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Spatial distribution of soil organic carbon content in the agricultural land uses: Case study at the territory of the Rahoveci municipality, Kosovo

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Abstract

Due to the soil formation factors and different geographic areas of Dukagjini Plain, particularly in Rahovec municipality, the variation of soil organic carbon is high. Soil organic carbon (SOC) has a crucial role in the determination of the physical, chemical and biological behaviour of the soil. The most common land use types of this area are vineyards, table grapes, horticulture such as peppers and cabbage, and arable lands such as maize, winter wheat, alfalfa, and meadows. Considering the lack of soil information data in Kosovo, it is necessary to have soil information about this territory. The main objectives of the present study are, therefore: i) to investigate and determine the concentration of the soil organic matter (SOM), SOC, nitrogen (N) and soil pH-H_2O, using laboratory analysis, and ii) to show the spatial distribution of SOC, SOM, N and pH using the Kriging and inverse weighting interpolation methods. Spatial variability of soil chemical parameters such as SOM, SOC, N, and pH are important to be interpolated to view the changeable soil properties by kriging and inverse distance weighting method and to generate the continuous sample for site-specific management. Disturbed soil samples were collected from the top soil 0-30 cm and 30-60 cm depth, to determine selected soil chemical parameters, during June-July 2019. A large number of soil samples were collected, 2087 in the first horizon and 2065 in the second. The average of SOC of the first horizon was 0.91%, which variates from 0.07 to 4.06%, while in the second horizon was 0.0 to 2.84%, the average content of N in the first horizon was 0.09%, which variate from 0.01 to 0.60%, while in the second horizon was 0.0 to 0.39%, meanwhile, the average of soil pH-H_2O in the first horizon was 7.67, which variates from 4.25 to 9.35, while in the second horizon was 7.79, which variate from 3.25 to 9.30.

Keywords: Soil organic carbon, agriculture land, spatial interpolation, kriging, inverse weighting.

Introduction

When it comes to soil fertility soil organic matter (SOM) is a significant factor for sustainability and productivity (Johnston et al., 2009) and has great importance in any terrestrial ecosystem (Dengiz et al., 2019).

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It has numerous functions, which determine physical factors, and it is essential for the supply of plant nutrients and to regulate the water flow. It is important to manage soil organic matter, to sustain croplands, grasslands, and forests. According to (Lal, 2008) the amount of stored carbon in the soil is around 2500 GT tons, which is 3.1 times larger than the amount of what is found as (CO_2) in the atmosphere (Oelkers and Cole, 2008). The storage of carbon in SOM can also have an impact on greenhouse concentrations, and if soils increase their organic matter, CO_2 content in the atmosphere will be decreased (Cotrufo et al., 2011). The amount of SOM depends on organic materials and their breakdowns in soil, where plant communities and microorganisms are the basic sources of the process of decomposition. The amount of organic matter that is needed in the soil depends on the form of land use. It is worth notice that if there is a decrease in soil organic matter, the soils will experience loss of structure and erosion (Spain and Isbell, 1983). Soil organic matter is no doubt that is highly important but defining the nature of SOM is still challenging. However, organic matter retains nutrients, which increases plant growth and water quality content. The process that is studied is humification and humic substances which make soil humus. But no precise evidence or analytic techniques are made to observe this substance. What makes it difficult for this observation is that organic compounds are mixed with soil minerals. Its specific is dark coloration and in some soils such as arable soils, organic matter is around 5% (Lehmann and Kleber, 2015). The percentage of organic matter usually is between 2-10%. However, even if a small percentage is detected it is important because the biological activity of soil depends on it. It affects soil in numerous in every feature, and there is a need for restoring organic matter to balance the agro-ecosystem and to provide sufficient nutrients for plants (Bot and Benites, 2005).

According to Bresilla (2012), the most representative reference soil groups of Kosovo are Cambisols, Vertisols, Luvisols, Fluvisols, Leptosols, and Calcisols, and because of this wide range of these soil are characterized by the highly changed spatial distribution of the Kosovo relief materials as referring to (USDA-NRCS, 2012) .

Agricultural practices does make certain changes into the soil. In order to define these changes there is developed the soil quality index which helps to identify the effects and changes on soil parameters (Gelaw et al., 2015).

The degradation of soil and deterioration of soil fertility are considered a serious threat to human existence and the natural environment due to changing climate change, topography, soil characteristics, and the uniqueness of agriculture.

