.00	35.49	122.67	8,493.00	5.64	14.29
11367	8.94	1,344.00	34.31	122.10	8,310.00	5.03	14.51
	Co	Se	Cr	Cd	As	Hg	Pb
	(mg kg^{-1})	(µg kg^{-1})	(mg kg^{-1})	(µg kg^{-1})			(mg kg^{-1})
Var	2.88	17,561.71	88.11	254.38	3,006,483.55	11.39	1.19
Min	8.28	899.40	12.79	99.19	4,950.00	1.98	10.23
Max	20.56	1,603.00	45.49	210.80	13,070.00	21.42	20.01
Average	11.43	1,190.04	28.81	136.93	8,735.94	5.78	14.82
StDev	1.70	132.52	9.39	15.95	1,733.92	3.38	1.09
CV (%)	14.84	11.14	32.58	11.65	19.85	58.40	7.36

Appendix table 7. Basic agrochemical soil properties in soil samples from the Đurđevac location.

Lab number	pH_{H_2O}	pH_{KCl}	Humus	Hy	P_2O_5	K_2O
			(%)	cmol(+)kg^{-1}	mg 100g^{-1} soil	
12933	5.12	3.83	1.49	4.65	21.80	17.99
12934	5.15	4.11	1.75	4.20	12.81	16.88
12935	5.09	4.18	2.01	4.69	18.00	26.76
12936	5.39	4.65	2.18	2.80	16.54	25.36
12937	5.27	4.06	1.76	4.88	22.46	19.14
12938	5.33	4.20	1.60	4.17	8.26	13.02
12939	5.24	4.15	1.89	4.29	15.36	19.38
12940	5.32	4.43	1.97	3.95	11.67	15.84
12941	5.29	4.04	1.51	4.18	20.75	16.85
12942	5.26	4.12	1.75	4.06	10.03	14.40
12943	5.31	4.18	1.68	4.44	12.47	18.55
12944	5.29	4.30	1.84	4.36	9.82	12.90
12945	5.16	3.89	1.55	4.83	20.41	16.43
12946	5.23	4.06	1.62	4.11	10.21	12.29
12947	5.51	4.45	1.77	3.90	14.95	19.17
12948	5.43	4.24	1.92	4.45	9.89	12.46
12949	5.27	4.15	1.56	4.10	22.07	21.14
12950	5.32	4.16	1.67	3.96	11.00	15.17
12951	5.27	4.17	2.01	4.60	15.80	20.29
12952	5.42	4.47	1.83	3.75	8.03	12.86
12953	5.18	4.05	1.49	4.18	20.21	18.20
12954	5.34	4.31	1.67	3.73	11.08	14.68
12955	5.46	4.55	1.69	3.48	15.54	21.70
12956	5.44	4.34	1.66	4.23	9.44	12.43
12957	5.11	4.00	1.43	4.51	19.64	15.65
12958	5.27	4.30	1.96	4.00	12.45	16.04
12959	5.19	4.22	1.66	4.59	15.42	18.56
12960	5.50	4.60	2.01	3.67	14.21	14.31
12961	5.16	4.02	1.64	4.73	20.27	16.42
12962	5.44	4.53	1.79	3.59	18.33	14.36
12963	5.47	4.20	1.76	4.45	14.40	13.28
12964	5.42	4.43	2.01	4.09	12.93	15.27
12965	5.17	4.08	1.59	4.67	20.67	17.16
12966	5.37	4.33	1.71	3.84	13.35	13.86
12967	5.38	4.18	1.80	4.66	16.03	17.75
12968	5.48	4.41	1.89	4.18	13.33	14.59
12969	4.84	3.85	1.57	5.36	21.75	20.98
12970	5.16	4.18	1.61	4.34	13.33	16.18
12971	6.04	5.07	2.11	2.63	27.85	27.95
12972	5.83	4.33	2.02	3.98	9.57	13.85
12973	4.80	3.63	1.60	5.83	19.84	14.08
12974	4.92	3.95	1.76	4.54	12.91	16.74
12975	5.50	4.70	1.73	3.56	20.26	19.12
12976	5.48	4.25	1.84	4.04	10.92	15.23
12977	4.75	3.57	1.62	6.62	21.96	17.60
12978	4.99	4.19	1.71	4.61	13.30	19.31
12979	5.32	4.37	1.66	4.23	14.10	17.63
12980	5.37	4.34	1.85	3.86	10.40	16.55
12981	4.63	3.59	1.71	6.55	23.62	16.56
12982	5.87	4.15	1.67	3.70	7.86	11.58
12983	6.38	5.02	1.91	2.25	17.14	31.75
12984	5.95	4.40	1.81	3.18	9.90	22.74
12985	4.85	3.80	1.87	5.07	20.24	17.65
12986	5.34	4.14	1.73	2.72	8.36	20.22
12987	5.07	4.44	1.72	4.49	11.58	24.90

Lab number	pH_{H_2O}	pH_{KCl}	Humus	Hy	P_2O_5	K_2O
			(%)	cmol(+)kg^{-1}	mg 100g^{-1} soil	
12988	5.38	4.35	2.01	3.62	10.80	26.47
12989	4.98	4.06	1.76	3.97	21.59	20.46
12990	5.63	4.25	1.71	3.62	9.14	17.22
12991	5.87	4.70	1.74	3.09	10.92	24.09
12992	6.98	5.61	2.22	1.79	29.78	38.98
12993	5.33	3.94	2.03	5.36	24.90	27.44
12994	6.02	4.34	1.84	3.58	9.51	12.01
12995	5.82	4.57	1.75	3.12	10.08	19.84
12996	6.88	5.24	2.10	2.14	17.81	39.46
12997	5.10	3.70	1.92	5.87	24.23	23.98
12998	5.98	4.97	2.01	2.98	16.54	24.60
12999	6.37	5.05	2.05	2.30	19.39	32.15
13000	5.63	4.56	1.81	3.31	7.38	21.44
13001	5.43	4.13	1.94	4.67	26.38	34.24
13002	5.50	4.35	1.98	3.52	9.23	16.62
13003	5.97	4.54	1.86	3.43	12.61	23.90
13004	5.92	4.81	1.98	3.05	12.59	33.22
13023	5.06	4.36	1.64	4.39	20.28	24.26
13024	4.91	4.04	1.74	4.58	18.96	18.89
13025	4.89	3.96	1.62	4.90	27.82	29.34
13026	4.73	3.66	1.81	6.17	24.42	20.13
13027	4.93	4.09	1.83	5.63	19.37	20.79
13028	4.66	3.90	1.87	5.58	19.37	27.51
13029	4.96	3.96	1.42	5.29	24.67	27.58
13030	4.78	3.76	1.83	5.90	21.23	21.40
13031	4.94	4.03	1.72	4.59	15.26	16.45
13032	4.80	3.96	1.58	5.19	20.03	24.80
13033	5.19	4.21	1.48	4.31	27.39	22.29
13034	5.04	3.88	1.53	4.51	21.78	17.12
13035	5.09	4.21	1.67	4.97	15.91	16.79
13036	4.94	4.04	1.68	4.85	20.49	23.67
13037	5.06	4.00	1.43	4.85	26.28	23.61
13038	5.22	4.12	1.61	4.49	22.39	20.13
13039	5.22	4.21	1.69	3.94	12.42	13.85
13040	4.92	3.96	1.44	5.03	17.08	20.20
13041	5.13	4.17	1.48	4.95	26.43	22.97
13042	5.31	4.29	1.70	4.05	21.03	22.50
13043	5.29	4.33	1.74	5.08	12.82	15.15
13044	5.10	4.04	1.52	4.79	17.44	16.87
13045	5.32	4.59	1.55	4.00	33.94	32.00
13046	5.57	4.62	1.44	3.32	23.00	22.80
13047	5.39	4.41	2.17	4.41	14.63	15.36
13048	5.10	3.96	1.57	4.87	16.74	16.96
13049	5.61	5.02	1.52	2.85	28.60	21.16
13050	5.26	4.29	1.60	4.30	30.35	34.83
13051	5.34	4.37	1.57	3.94	12.80	13.65
13052	5.42	4.52	1.74	3.91	24.41	20.34
13053	5.48	4.76	1.52	2.98	25.86	24.37
13054	5.14	4.21	1.67	5.15	40.62	30.32
13055	5.27	4.35	1.81	4.00	15.13	12.85
13056	5.24	4.10	1.50	4.31	18.40	16.98
13057	5.33	4.39	1.44	4.03	22.78	21.14
13058	5.32	4.26	1.53	4.45	17.25	18.80
13059	5.42	4.28	1.57	4.66	18.41	18.66
13060	5.45	4.33	1.70	3.99	15.11	16.01
13061	5.90	5.09	1.56	2.72	23.73	21.92
13062	5.49	4.64	2.01	3.96	15.97	19.25
13063	5.36	4.30	1.69	4.01	16.35	15.29
13064	5.17	4.03	1.62	4.63	18.02	18.41