Performance indicators of healthy soil are soil colour, soil texture, organic matter, weeds, topography, and soil water holding capacity (Nimmo, 2004).

Devastation impacts of agricultural practices on soil quality include salinization, erosion, compaction, desertification, and pollution (Lal and Stewart, 2015). One of the major threats to agricultural productivity in developing countries is declining soil fertility. These factors which affect soil degradation are extensive use of farming practices, poor agronomic practices, low use of inputs, low rotation spectra, and climate change effects.

Soil information remains an issue for farmers and agricultural institutions of Kosovo. Therefore, having a unique database for the location n-based analysis is more than important for agricultural development and policies. Soil resource inventories has undergone in many countries changes from physical to digital techniques.

This municipality's soil use is distinguished by intensive plantation owners of vineyards, cereal products, and vegetable production. Crop plantation variation occurs as a consequence of land formation and climatic condition, which makes it suitable to many farming system where soil organic matter is produced; as long as there is a diverse crop production, litter from multiple sources is provided, increasing soil organic matter and sustaining cultivars.

Since this area, is agricultural intensively used in different cropping systems many agricultural practices are applied as: land cultivation, preparation, fustigation, fertiliser and manure use – as indicators on soil and crop health and to provide the ability to change soils mineral and biological activity.

The current study aims: i) to investigate and determine the concentration of the soil organic matter [SOM], soil organic carbon (SOC), nitrogen (N) and soil pH-H_2O, using laboratory analysis, and ii) to show the spatial distribution of SOC using the Kriging and inverse weighting interpolation methods. Moreover, it was relevant: i) to determine SOC, SOM, N and soil pH – H_2O in two soil depths and show their spatial variability, ii) differentiate the differences on two soil horizons in order for later to identify the effects which came to these spatial changes, and iii) classify soil sampling locations based on corine land cover classification.

Material and Methods

Study area

This study was conducted in Rahoveci Municipality, which is located in the western part of Kosovo, on the Dukagjini plain, with a surface of 275.9 km^2, and is about 2.5% of the country (Figure 1). Due to the soil formation factors and different geographic areas of Dukagjini Plain, soils of the agricultural land of Rahoveci Municipality are very diverse and are situated between the northern latitude of $42^0 29'12.54''$ and $42^0 17'31.43''$ and between the longitude of $20^0 40'19.39''$ and $20^0 39'19.49''$ east, in Drini Bardh River basin and are characterized with a great potential for agriculture development, mainly for vegetables in flat area and vineyard in sloping land and hilly sites. The most common land use types of this area are vineyards, table grapes, horticulture such as peppers and cabbage, arable lands such as maize, winter wheat, alfalfa, and meadows.

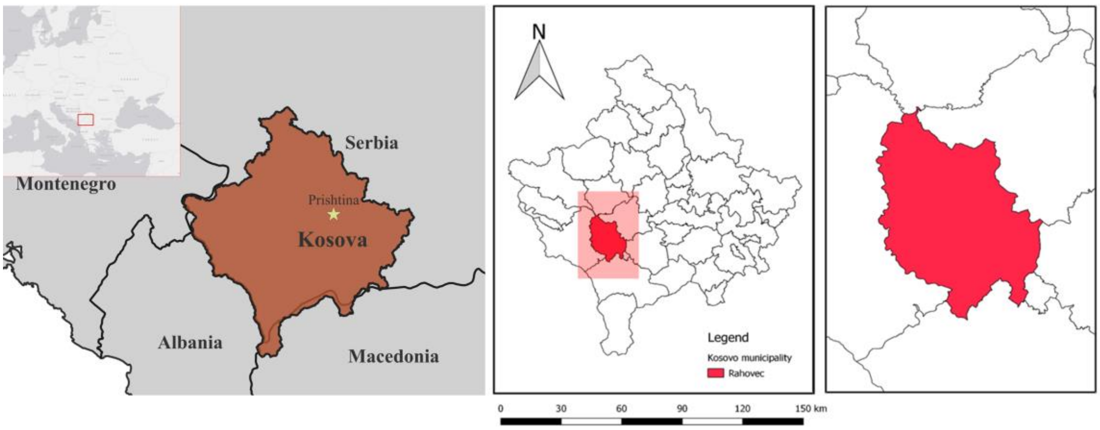

Figure 1. Study area, Rahovec

The highest peak above sea level is 920 m and is situated in the northern part of the territory and the lowest peak above sea level is 310 m and is situated in the southern part of the territory (Figure 2).

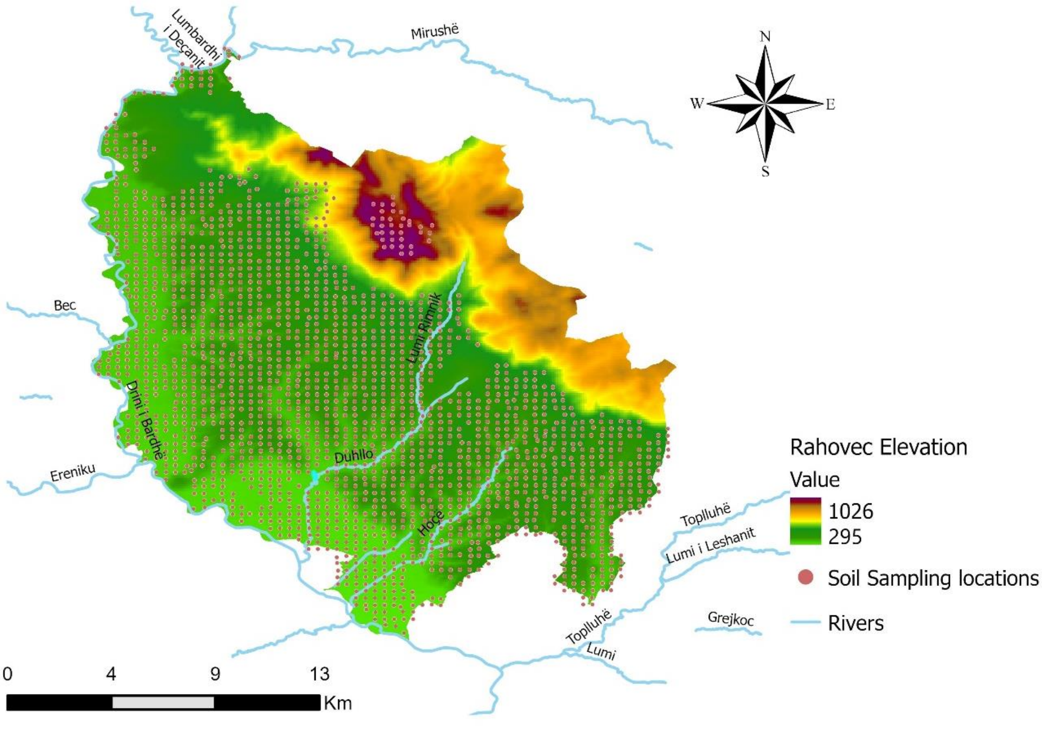

Figure 2. Soil sampling location map

Climate condition of the study area

Based on (KECA, 2008), the climate of the country is predominantly continental. The study area climate is characterized by warm to hot summers and cold winters, with an average of 700-780 mm precipitation per year, moreover, air temperatures are characterized by an average annual temperature of 12.2 ^{0}C which may range from -20 ^{0}C in the winter to +35 ^{0}C in the summer (KEPA, 2020) .

Soil sampling

The field sampling was carried out during June-July, 2019. In order to determine selected soil chemical parameters, disturbed soil sampling were collected in two depths, from the top soil horizon 0-30 cm and second soil horizon 30-60 cm. A total of 4152 soil samples were collected, 2087 soil samples belongs to the top soil horizon 0-30 cm and 2065 soil samples belong to the second soil horizon 30-60 cm. The samples were organised based on a pre prepared sampling grid of 300 x 300 m (every 9 ha) (Figure 2). The auguring samples were taken based on the sampling grid with a maximum of 49 m deviation, when it was needed. The samples that were marked based on the grid in the middle of group of the houses and had the possibility of displaced to a maximum distance of 49 m, were displaced, otherwise those that did not have this possibility were cancelled. For each disturbed soil sample were taken approximately 500 g of soil, then the samples were purified from stones, granules, leaves and roots, then were subjected for further procedure. The soil samples were dried at room temperature, crushed, homogenized, and sifted with a 2 mm sieve. The chemical parameter that were performed are pH-H_2O, soil organic carbon (SOC), soil organic matter (SOM) and nitrogen (N). Soil organic matter (SOM) and nitrogen (N) were analyzed based on the soil organic carbon (SOC).