Lab number	pH_{H_2O}	pH_{KCl}	Humus	Hy	P_2O_5	K_2O
			(%)	cmol(+)kg^{-1}	mg 100g^{-1} soil	
13065	5.48	4.03	1.42	4.12	21.08	15.50
13066	6.63	4.59	1.84	3.50	13.31	16.14
13067	5.72	4.61	1.57	3.12	13.95	15.65
13068	5.26	4.06	1.55	4.31	18.37	17.74
13069	5.97	4.96	1.60	2.38	22.80	18.51
13070	5.60	4.75	1.83	3.21	17.69	15.00
13071	5.62	4.56	1.75	3.40	14.16	15.52
13072	5.25	3.96	1.55	4.83	17.02	19.16
13073	6.05	4.99	1.45	2.97	20.71	16.57
13074	5.76	4.86	1.96	2.72	16.86	22.17
13075	5.77	4.81	1.65	2.43	16.98	18.71
13076	5.11	3.91	1.55	5.04	15.77	16.43
13077	5.68	4.87	1.39	2.90	19.65	15.91
13078	5.55	4.52	2.00	4.19	17.30	19.38
13079	5.59	4.48	1.50	3.37	17.06	16.33
13080	5.16	3.83	1.45	5.01	16.14	15.30
13081	5.17	4.19	1.52	4.20	17.97	15.29
13082	5.31	4.40	1.61	4.16	15.01	16.33
13083	5.40	4.55	1.52	3.11	21.49	17.89
13084	5.49	4.19	1.55	4.48	17.61	16.05
13085	5.47	4.44	1.61	4.33	16.62	15.85
13086	5.46	4.23	1.83	3.98	12.56	18.25
13087	5.42	4.54	1.66	3.61	20.50	26.50
13088	5.24	3.92	1.53	5.11	18.69	18.31
13089	5.17	4.03	1.64	4.50	17.49	20.91
13090	5.18	4.16	1.77	4.45	9.99	16.02
13091	5.27	4.51	1.61	3.66	18.25	17.54
13092	5.31	4.20	1.92	4.11	23.27	25.58
13093	5.34	3.95	1.66	4.66	16.79	15.48
13094	5.23	4.16	1.90	4.23	9.42	15.19

	pH_{H_2O}	pH_{KCl}	Humus	Hy	P_2O_5	K_2O
			(%)	cmol(+)kg^{-1}	mg 100g^{-1} soil	
Var	0.15	0.12	0.03	0.74	32.89	29.62
Min	4.63	3.57	1.39	1.79	7.38	11.58
Max	6.98	5.61	2.22	6.62	40.62	39.46
Average	5.37	4.30	1.72	4.14	17.41	19.48
StDev	0.38	0.35	0.18	0.86	5.74	5.44
CV (%)	7.15	8.10	10.75	20.81	32.94	27.94

Appendix table 8. Concentrations of exchangeable cations on the soil adsorption complex and cation exchange capacity (CEC) in soil samples from the Đurđevac location.

Lab number	Ca	Mg	K	Na	CEC
	(mg kg^{-1})				(cmol(+)kg^{-1})
12933	313.12	61.11	89.77	12.06	7.00
12934	831.06	147.98	125.22	12.95	9.94
12935	533.55	76.07	137.35	2.80	8.34
12936	340.63	65.82	98.10	2.31	5.30
12937	548.90	118.81	118.87	11.21	8.95
12938	877.28	153.87	101.91	5.46	10.10
12939	875.99	126.08	142.70	5.15	10.09
12940	786.81	172.89	129.49	4.88	9.65
12941	635.68	134.25	123.73	9.09	8.81
12942	846.56	158.53	116.16	8.12	9.92
12943	641.53	93.79	118.59	5.70	8.74
12944	715.08	136.21	97.00	10.55	9.34
12945	538.86	115.60	123.23	9.06	8.82
12946	784.90	134.08	94.23	15.39	9.44
12947	906.16	145.98	142.70	8.52	10.03
12948	528.38	101.39	79.92	4.56	8.15
12949	685.92	102.52	150.63	8.83	8.79
12950	602.08	114.96	105.60	7.85	8.21
12951	735.41	110.82	145.88	9.86	9.60
12952	725.89	156.01	99.39	12.15	8.96
12953	621.12	109.16	147.65	15.48	8.62
12954	660.07	113.71	100.88	7.33	8.25
12955	812.39	137.07	151.20	8.47	9.09
12956	654.29	127.66	98.66	2.82	8.81
12957	294.23	50.94	85.67	2.41	6.63
12958	798.92	121.71	121.44	5.93	9.32
12959	748.76	123.24	126.20	22.75	9.76
12960	737.96	158.42	104.29	3.01	8.94
12961	533.33	78.78	122.57	2.63	8.36
12962	819.24	126.13	116.16	11.03	9.06
12963	759.22	109.36	99.89	10.34	9.44
12964	546.97	120.69	99.05	3.19	8.08
12965	589.89	97.70	138.26	7.02	8.80
12966	637.95	97.07	98.34	7.76	8.11
12967	673.26	106.06	129.72	45.02	9.42
12968	655.71	143.79	95.48	50.96	9.10
12969	471.66	84.59	158.49	9.84	8.86
12970	592.80	90.02	115.78	9.33	8.38
12971	1,334.25	160.44	217.85	15.32	11.23
12972	641.67	130.90	99.88	7.28	8.55
12973	322.05	50.85	99.05	15.43	8.18
12974	457.22	67.30	119.64	6.70	7.71
12975	769.44	103.32	131.38	10.65	8.63
12976	599.95	123.04	100.07	9.42	8.34
12977	277.96	45.63	134.55	5.67	8.75
12978	521.45	70.54	134.07	11.98	8.19
12979	583.89	101.29	114.62	12.26	8.32
12980	656.03	112.42	112.74	7.98	8.38
12981	259.33	40.06	117.74	8.82	8.51
12982	501.36	68.21	89.66	17.09	7.07
12983	905.02	143.90	232.74	17.76	8.62
12984	592.71	111.14	159.78	12.68	7.52
12985	379.91	50.25	138.32	13.01	7.79
12986	500.66	69.62	145.99	10.44	6.21
12987	666.14	109.73	208.55	19.78	9.34