Soil chemical analyses

The chemical parameters that have been analyzed and the methods that have been used for determination are presented in Table 1. The Walkley-Black procedure was followed for the determination of Soil Organic Carbon (SOC), 1 g of dried fine earth sample were mixed with 10 ml of potassium dichromate 0.1667 M and 20 ml of sulphuric acid 36%, and after 30 minutes 250 ml of distilled water was added and 3-4 drops of indicator solution added. The 1 M ferrous sulphate solution was used for titration (GLOSOLAN, 2019). For pH determination, the 1:5 ratio of soil and water was used, following ISO 10390:2005 method. Calcium carbonate ($CaCO_3$) was analyzed based on the volumetric methodology, using Calcimeter Bernard.

Table 1. Chemical characteristics of the soil and their representative methods and standards

Soil parameters	Unit	Methods
Chemical parameters		
Soil Organic Carbon [SOC] Soil Organic matter [SOM] Nitrogen [N]	%	Walkley and Black, FAO, 2019
pH		ISO 10390: 2005

Interpolation and statistical analysis

The geostatistical method was used to generate SOC, SOM, N and soil pH – H_2O distribution maps of the study area for the two first soil horizons (0-30 and 30-60 cm). Values of the SOC, SOM, N and soil pH – H_2O were described with classical statistics [mean, standard error, media, mode, standard deviation, sample variance, kurtosis, skewness, range, minimum, maximum, count and Confidence Level (95.0%) were generated using Excel. The IDW method was generated in QGIS 3.16 while the Kriging method was on ArcGIS Pro 2.9.

For the interpolation methods, we have decided to make the spatial distribution using the inverse weighing distance and with the kriging method. Although the spatial distribution of the measured parameters using the IDW method does not cancel any bias when displaying the data from the sample location to the surroundings from the maps which were made of out soil analysis its spatial distribution is highlighted more when displayed with the kriging method (Cressie, 1990).

$$Z(s_0) = \sum_{i=0}^{N} \Lambda_i Z(s_i)$$

Where $Z(s_i)$ is the measured value at the i location; $\Lambda_i (lambda)$ is an unknown weight for the measured value at the i location; s_0 is the prediction location; N is the number of measured values.

For the kriging method the measured values determine the unknown location Λ_i for as in our case the spherical and Gaussian methods were used in which the value of the unknown location was determined by weighting the 5 surrounding known locations whereas in the IDW interpolation is does predict or rely on spatial distribution values of other close values. IDW in this classification is considered as a mathematical method whereas the kriging method is applied as geostatistical method. For such we have considered the kriging method is more suitable since the data are spatially correlated (Virdee and Kottegoda, 1984). Reza et al. (2010) on the evaluation and comparison or ordinary kriging and inverse distance weighting methods does display the similarities of two methods although the accuracy of spatial analytical methods through cross-validation does give.

Results and Discussion

Evaluation of SOM, SOC, N and pH in different soil depths

The descriptive statistical properties of chemical analysis of the soil analysis of both depths have been summarized in Table 2.

Table 2. Descriptive statistics analysis of the SOM, SOC, N and pH – H_2O for 0 – 30 depth

	pH - H_2O		SOM %		SOC %		N %	
	0-30	30-60	0-30	30-60	0-30	30-60	0-30	30-60
Mean	7.67	7.79	1.56	0.92	0.91	0.53	0.09	0.05
Standard Error	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00
Median	7.91	8.10	1.48	0.83	0.86	0.48	0.08	0.05
Mode	8.46	8.59	1.62	0.77	0.94	0.45	0.08	0.04
Std	0.90	0.94	0.73	0.54	0.43	0.31	0.04	0.03
Sample Variance	0.82	0.89	0.54	0.29	0.18	0.10	0.00	0.00
Skewness	-0.87	-1.07	1.78	1.68	1.78	1.68	1.76	4.80
Range	5.10	6.05	6.88	4.85	3.99	2.84	0.38	0.60
Minimum	4.25	3.25	0.12	0.00	0.07	0.00	0.01	0.00
Maximum	9.35	9.30	7.00	4.85	4.06	2.84	0.60	0.39

The results of the Table 2 showed that the mean value of SOM, SOC and N content decreases with soil depth and variates from 1.56% to 0.92%, 0.91% to 0.53% and 0.09 to 0.05% respectively, while soil pH increases with the depth and variates from 7.67 to 7.79. Moreover, the SOC was determined from 0.07% to 4.06% in the top soil horizon 0-30 cm, while in the second soil horizon 30-60 cm was determined from 0.00% to 2.84%.

The reduction or accumulation of soil organic carbon content in the top soil horizon can be influenced by shifting of land use types and land cover management in short term periods. The high variation of SOC in the studied area may be influenced by the dominance of differences of land use types are vineyards, table grapes, horticulture such as peppers and cabbage, arable land such as maize, winter wheat, alfalfa and meadows, as well as due to the undulating landscape of Dukagjini Plain, particularly in Rahovec municipality (Green Report, 2021).

Converting native pasture to cropland can lead to a decrease in SOM and soil aggregate stability (Celik, 2005). Some of the other changes, such as returning natural land into croplands, erosion was increased because it influenced soil physical properties (Li et al., 2007). One of the main attributes is also tillage practices because observation leads to the lowest SOM is founded on these cultivated lands (Haghighi et al., 2010). Moreover, natural pastures, which were not influenced by tillage or other agriculture practices showed that have better conditions in the aspect of soil properties (Bormann and Klaassen, 2008), whereas the agricultural practices in Rahoveci municipality may change from very intensive to non-intensive, due to that we have considered that using the top soil horizon 0-30 cm and second soil horizon 30-60 cm would provide accurate information for the agricultural practices and land uses in Kosovo.

The relationship between variation of land cover type and SOC content

To determine the land cover of the study area, Corine land cover classification (CLC) raster image of 2020 were used. Based on the Corine land cover classification of the Figure 3 and Table 3 the main land cover are complex cultivation patterns with 41% of the area which mainly includes crops such as winter wheat and maize and contain around 0.7 to 0.873% SOC, non-irrigates arable land with 21% of the area which mainly includes vegetables such as peppers, melons and water melons, cabbage contains 0.937 to 1.804% SOC, agriculture land (natural vegetation) which cover 18% of the studied area and dominate uncultivated land contains 0.923 to 0.936% SOC, vineyards occupy 8% of the territory and because of very intensive agriculture practices and unfavourable land management practices showed the lowest SOC content with 0.072 to 0.699% same results were observed by Martin et al. (2011), while the rest belong to broad leave forest with 0.937 to 4.05% SOC, natural grassland with 0.94 to 1.176% SOC, pastures 0.94 to 1.001%, orchards and urban representing smaller area, table 3 displays the sample distribution on each CLC category.

Land use has a great impact on carbon stock in the soil (Dengiz et al., 2019). According to Martin et al. (2011) the SOC content on the soil depends mostly on the land use and land cover type, while, the highest vales of SOC were observed under natural vegetation such as forest, grassl, and and wetland, while the lowest SOC content was observed in vineyards. Agriculture activities that enhance the decomposition of SOM as a result of land preparation activities, in most cases reduce the SOM (Six et al., 2000), meanwhile vegetation has a significant effect on the quality and quantity of SOM (Lovett et al., 1993).

Table 3. Distribution of sampling points in land uses

CLC classification	Samples	Samples (%)
112 - Discontinuous urban fabric	18	1%
211 - Non-irrigated arable land	433	21%
221 - Vineyards	166	8%
222 - Fruit trees and berry plantations	15	1%
231 - Pastures	43	2%
242 - Complex cultivation patterns	853	41%
243 - Agriculture land (natural vegetation)	382	18%
311 - Broad-leaved Forest	69	3%
321 - Natural grasslands	42	2%
324 - Transitional woodland-shrub	45	2%
331 - Beaches - dunes - sands	1	0%
333 - Sparsely vegetated areas	8	0%
	2057	100%