Lab number	Ca	Mg	K	Na	CEC
	(mg kg^{-1})				(cmol(+)kg^{-1})
12988	614.92	110.48	185.22	14.62	8.13
12989	367.57	101.21	158.28	20.63	7.13
12990	576.25	84.46	127.02	50.16	7.73
12991	671.67	134.24	175.21	15.12	8.06
12992	1,334.77	170.07	277.58	25.77	10.67
12993	375.82	83.87	214.22	17.83	8.55
12994	635.84	87.23	92.28	15.89	7.78
12995	631.74	117.06	145.02	35.20	7.76
12996	866.15	130.34	259.36	21.26	8.29
12997	299.37	66.07	189.30	16.30	8.46
12998	975.32	125.59	174.74	18.46	9.41
12999	1,029.73	145.22	247.58	57.09	9.51
13000	635.36	121.73	156.96	21.71	7.98
13001	462.51	81.57	261.21	51.77	8.54
13002	644.34	107.54	112.67	36.13	8.07
13003	703.15	111.31	185.49	14.47	8.39
13004	787.39	164.35	231.89	14.45	8.99
13023	686.05	94.06	175.44	13.82	9.10
13024	531.84	95.27	153.58	17.66	8.49
13025	299.05	63.91	202.71	17.59	7.51
13026	264.07	64.86	178.16	11.68	8.53
13027	496.42	87.25	149.53	16.85	9.28
13028	446.54	85.45	212.02	18.80	9.14
13029	350.81	83.43	217.24	21.56	8.38
13030	385.98	94.34	204.88	14.12	9.19
13031	580.08	100.99	126.97	15.41	8.71
13032	451.56	90.40	182.03	11.78	8.70
13033	491.40	115.41	161.54	14.91	8.19
13034	223.38	48.25	104.69	5.19	6.31
13035	698.35	131.41	135.47	19.04	9.97
13036	569.01	100.93	183.87	16.07	9.06
13037	478.95	101.29	202.99	18.43	8.67
13038	425.63	95.71	144.17	7.41	7.80
13039	647.65	115.43	119.53	8.78	8.47
13040	483.88	111.94	155.92	13.09	8.82
13041	496.94	120.88	173.09	10.93	8.91
13042	450.71	106.20	158.45	4.68	7.60
13043	617.54	108.86	112.66	7.01	9.38
13044	504.14	106.95	132.37	13.53	8.58
13045	699.60	161.30	255.86	17.75	9.55
13046	692.41	225.30	202.20	11.72	9.20
13047	709.10	141.86	130.69	9.79	9.49
13048	471.50	116.47	143.60	7.79	8.58
13049	763.36	238.02	187.63	19.74	9.18
13050	524.72	129.91	299.00	11.23	8.80
13051	690.05	175.83	111.30	9.66	9.16
13052	444.44	89.24	120.80	6.74	7.20
13053	650.82	185.79	179.67	19.89	8.30
13054	521.89	82.49	204.27	14.27	9.02
13055	637.43	135.02	101.37	8.56	8.59
13056	489.12	113.05	117.37	6.96	8.01
13057	483.96	138.34	157.19	7.40	8.02
13058	701.53	133.97	169.13	7.65	9.52
13059	616.49	168.88	158.52	9.58	9.57
13060	693.24	142.02	138.89	10.42	9.02
13061	708.18	226.30	179.68	9.24	8.62
13062	713.35	151.67	157.38	14.78	9.23
13063	767.19	160.34	131.66	9.43	9.54
13064	575.80	135.14	168.15	9.10	9.08

Lab number	Ca	Mg	K	Na	CEC
	(mg kg^{-1})				(cmol(+)kg^{-1})
13065	611.63	170.98	144.18	11.37	9.00
13066	685.52	130.75	148.20	6.77	8.41
13067	669.58	168.55	125.00	6.03	8.19
13068	598.06	144.11	157.04	11.61	8.93
13069	908.90	342.69	200.60	10.31	10.29
13070	764.08	135.87	126.92	8.42	8.50
13071	866.72	187.52	168.75	10.61	9.75
13072	492.09	112.59	157.62	8.69	8.65
13073	841.34	183.95	179.47	8.57	9.18
13074	745.35	213.29	144.81	9.11	8.60
13075	926.04	227.48	178.12	9.68	9.42
13076	638.47	156.91	177.74	7.79	10.01
13077	577.02	173.01	120.92	6.96	7.54
13078	724.41	127.51	156.90	7.21	9.29
13079	638.29	135.88	140.09	7.90	8.07
13080	419.00	96.76	134.64	8.67	8.28
13081	541.30	131.12	142.02	7.97	8.38
13082	689.42	104.95	144.06	8.13	8.87
13083	696.43	165.62	161.65	14.57	8.42
13084	582.09	122.97	142.75	10.33	8.81
13085	469.37	101.57	123.15	5.64	7.85
13086	700.48	113.82	167.38	6.39	8.87
13087	510.34	101.12	180.83	13.12	7.51
13088	544.48	120.86	172.39	31.52	9.40
13089	459.52	105.32	189.83	18.46	8.23
13090	492.34	79.00	129.70	13.17	7.95
13091	668.14	149.40	160.14	17.35	8.71
13092	582.56	120.42	242.85	22.18	8.73
13093	408.39	92.24	142.74	7.94	7.86
13094	432.70	63.86	110.39	22.11	7.29
	Ca	Mg	K	Na	CEC
	(mg kg^{-1})				(cmol(+)kg^{-1})
Var	32,887.34	1,783.08	1,818.12	87.32	0.72
Min	223.38	40.06	79.92	2.31	5.30
Max	1,334.77	342.69	299.00	57.09	11.23
Average	615.70	120.68	149.81	13.19	8.65
StDev	181.35	42.23	42.64	9.34	0.85
CV (%)	29.45	34.99	28.46	70.84	9.82

Appendix table 9. Soil texture components in soil samples from the Đurđevac location.

Lab number	Coarse sand	Fine sand	Coarse silt	Fine silt	Clay
	(%)				
12933	2.85	17.23	51.39	16.24	12.28
12935	2.19	10.37	50.28	24.33	12.83
12938	2.56	15.67	51.58	18.20	12.00
12940	4.08	13.45	57.29	15.94	9.24
12941	2.58	18.27	51.05	16.64	11.46
12943	2.26	14.75	46.56	22.29	14.15
12946	3.17	20.20	49.02	16.64	10.96
12948	4.24	14.26	50.96	20.80	9.74
12949	2.64	17.45	48.14	18.17	13.60
12951	2.48	12.95	51.38	19.75	13.44
12954	3.41	17.53	51.04	16.85	11.17
12956	4.11	12.85	53.01	20.90	9.13
12957	3.26	14.55	51.55	17.96	12.68
12959	2.69	12.88	50.35	21.67	12.41
12962	3.46	18.69	52.50	15.11	10.24
12964	5.03	14.63	50.18	20.61	9.54
12965	3.33	13.47	52.38	19.16	11.66
12967	3.01	12.95	53.18	20.10	10.76
12970	3.99	18.91	50.47	16.40	10.23
12972	5.29	14.15	53.58	17.85	9.13
12973	3.63	12.39	55.15	20.64	8.20
12975	3.40	12.50	54.16	19.89	10.05
12978	3.96	16.42	53.41	17.51	8.70
12980	5.18	12.86	51.32	20.29	10.35
12981	3.64	16.06	55.59	15.09	9.62
12983	3.69	18.40	47.72	20.24	9.97
12986	3.23	14.52	53.76	19.07	9.43
12988	5.49	15.09	52.49	18.39	8.54
12989	3.72	16.70	51.59	18.56	9.43
12991	3.40	12.98	50.71	21.74	11.17
12994	3.36	12.97	50.02	23.07	10.57
12996	6.72	18.20	45.79	19.22	10.07
12997	3.90	14.53	48.59	21.21	11.77
12999	3.29	13.24	48.16	23.91	11.40
13002	3.07	11.64	46.24	27.05	12.00
13004	5.66	17.14	40.83	26.41	9.95
13024	3.87	16.80	51.37	16.00	11.95
13026	6.48	31.16	37.37	14.57	10.42
13027	5.18	30.23	37.23	17.03	10.34
13029	3.64	22.87	41.78	19.55	12.16
13032	3.94	27.32	38.57	18.63	11.54
13034	6.03	28.91	37.13	16.19	11.74
13035	4.27	28.14	39.12	17.08	11.39
13037	3.64	25.56	39.49	18.50	12.81
13040	3.40	27.27	38.58	19.14	11.61
13042	7.32	30.66	34.38	14.90	12.74
13043	4.49	30.99	36.96	16.93	10.64
13045	4.04	23.74	41.43	18.13	12.66
13048	3.38	17.82	49.42	18.64	10.74
13050	6.10	20.88	44.96	16.20	11.85
13051	4.43	20.16	48.18	17.61	9.62
13053	4.35	14.70	51.46	19.05	10.44
13056	3.40	13.31	52.37	20.48	10.44
13058	5.74	18.82	45.35	18.94	11.14
13059	3.36	14.08	50.50	21.00	11.06
13061	4.59	17.46	46.25	21.37	10.33
13064	3.30	13.19	50.64	20.80	12.07