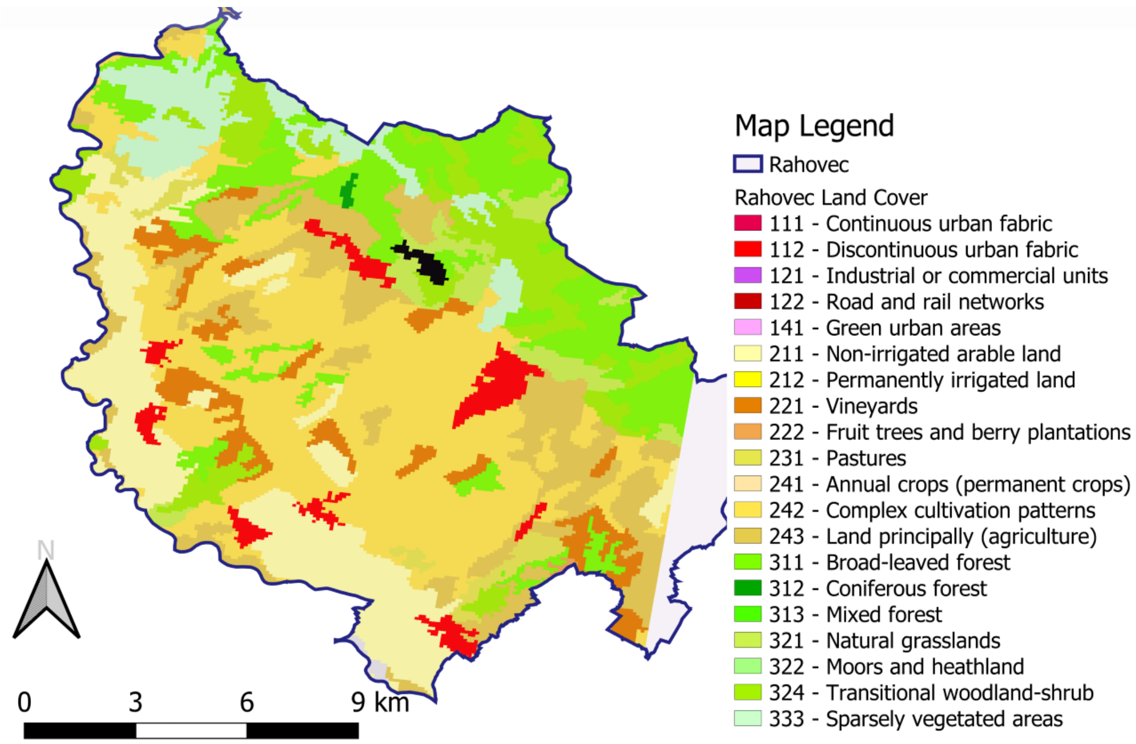

Figure 3. Land cover map of Rahoveci municipality

Estimation of interpolation maps for SOM, SOC, N and pH

Spatial analysis of the analysed parameters are shown in Figure 4, 5, 6 and 7. In two different sample selection depths, we directly interpolated the data in QGIS and ArcGIS using inverse distance weighting and the kriging model. For IDW interpolation for its analysis requires wights of neighbouring samples the spatial distribution of samples is displayed the non-continuity of soil mapping results figure 4 and 6. For SOC, SOM, and N, we have used optimized Gaussian model for Kriging interpolation, meanwhile for pH, we used the spherical model shown in Figures 5 and 7. Mapping produced an interconnected soil surveying result display importance of soil analysis.

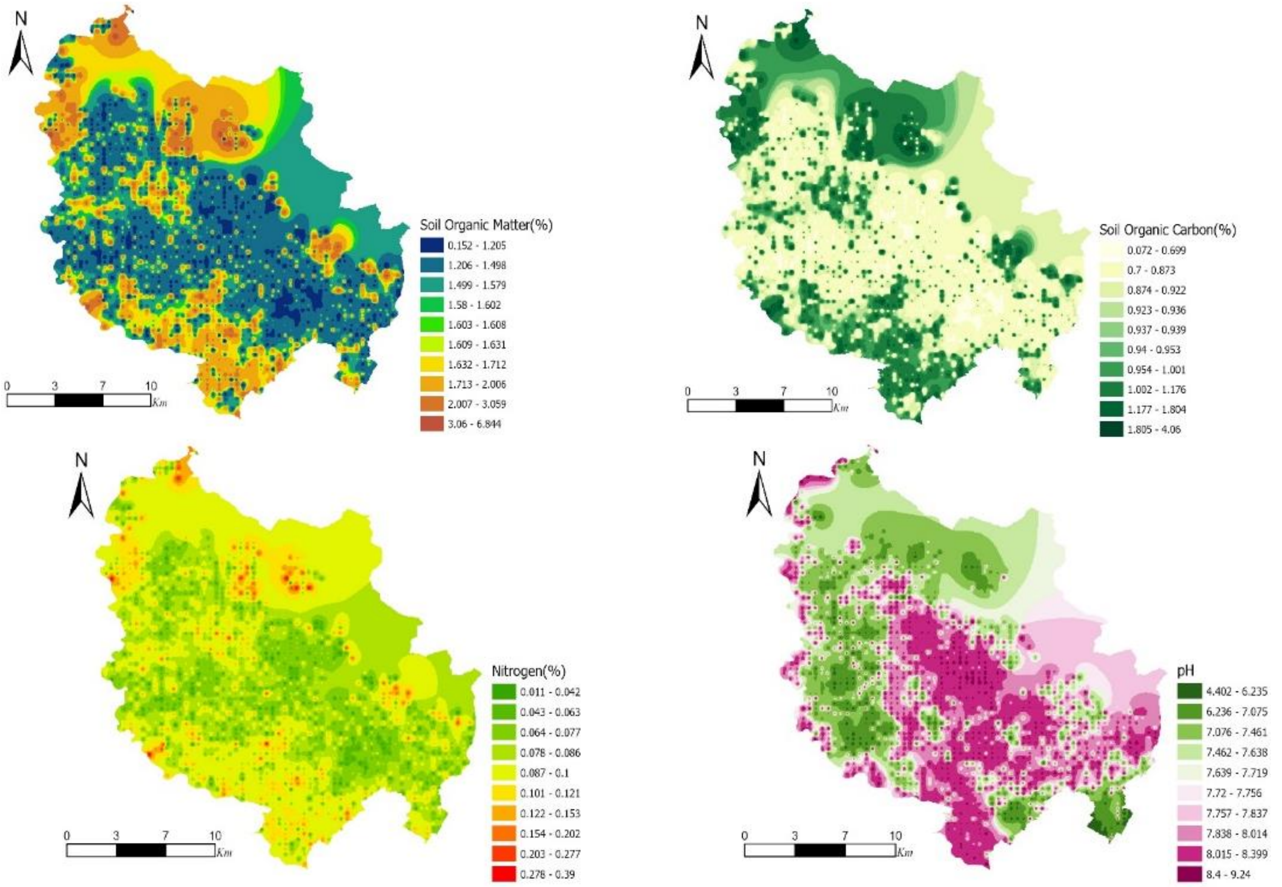

Figure 4. Inverse Distance Weighted interpolation of the results of the 0-30 cm soil samples for SOM – Soil organic matter, SOC – Soil organic carbon, N – Nitrogen and soil pH – H2O.