Lab number	Coarse sand	Fine sand	Coarse silt	Fine silt	Clay
	(%)				
13066	6.16	17.50	45.14	21.99	9.22
13067	4.43	21.30	46.80	17.53	9.93
13069	4.80	14.15	49.14	21.87	10.02
13072	3.70	15.98	47.68	20.17	12.47
13074	6.77	20.13	44.22	20.67	8.21
13075	4.84	19.09	48.50	17.94	9.63
13077	4.46	15.26	48.62	21.30	10.35
13080	3.60	13.29	50.17	21.65	11.28
13082	7.18	19.45	43.24	19.98	10.14
13083	6.30	24.71	38.33	19.41	11.24
13085	5.56	22.79	39.99	20.60	11.06
13088	4.42	19.30	41.01	23.72	11.55
13090	8.83	25.19	35.08	19.82	11.08
13091	4.57	25.44	39.36	20.18	10.45
13093	5.13	21.66	41.41	21.17	10.64

	Coarse sand	Fine sand	Coarse silt	Fine silt	Clay
	(%)				
Var	1.78	28.50	32.13	6.53	1.66
Min	2.19	10.37	34.38	14.57	8.20
Max	8.83	31.16	57.29	27.05	14.15
Average	4.27	18.20	47.26	19.40	10.87
StDev	1.33	5.34	5.67	2.56	1.29
CV (%)	31.22	29.34	11.99	13.17	11.86

Appendix table 10. Total concentrations of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) in soil samples from the Đurđevac location.

Lab number	P	K	Ca	Mg
	(mg kg^{-1})			
12933	754.90	2,673.00	2,983.00	3,683.00
12934	625.70	2,391.00	3,332.00	4,062.00
12935	639.70	3,205.00	3,130.00	4,242.00
12936	339.60	1,348.00	1,643.00	1,835.00
12937	683.50	2,354.00	2,940.00	3,756.00
12938	504.30	2,362.00	3,280.00	4,106.00
12939	673.50	2,962.00	2,877.00	4,181.00
12940	582.50	2,690.00	3,288.00	3,696.00
12941	630.40	3,034.00	3,808.00	3,736.00
12942	520.00	3,139.00	3,450.00	4,097.00
12943	619.30	3,329.00	3,154.00	4,197.00
12944	550.80	3,279.00	3,446.00	3,793.00
12945	306.70	1,315.00	1,540.00	1,842.00
12946	512.80	2,630.00	3,349.00	3,749.00
12947	692.20	3,318.00	3,279.00	4,220.00
12948	608.00	2,989.00	3,547.00	3,580.00
12949	637.60	3,151.00	3,272.00	3,788.00
12950	533.60	3,262.00	3,412.00	3,984.00
12951	677.20	3,465.00	3,187.00	4,006.00
12952	577.30	3,887.00	3,435.00	3,597.00
12953	568.90	2,905.00	3,234.00	3,551.00
12954	541.10	2,775.00	3,445.00	3,594.00
12955	549.80	1,343.00	1,910.00	3,447.00
12956	556.10	1,146.00	1,601.00	3,070.00
12957	546.50	1,138.00	1,350.00	3,077.00
12958	514.60	1,085.00	1,465.00	3,177.00
12959	605.20	1,400.00	1,568.00	3,457.00
12960	586.70	1,082.00	1,519.00	3,086.00
12961	559.70	1,115.00	1,445.00	3,010.00
12962	548.70	1,026.00	1,513.00	2,916.00
12963	559.50	1,172.00	1,534.00	3,327.00
12964	612.90	1,069.00	1,450.00	3,037.00
12965	541.80	1,027.00	1,266.00	2,888.00
12966	464.40	971.30	1,501.00	2,891.00
12967	580.00	1,217.00	1,470.00	3,192.00
12968	561.20	1,125.00	1,555.00	3,071.00
12969	573.40	1,016.00	1,099.00	2,737.00
12970	514.00	995.10	1,336.00	2,735.00
12971	665.50	1,172.00	2,068.00	3,086.00
12972	528.90	1,069.00	1,403.00	3,000.00
12973	534.20	984.70	1,115.00	2,715.00
12974	507.40	1,029.00	1,387.00	2,685.00
12975	562.30	1,224.00	1,598.00	3,080.00
12976	614.70	1,257.00	1,832.00	3,190.00
12977	574.30	1,121.00	1,304.00	2,826.00
12978	456.90	1,038.00	1,455.00	2,775.00
12979	548.00	1,271.00	1,625.00	3,121.00
12980	590.40	1,290.00	1,698.00	3,163.00
12981	570.70	1,131.00	1,174.00	2,748.00
12982	530.70	1,041.00	1,536.00	2,813.00
12983	607.80	1,354.00	1,939.00	3,311.00
12984	595.40	1,239.00	1,688.00	2,974.00
12985	704.00	1,167.00	1,347.00	2,754.00
12986	569.10	1,083.00	1,430.00	2,855.00
12987	627.70	1,256.00	1,455.00	2,925.00

Lab number	P	K	Ca	Mg
	(mg kg^{-1})			
12988	678.10	1,112.00	1,575.00	2,826.00
12989	639.30	1,040.00	1,156.00	2,715.00
12990	515.40	1,016.00	1,394.00	2,811.00
12991	624.30	1,182.00	1,461.00	3,035.00
12992	584.40	1,249.00	2,167.00	2,887.00
12993	664.40	1,161.00	1,237.00	2,743.00
12994	511.70	1,108.00	1,581.00	2,861.00
12995	569.60	1,232.00	1,422.00	2,997.00
12996	606.20	1,403.00	1,974.00	2,848.00
12997	589.20	1,114.00	1,157.00	2,429.00
12998	514.50	1,235.00	1,791.00	2,765.00
12999	637.70	1,306.00	2,625.00	2,940.00
13000	459.10	1,006.00	1,376.00	2,468.00
13001	598.10	1,235.00	1,318.00	2,725.00
13002	550.30	1,088.00	1,474.00	3,059.00
13003	562.50	1,223.00	1,597.00	2,954.00
13004	493.50	1,142.00	1,541.00	2,608.00
13023	600.90	1,053.00	1,636.00	2,468.00
13024	559.50	970.50	1,376.00	2,428.00
13025	593.90	1,161.00	1,281.00	2,410.00
13026	672.00	956.80	1,118.00	2,367.00
13027	592.30	1,021.00	1,525.00	2,505.00
13028	568.00	1,185.00	1,493.00	2,539.00
13029	663.00	1,101.00	1,211.00	2,654.00
13030	656.60	1,012.00	1,248.00	2,419.00
13031	526.20	945.80	1,327.00	2,483.00
13032	624.40	1,063.00	1,290.00	2,505.00
13033	691.80	1,151.00	1,403.00	2,714.00
13034	684.20	1,120.00	1,368.00	2,512.00
13035	520.90	1,058.00	1,475.00	2,564.00
13036	631.80	1,165.00	1,503.00	2,683.00
13037	679.90	1,298.00	1,436.00	2,747.00
13038	680.60	1,166.00	1,541.00	2,555.00
13039	631.40	1,068.00	1,546.00	2,514.00
13040	719.90	1,218.00	1,447.00	2,809.00
13041	713.60	1,307.00	1,459.00	2,778.00
13042	676.90	1,270.00	1,534.00	2,687.00
13043	582.10	1,047.00	1,561.00	2,577.00
13044	609.80	1,207.00	1,427.00	2,769.00
13045	680.50	1,346.00	1,528.00	2,808.00
13046	687.60	1,200.00	1,593.00	2,720.00
13047	548.70	1,040.00	1,604.00	2,609.00
13048	642.20	1,050.00	1,280.00	2,708.00
13049	671.30	1,244.00	1,681.00	2,801.00
13050	666.20	1,176.00	1,383.00	2,556.00
13051	546.40	1,012.00	1,477.00	2,647.00
13052	699.40	1,153.00	1,611.00	2,871.00
13053	702.60	1,211.00	1,669.00	2,772.00
13054	808.40	1,218.00	1,906.00	2,572.00
13055	534.00	1,023.00	1,588.00	2,524.00
13056	593.60	1,190.00	1,383.00	2,832.00
13057	628.80	2,573.00	2,719.00	3,072.00
13058	611.10	2,471.00	2,947.00	2,821.00
13059	606.30	2,591.00	2,694.00	3,077.00
13060	571.40	2,170.00	2,937.00	2,869.00
13061	701.10	2,593.00	3,137.00	3,047.00
13062	977.40	2,551.00	3,063.00	2,943.00
13063	657.10	2,260.00	2,953.00	2,858.00
13064	642.90	2,635.00	2,659.00	3,065.00

Lab number	P	K	Ca	Mg
	(mg kg^{-1})			
13065	721.10	3,522.00	3,218.00	2,658.00
13066	710.50	3,149.00	3,690.00	2,380.00
13067	665.10	2,542.00	3,253.00	2,343.00
13068	701.30	3,430.00	3,151.00	2,607.00
13069	789.60	3,091.00	3,245.00	2,556.00
13070	667.60	2,975.00	3,652.00	2,251.00
13071	596.70	2,620.00	3,344.00	2,280.00
13072	662.00	3,212.00	3,116.00	2,461.00
13073	779.10	2,797.00	3,137.00	2,394.00
13074	742.20	2,902.00	4,004.00	2,231.00
13075	602.50	2,426.00	3,199.00	2,245.00
13076	893.40	3,223.00	3,020.00	2,377.00
13077	671.50	2,647.00	3,070.00	2,366.00
13078	723.60	2,919.00	3,465.00	2,185.00
13079	603.30	1,039.00	1,628.00	2,158.00
13080	592.00	1,179.00	1,523.00	2,228.00
13081	624.00	1,158.00	1,522.00	2,243.00
13082	667.80	1,154.00	1,718.00	2,217.00
13083	646.20	1,086.00	1,695.00	2,183.00
13084	655.80	1,179.00	1,454.00	2,375.00
13085	587.10	1,161.00	1,596.00	2,185.00
13086	652.80	1,195.00	1,580.00	2,270.00
13087	619.60	1,099.00	1,606.00	2,180.00
13088	667.20	1,113.00	1,293.00	2,380.00
13089	605.20	1,033.00	1,327.00	2,118.00
13090	607.70	1,091.00	1,520.00	2,111.00
13091	620.10	1,117.00	1,648.00	2,244.00
13092	703.70	1,223.00	1,565.00	2,325.00
13093	574.80	952.40	1,204.00	2,162.00
13094	544.60	1,010.00	1,518.00	1,999.00

	P	K	Ca	Mg
	(mg kg^{-1})			
Var	7,284.70	683,632.67	672,249.31	278,355.71
Min	306.70	945.80	1,099.00	1,835.00
Max	977.40	3,887.00	4,004.00	4,242.00
Average	612.47	1,649.06	2,010.35	2,844.97
StDev	85.35	826.82	819.91	527.59
CV (%)	13.94	50.14	40.78	18.54

Appendix table 11. Total concentrations of microelements: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), molybdenum (Mo) in soil samples from the Đurđevac location.

Lab number	Fe	Mn	Zn	Cu	Ni	Mo
	(mg kg^{-1})					(µg kg^{-1})
12933	22,730.00	415.00	45.05	12.47	18.31	365.74
12934	23,850.00	407.20	49.62	13.56	20.58	341.85
12935	23,610.00	454.40	56.01	14.16	20.47	383.64
12936	10,810.00	293.50	24.03	5.80	8.20	202.45
12937	21,750.00	408.20	47.25	12.93	18.58	439.91
12938	23,660.00	390.10	48.48	13.49	20.52	346.85
12939	24,130.00	500.80	54.02	13.85	20.43	370.39
12940	19,970.00	526.80	45.53	11.17	16.36	362.39
12941	21,470.00	408.80	45.17	12.10	17.98	362.24
12942	23,860.00	403.50	47.48	13.50	20.04	353.28
12943	23,750.00	468.80	53.68	13.57	20.37	376.01
12944	19,760.00	524.00	48.29	10.90	16.10	334.64
12945	10,530.00	207.80	21.70	5.80	8.63	175.40
12946	22,770.00	413.50	48.29	12.69	18.99	368.74
12947	23,750.00	512.90	50.87	13.17	19.97	389.35
12948	22,220.00	688.30	51.93	11.75	17.16	366.50
12949	21,800.00	423.90	47.31	11.92	17.82	367.08
12950	23,190.00	412.40	48.80	13.01	19.49	382.29
12951	22,740.00	505.90	52.18	12.64	18.67	391.82
12952	20,860.00	528.50	47.63	10.40	15.99	333.20
12953	21,320.00	455.60	44.89	11.66	17.24	331.10
12954	22,470.00	443.30	49.24	12.19	17.95	327.56
12955	19,850.00	463.50	46.43	11.82	17.04	368.97
12956	17,560.00	507.50	41.73	10.26	14.10	321.54
12957	16,450.00	340.20	38.71	10.02	14.46	288.30
12958	17,930.00	334.60	40.01	11.33	15.56	302.88
12959	19,800.00	482.10	44.58	11.66	17.05	337.92
12960	17,000.00	475.40	42.30	10.92	14.03	323.64
12961	17,500.00	407.60	37.66	10.37	14.72	314.84
12962	17,040.00	388.40	38.46	10.43	14.32	296.23
12963	18,640.00	461.00	42.04	11.14	16.19	353.14
12964	17,860.00	552.20	41.33	10.75	14.46	402.15
12965	16,230.00	378.80	36.88	9.82	13.98	398.27
12966	16,330.00	371.20	35.85	10.02	14.09	269.92
12967	17,850.00	493.20	41.80	10.65	15.52	305.63
12968	17,170.00	495.00	40.28	10.42	14.17	355.96
12969	15,550.00	400.50	35.32	9.11	12.91	331.37
12970	15,080.00	387.60	35.77	9.03	12.97	250.39
12971	17,780.00	480.50	40.65	12.25	14.67	349.86
12972	16,110.00	456.30	38.08	9.96	13.52	318.26
12973	14,490.00	364.10	33.48	8.38	12.12	298.28
12974	15,320.00	419.50	32.51	9.18	12.65	312.76
12975	17,490.00	485.00	40.84	10.41	14.23	317.86
12976	17,370.00	541.90	41.05	11.20	14.63	341.99
12977	15,520.00	391.40	34.60	8.87	12.93	292.10
12978	14,760.00	382.60	35.79	9.09	12.47	280.61
12979	17,450.00	527.50	40.13	9.86	14.75	339.09
12980	17,450.00	515.90	41.81	10.64	14.49	344.61
12981	15,250.00	357.20	34.04	8.87	12.49	307.49
12982	16,340.00	454.80	34.61	9.09	13.25	306.56
12983	17,330.00	515.30	41.44	11.58	14.79	308.60
12984	17,970.00	578.90	41.60	10.34	16.27	323.19
12985	16,670.00	462.90	38.80	9.61	15.18	330.49

Lab number	Fe	Mn	Zn	Cu	Ni	Mo
	(mg kg^{-1})					(µg kg^{-1})
12986	16,830.00	496.50	37.55	9.59	16.33	328.01
12987	18,500.00	596.70	41.10	10.07	17.20	348.14
12988	18,090.00	600.10	45.52	10.98	16.37	364.89
12989	16,250.00	489.20	35.73	9.53	15.85	341.86
12990	16,710.00	490.30	39.70	9.87	16.62	300.62
12991	18,370.00	576.00	41.72	9.86	17.44	339.58
12992	16,750.00	534.10	43.13	12.37	16.65	363.62
12993	16,350.00	449.70	37.99	9.79	16.03	333.68
12994	17,330.00	515.60	40.54	10.54	17.40	329.64
12995	18,260.00	610.60	41.02	9.87	17.98	325.28
12996	17,270.00	540.20	43.31	11.20	17.10	311.73
12997	16,790.00	451.90	37.50	10.30	15.87	335.51
12998	17,540.00	557.20	41.91	11.49	18.88	357.45
12999	17,810.00	573.20	43.54	12.84	18.23	350.57
13000	16,850.00	562.60	38.34	10.09	16.20	313.66
13001	17,820.00	485.30	40.18	11.20	17.19	340.80
13002	19,110.00	618.10	47.12	11.39	19.26	345.00
13003	18,450.00	754.90	43.23	11.22	18.92	361.75
13004	16,230.00	572.20	41.84	10.22	16.25	296.00
13023	16,340.00	454.10	39.57	10.70	15.93	348.42
13024	15,490.00	436.50	35.98	9.23	15.18	285.44
13025	15,660.00	450.40	37.88	9.14	16.78	259.11
13026	15,360.00	411.70	32.92	8.68	15.72	259.83
13027	16,940.00	461.90	38.92	11.02	15.90	355.59
13028	16,440.00	503.20	36.08	9.27	15.66	299.31
13029	16,900.00	499.40	37.19	9.24	16.35	270.60
13030	15,990.00	497.80	36.51	8.94	15.75	278.99
13031	16,320.00	443.60	40.84	10.66	16.12	342.82
13032	15,740.00	461.90	36.68	9.51	15.32	262.38
13033	17,930.00	536.30	38.72	10.13	17.58	284.38
13034	16,290.00	474.80	38.13	9.08	17.12	292.84
13035	16,060.00	455.60	40.15	10.29	16.09	336.54
13036	17,150.00	515.60	37.02	9.97	16.43	303.72
13037	16,910.00	492.30	36.45	9.47	17.03	268.33
13038	17,060.00	473.30	37.89	9.56	17.58	334.34
13039	17,230.00	473.70	38.37	9.66	16.13	336.50
13040	18,010.00	604.80	38.57	9.39	17.33	306.34
13041	16,920.00	491.70	38.58	9.63	17.48	249.91
13042	16,320.00	466.90	36.60	8.79	17.22	265.86
13043	16,280.00	415.60	40.35	10.10	16.27	357.45
13044	16,480.00	472.70	36.93	9.66	16.19	243.45
13045	15,950.00	416.30	36.02	9.43	16.33	252.05
13046	17,140.00	467.20	37.14	9.22	17.09	308.74
13047	16,480.00	400.10	39.29	10.23	16.68	347.86
13048	15,900.00	480.50	35.59	9.31	17.02	243.16
13049	16,570.00	461.00	35.10	9.09	16.25	304.93
13050	15,640.00	415.20	36.89	9.56	15.91	268.73
13051	16,300.00	381.50	39.05	10.26	17.13	334.66
13052	18,750.00	509.20	39.96	11.41	17.47	321.76
13053	16,490.00	494.90	35.72	9.08	15.78	265.04
13054	15,470.00	468.30	36.05	10.61	16.28	275.07
13055	16,050.00	394.10	39.54	10.15	16.09	289.74
13056	16,510.00	447.30	38.63	9.94	17.66	252.56
13057	18,310.00	529.30	39.83	9.18	17.33	253.58
13058	18,280.00	540.80	41.55	9.11	16.65	255.22
13059	19,710.00	519.30	42.07	10.39	18.51	306.80
13060	18,770.00	503.50	42.74	10.32	17.59	321.63
13061	17,430.00	518.80	39.77	8.74	16.26	255.52
13062	20,050.00	632.70	41.68	9.21	16.51	275.40

Lab number	Fe	Mn	Zn	Cu	Ni	Mo
	(mg kg^{-1})					(µg kg^{-1})
13063	20,520.00	735.40	44.81	10.49	17.19	361.47
13064	20,010.00	585.80	42.48	10.53	18.07	314.85
13065	19,480.00	537.50	44.03	9.77	14.00	275.87
13066	19,900.00	614.50	41.46	9.22	16.90	303.23
13067	20,700.00	522.10	40.03	10.54	14.40	332.21
13068	21,020.00	504.70	43.34	10.86	14.44	327.25
13069	19,930.00	583.30	38.21	9.43	13.48	304.47
13070	18,230.00	536.40	39.64	10.39	12.71	311.00
13071	19,360.00	480.90	43.00	10.35	13.64	325.07
13072	20,640.00	541.80	42.51	10.26	13.70	318.64
13073	19,910.00	621.90	39.48	9.41	13.31	325.55
13074	20,680.00	568.30	42.99	11.17	12.43	399.55
13075	18,660.00	469.10	39.74	9.76	13.33	313.10
13076	21,570.00	603.50	40.38	9.90	13.32	335.91
13077	18,930.00	519.00	40.33	9.45	13.01	268.89
13078	19,350.00	539.20	41.06	10.50	12.67	366.25
13079	16,740.00	415.10	35.28	9.60	12.65	331.21
13080	17,300.00	468.90	34.43	9.85	13.04	286.00
13081	16,060.00	479.10	34.68	8.61	12.11	239.17
13082	16,990.00	539.60	38.83	10.72	12.87	306.68
13083	17,350.00	459.20	35.66	10.02	12.40	326.90
13084	17,460.00	503.60	36.74	10.03	13.18	322.24
13085	16,610.00	515.30	31.63	8.98	12.39	269.52
13086	17,140.00	504.30	35.71	9.47	12.59	271.43
13087	17,570.00	460.40	33.61	9.77	12.07	340.95
13088	18,100.00	460.60	36.09	10.44	13.31	344.05
13089	16,420.00	453.50	32.15	8.79	11.54	279.57
13090	16,160.00	492.20	34.82	8.84	12.09	282.01
13091	16,400.00	449.80	37.63	9.75	12.35	310.39
13092	18,010.00	501.10	37.02	10.60	13.17	336.85
13093	16,840.00	529.00	33.57	8.87	12.09	311.86
13094	15,320.00	458.80	33.64	8.36	11.22	277.79
	Fe	**Mn**	**Zn**	**Cu**	**Ni**	**Mo**
	(mg kg^{-1})					(µg kg^{-1})
Var	5,950,251.63	5,938.81	26.75	1.85	5.62	1,734.89
Min	10,530.00	207.80	21.70	5.80	8.20	175.40
Max	24,130.00	754.90	56.01	14.16	20.58	439.91
Average	17,989.10	485.19	40.06	10.31	15.62	317.69
StDev	2,439.31	77.06	5.17	1.36	2.37	41.65
CV (%)	13.56	15.88	12.91	13.21	15.18	13.11

Appendix table 12. Total concentrations of beneficial elements: cobalt (Co), selenium (Se), and toxic elements: chromium (Cr), cadmium (Cd), arsenic (As), mercury (Hg), lead (Pb) in soil samples from the Đurđevac location.

Lab number	Co	Se	Cr	Cd	As	Hg	Pb
	(mg kg^{-1})	(µg kg^{-1})	(mg kg^{-1})	(µg kg^{-1})			(mg kg^{-1})
12933	7.98	930.20	27.67	108.20	6,644.00	0.85	13.59
12934	8.29	1,120.00	29.40	111.33	6,684.00	0.93	11.84
12935	8.52	952.90	31.51	111.62	6,613.00	0.79	13.46
12936	4.17	449.60	13.41	55.43	3,067.00	0.59	7.15
12937	7.77	1,121.00	27.71	109.23	6,139.00	0.51	12.62
12938	8.49	1,073.00	28.77	132.73	6,562.00	3.74	12.10
12939	8.90	1,024.00	31.09	112.60	7,212.00	1.33	13.90
12940	8.08	1,135.00	26.55	109.09	5,391.00	1.40	13.10
12941	7.70	975.60	29.49	109.17	6,068.00	0.37	12.91
12942	8.65	1,050.00	30.94	104.75	6,726.00	1.82	12.85
12943	8.58	1,034.00	32.10	113.37	6,817.00	0.70	13.63
12944	7.81	1,113.00	28.51	112.61	5,178.00	0.99	13.49
12945	3.86	533.10	13.59	55.00	2,840.00	0.41	6.60
12946	8.13	1,057.00	29.13	98.64	6,275.00	0.74	12.32
12947	8.96	763.30	31.59	117.26	6,592.00	0.79	13.89
12948	10.05	858.00	30.09	110.46	6,205.00	1.47	14.70
12949	7.67	867.30	29.13	97.38	6,011.00	0.17	13.38
12950	8.13	793.50	30.63	101.46	6,580.00	0.95	12.79
12951	8.44	921.90	31.44	120.24	6,610.00	1.00	14.66
12952	7.88	922.30	30.81	96.87	5,736.00	0.73	13.59
12953	7.91	936.70	29.23	95.89	5,681.00	0.15	12.80
12954	7.81	851.10	29.03	116.98	5,843.00	0.73	12.55
12955	8.54	857.60	20.58	122.32	5,983.00	1.50	11.56
12956	7.51	642.70	17.29	114.49	5,257.00	1.50	13.03
12957	6.57	795.70	17.17	80.26	4,642.00	0.22	10.95
12958	6.81	739.70	18.24	98.39	5,251.00	2.30	11.49
12959	8.70	834.80	20.53	103.60	5,835.00	0.96	13.11
12960	7.76	626.90	16.65	106.53	5,203.00	1.59	13.34
12961	7.12	667.90	17.72	88.87	4,818.00	0.49	11.54
12962	6.84	651.40	16.06	115.73	4,766.00	0.59	11.53
12963	8.19	683.80	18.75	116.09	5,339.00	0.67	12.20
12964	8.56	707.00	16.96	105.07	5,395.00	1.22	13.99
12965	6.97	604.30	16.25	89.52	4,414.00	<LD	12.66
12966	6.58	533.10	15.95	93.78	4,399.00	0.13	11.13
12967	8.25	692.30	18.13	108.91	4,997.00	0.40	12.39
12968	7.65	626.60	16.62	108.31	4,937.00	1.32	13.04
12969	6.70	644.50	14.98	99.67	4,407.00	0.09	12.09
12970	6.45	517.00	14.80	101.18	4,107.00	0.33	10.78
12971	7.64	580.20	16.58	112.70	5,184.00	0.32	13.17
12972	7.83	722.90	15.58	104.76	4,508.00	1.12	12.55
12973	6.10	557.00	14.37	85.84	4,019.00	0.29	11.64
12974	6.56	547.70	15.26	101.78	4,248.00	<LD	11.81
12975	7.41	572.20	16.93	100.38	4,936.00	1.04	12.72
12976	8.19	556.30	18.06	119.03	5,019.00	0.23	13.03
12977	6.52	777.30	15.84	81.70	4,365.00	<LD	11.56
12978	6.07	683.50	14.65	93.25	4,003.00	0.26	10.74
12979	7.97	817.90	17.83	104.04	4,985.00	0.12	12.90
12980	7.95	540.40	17.29	104.58	5,053.00	0.81	13.61
12981	6.13	596.30	15.43	75.99	4,180.00	<LD	12.07
12982	6.93	572.70	16.05	94.20	4,346.00	0.46	12.39
12983	7.78	681.60	17.75	98.78	4,818.00	0.21	13.02
12984	7.74	683.60	22.74	113.67	5,300.00	2.87	13.14
12985	6.42	773.20	21.35	83.95	4,745.00	1.28	13.33

Lab number	Co	Se	Cr	Cd	As	Hg	Pb
	(mg kg^{-1})	(µg kg^{-1})	(mg kg^{-1})	(µg kg^{-1})			(mg kg^{-1})
12986	6.98	932.50	20.75	106.81	4,584.00	1.32	13.11
12987	7.85	895.00	22.88	113.95	5,195.00	1.68	14.04
12988	7.74	664.90	22.46	120.50	5,576.00	1.90	14.84
12989	7.27	808.90	20.03	79.84	4,820.00	0.95	14.47
12990	6.91	688.80	20.92	104.69	4,696.00	0.97	12.83
12991	7.66	671.20	21.42	99.76	5,305.00	1.28	13.97
12992	7.68	671.30	20.97	127.64	4,584.00	1.50	12.21
12993	6.72	841.10	20.53	83.22	4,655.00	1.32	13.48
12994	7.71	916.10	21.37	114.09	4,747.00	0.96	12.92
12995	8.07	860.90	20.19	115.59	5,503.00	1.68	14.85
12996	7.08	787.20	19.01	114.25	4,799.00	1.64	12.74
12997	6.81	689.30	18.88	86.86	4,574.00	1.08	11.93
12998	8.07	855.30	20.52	130.32	4,693.00	1.60	12.64
12999	7.83	796.70	20.84	131.00	5,128.00	1.39	13.82
13000	7.52	876.20	17.92	115.29	4,721.00	1.62	12.77
13001	7.47	925.90	20.06	94.40	4,866.00	0.74	13.03
13002	8.83	855.50	20.87	135.78	5,332.00	1.75	15.03
13003	10.98	875.60	20.79	122.23	5,119.00	1.27	15.61
13004	7.70	765.50	19.84	100.64	4,623.00	1.50	13.05
13023	6.05	910.10	18.33	106.89	4,847.00	1.81	12.23
13024	6.26	923.00	18.31	97.75	4,208.00	1.12	11.16
13025	6.36	687.30	19.23	107.56	3,963.00	1.02	10.40
13026	6.15	965.30	18.08	95.56	3,937.00	1.12	11.77
13027	6.86	875.40	19.68	112.91	4,785.00	1.63	12.37
13028	6.97	778.60	19.78	105.35	4,325.00	1.28	10.56
13029	6.74	933.10	19.67	103.80	4,132.00	1.16	12.18
13030	6.83	744.80	18.41	104.89	4,090.00	1.61	12.06
13031	6.62	732.30	18.42	103.57	4,613.00	1.75	12.38
13032	6.57	828.80	18.38	98.51	4,383.00	0.92	12.06
13033	7.44	728.30	20.61	106.16	4,866.00	0.85	12.66
13034	6.19	801.80	18.92	117.58	4,183.00	1.79	11.69
13035	6.69	884.70	18.39	123.08	4,592.00	1.55	12.30
13036	7.08	661.50	19.88	104.94	4,807.00	1.53	12.90
13037	6.84	877.30	20.07	117.75	4,501.00	0.95	12.43
13038	6.31	747.40	20.51	128.08	4,341.00	1.49	11.75
13039	6.37	847.30	18.40	124.00	5,277.00	1.19	13.13
13040	8.40	783.40	19.95	116.92	5,294.00	1.50	14.01
13041	6.72	822.00	19.29	107.99	4,605.00	1.06	12.95
13042	6.32	860.70	19.44	124.99	4,197.00	1.75	12.26
13043	6.17	760.90	18.10	118.51	4,764.00	1.82	12.21
13044	6.53	711.10	19.15	109.38	4,784.00	0.92	12.33
13045	6.08	912.80	18.95	101.76	4,173.00	0.61	11.44
13046	6.59	943.10	20.30	125.20	4,320.00	1.22	12.08
13047	6.01	950.70	18.40	116.22	4,632.00	1.78	11.68
13048	6.87	698.00	18.30	117.80	4,609.00	1.31	12.85
13049	6.55	789.70	19.13	106.15	4,405.00	2.03	11.96
13050	5.88	765.30	18.11	101.49	4,010.00	1.35	11.30
13051	6.22	689.30	17.96	105.47	4,680.00	1.20	11.31
13052	7.31	820.00	20.08	115.62	5,479.00	1.32	13.52
13053	6.79	901.00	18.95	107.31	4,540.00	1.38	13.01
13054	6.31	605.70	18.39	122.49	3,992.00	1.25	12.42
13055	6.00	693.90	17.72	108.28	4,567.00	2.04	11.45
13056	6.79	929.60	18.73	107.26	4,606.00	1.17	11.77
13057	7.18	920.00	27.81	118.39	4,595.00	1.08	12.77
13058	6.28	1,015.00	27.40	122.57	4,356.00	1.70	12.39
13059	7.07	860.70	27.94	120.67	5,388.00	1.86	13.45
13060	7.52	1,086.00	26.33	110.07	5,160.00	1.53	13.33
13061	6.57	879.40	27.23	139.19	4,353.00	1.42	13.06
13062	7.19	893.50	28.02	138.74	5,388.00	1.29	13.98

Lab number	Co	Se	Cr	Cd	As	Hg	Pb
	(mg kg^{-1})	(µg kg^{-1})	(mg kg^{-1})	(µg kg^{-1})			(mg kg^{-1})
13063	9.02	811.30	27.40	121.40	5,819.00	0.86	15.33
13064	7.95	910.90	29.39	113.13	5,719.00	1.37	14.00
13065	7.42	940.90	30.11	109.14	5,422.00	4.78	15.32
13066	7.47	802.00	28.97	117.18	4,916.00	4.42	15.66
13067	8.02	1,137.00	26.64	101.94	6,470.00	3.05	16.28
13068	7.67	877.00	30.46	115.84	6,329.00	3.63	16.08
13069	7.76	938.40	27.33	130.37	6,120.00	3.82	18.21
13070	6.70	899.50	26.17	141.95	4,533.00	3.86	15.90
13071	7.47	956.50	26.96	117.76	5,496.00	6.36	15.08
13072	8.12	907.40	27.62	108.97	6,228.00	3.49	16.89
13073	8.18	1,018.00	25.47	120.04	6,105.00	3.33	17.92
13074	7.73	1,078.00	25.44	144.79	5,114.00	4.77	18.96
13075	7.17	848.40	24.99	113.31	5,490.00	2.75	15.12
13076	8.38	1,006.00	27.83	156.92	7,284.00	3.43	19.00
13077	7.17	941.10	24.89	124.25	5,616.00	3.26	16.11
13078	7.09	861.90	25.22	169.15	5,192.00	4.13	17.79
13079	6.65	730.50	17.11	107.11	4,973.00	2.72	14.37
13080	7.25	669.20	18.41	108.36	5,547.00	3.42	15.29
13081	6.74	754.40	16.72	111.44	5,128.00	3.28	15.10
13082	7.28	713.20	15.90	138.73	5,016.00	3.02	17.21
13083	7.02	640.30	15.99	103.55	5,247.00	2.57	16.33
13084	7.59	801.10	17.05	112.03	5,992.00	3.35	15.86
13085	7.59	822.10	16.14	133.06	4,978.00	3.32	15.53
13086	6.80	666.40	15.91	121.87	5,560.00	2.92	16.13
13087	6.97	782.70	15.06	112.60	5,774.00	2.58	17.44
13088	7.45	813.90	16.33	104.11	5,692.00	2.68	15.84
13089	6.86	774.20	14.90	125.68	5,036.00	2.78	14.89
13090	6.84	811.10	14.98	116.15	4,910.00	2.89	15.50
13091	6.76	801.20	15.15	110.55	5,061.00	2.88	15.97
13092	7.97	790.00	16.43	119.79	5,905.00	2.78	16.91
13093	8.03	727.00	14.34	117.84	5,476.00	3.19	17.33
13094	6.39	703.80	13.80	109.45	4,498.00	3.26	15.25

	Co	Se	Cr	Cd	As	Hg	Pb
	(mg kg^{-1})	(µg kg^{-1})	(mg kg^{-1})	(µg kg^{-1})			(mg kg^{-1})
Var	0.87	21,261.21	26.51	243.66	625,365.86	1.28	3.85
Min	3.86	449.60	13.41	55.00	2,840.00	0.09	6.60
Max	10.98	1,137.00	32.10	169.15	7,284.00	6.36	19.00
Average	7.29	809.05	21.14	110.44	5,096.15	1.64	13.39
StDev	0.93	145.81	5.15	15.61	790.80	1.13	1.96
CV (%)	12.78	18.02	24.35	14.13	15.52	68.96	14.66

11. List of tables

12. List of pictures

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BASIC DOCUMENTATION CARD

Josip Juraj Strossmayer University in Osijek **Graduate thesis**
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A GIS-based assesing of soil heterogeneity

Karolina Kajan

Abstract:
To meet the growing demand for food, it's essential to expand agriculture in suitable environments. Responsible use of resources and effective agricultural practices are crucial for maximizing productivity and maintaining soil quality and fertility. This thesis employed a GIS-based approach to assess the significance and distribution of basic soil properties—soil organic matter, pH, texture, available phosphorus, and potassium—in determining the homogeneity or heterogeneity of two arable plots in Trnava and Đurđevac. A total of 116 soil samples from Trnava and 144 from Đurđevac were analyzed for both essential and additional soil physical and chemical properties. Descriptive statistics, correlation, and multiple regression analyses were performed to evaluate these properties. The coefficient of variation for plant-available phosphorus was the highest at 44.61%, indicating significant heterogeneity, while fine silt content showed the lowest variation at 3.71% in Trnava. In Đurđevac, total potassium content exhibited the highest variation, and actual acidity the lowest at 8.10%. On the analyzed plots, the most significant indicators of soil heterogeneity and needs for variable fertilization are soil hydrolytic acidity and plant-available P, and to a lesser extent, plant-available K, which means that variable liming and fertilization with P and K are needed. Regression analysis validated the effectiveness of multiple linear regression models in predicting cation exchange capacity based on various soil properties. In Trnava, six models with high R values (0.9795 to 0.9936) and R^2 values (0.9592 to 0.9873) were developed, with standard errors of the estimate ranging from 3.0036 to 4.0488. The Đurđevac models, constructed with 72 samples, demonstrated even stronger correlations, with R values between 0.9945 and 0.9965, R^2 values from 0.9889 to 0.9935, and lower SEE values (0.6034 to 0.9324), indicating higher prediction precision. Geo-statistical results revealed diverse spatial distribution patterns of soil properties and plant available nutrients, exhibiting strong, moderate, and weak spatial dependence. These spatial distribution maps are valuable for developing site specific soil management strategies. This comprehensive analysis underscores the importance of detailed soil property assessment in enhancing agricultural productivity and soil management practices.

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Procjena heterogenosti tla upotrebom GIS-a

Karolina Kajan

Sažetak:
Poljoprivrednu proizvodnu neophodno je prilagoditi specifičnostima ekoustava i heterogenosti proizvodnih površina kako bi se zadovoljila rastuća potražnja za hranom. Odgovorno korištenje resursa i učinkovita poljoprivredna praksa presudni su za maksimiziranje produktivnosti i održavanje kvalitete i plodnosti tla. U ovom radu korišten je pristup temeljen na GIS-u za procjenu značaja i distribucije osnovnih svojstava tla - organske tvari u tlu, pH, teksture, dostupnog fosfora i kalija - u određivanju homogenosti ili heterogenosti dviju obradivih parcela u Trnavi i Đurđevcu. Analizirano je ukupno 116 uzoraka tla iz Trnave i 144 iz Đurđevca na osnovna i dodatna fizikalna i kemijska svojstva tla. Deskriptivna statistika, korelacije i višestruka regresijska analiza provedene su radi procjene povezanosti i heterogenosti analiziranih svojstava. Koeficijent varijacije biljkama raspoloživog fosfora bio je najveći (44,61%), što ukazuje na značajnu heterogenost, dok je sadržaj finog praha pokazao najmanju varijaciju (3,71%) u Trnavi. U Đurđevcu je najveće variranje pokazala ukupna koncentracija kalija, a najmanje pH_{H2O} 8,10%. Na analiziranim oranicama najznačajniji pokazatelji heterogenosti tla i potrebe za varijabilnom gnojidbom su hidrolitička kiselost i biljkama dostupni P, a u manjoj mjeri biljkama dostupni K, što znači da su potrebni varijabilna kalcizacija i gnojidba s P i K. Regresijskom analizom potvrđena je učinkovitost višestrukih linearnih regresijskih modela u predviđanju kationskog izmjenjivačkog kapaciteta tla na temelju različitih svojstava tla. U Trnavi je razvijeno šest modela s visokim R (0,9795 do 0,9936) i R^2 vrijednostima (0,9592 do 0,9873), sa standardnim pogreškama procjene u rasponu od 3,0036 do 4,0488. Modeli lokaliteta Đurđevac rezultirali su još značajnijim korelacijama, s R 0,9945 i 0,9965, R^2 vrijednostima od 0,9889 do 0,9935 i nižim SEE vrijednostima (0,6034 do 0,9324), što ukazuje na veću preciznost predviđanja, tj. veću točnost modela. Geostatistički rezultati otkrili su različite obrasce prostorne distribucije svojstava tla i biljkama raspoloživih hranjivih tvari, pokazujući jaku, umjerenu i slabu prostornu ovisnost. Ove karte prostorne distribucije vrijedne su za razvoj strategija upravljanja tlom specifičnih za točnu geopoziciju i preciznu provedbu mjera očuvanja plodnosti tala.

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