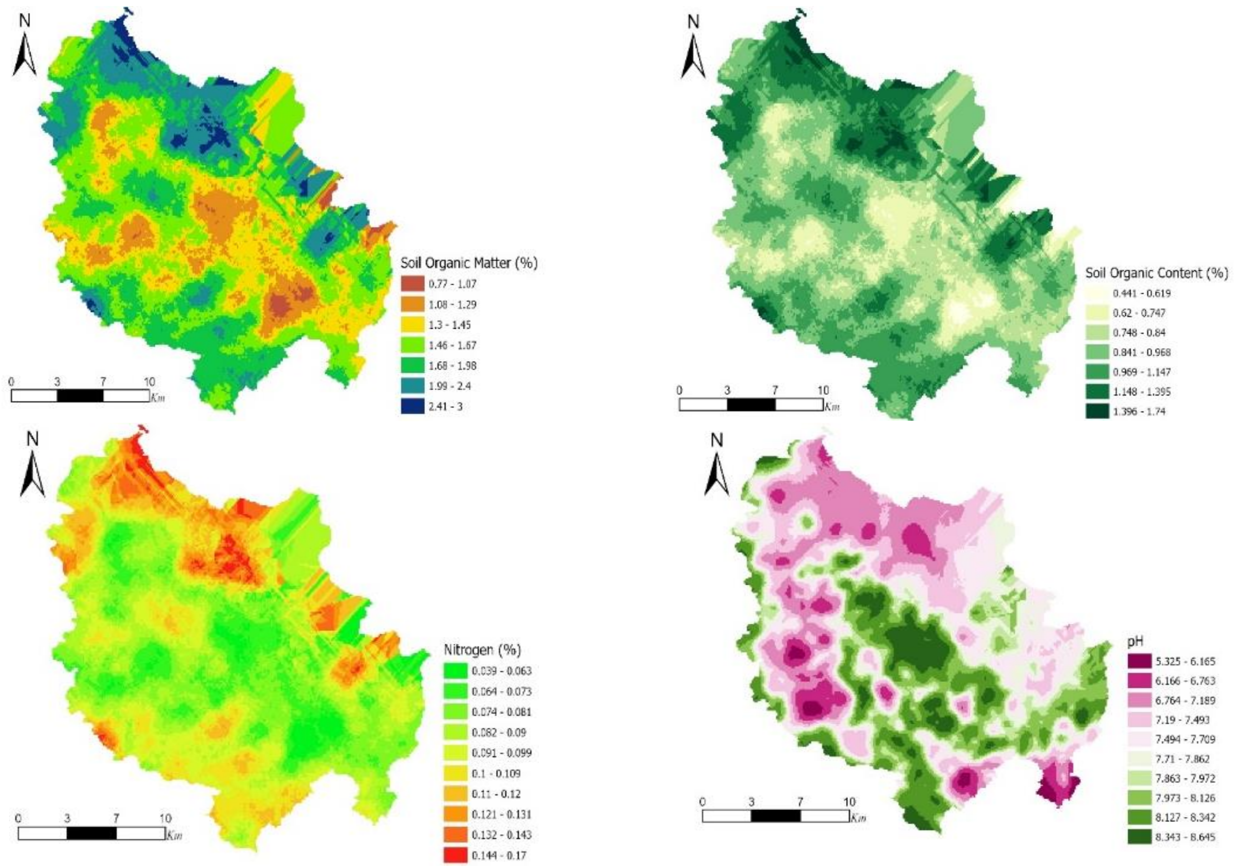

Figure 1. Kriging interpolation of the results of the 0-30 cm soil samples for SOM – Soil organic matter, SOC – Soil organic carbon, N – Nitrogen and soil pH – H_2O

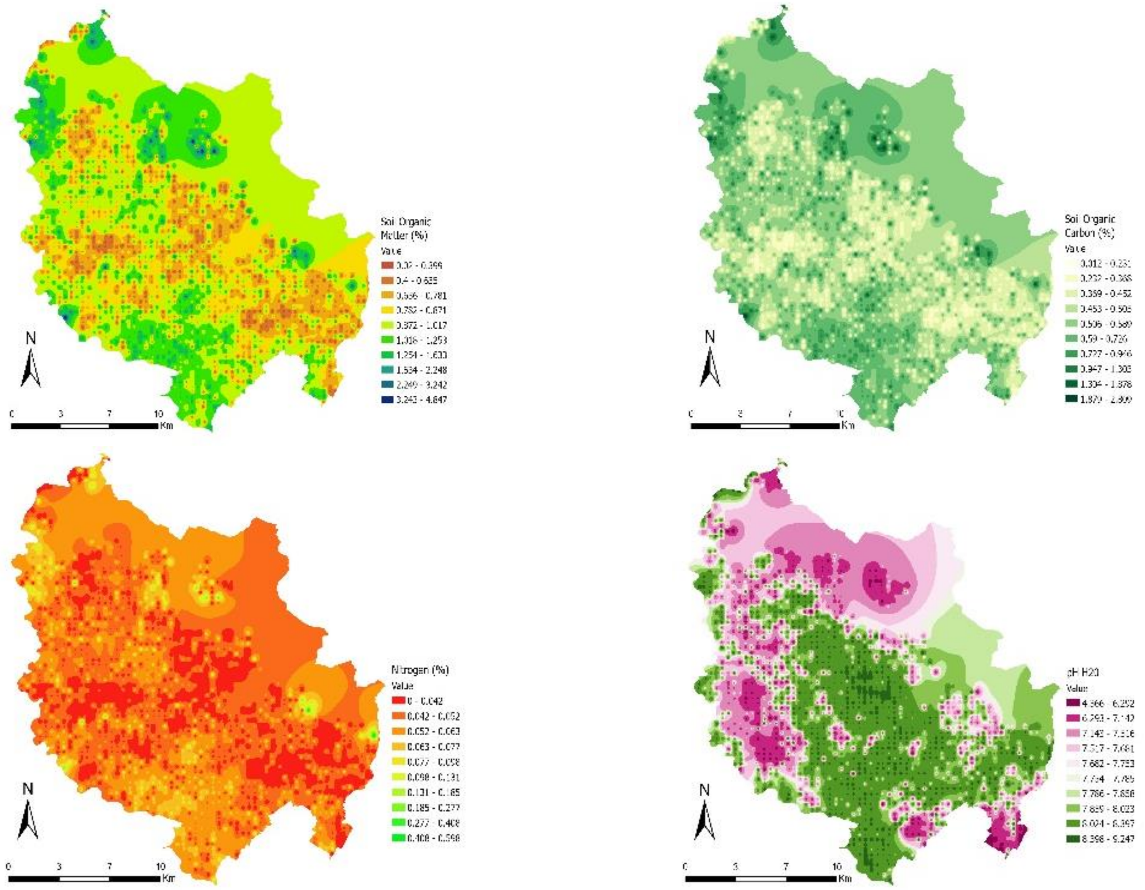

Figure 6. Inverse Distance Weighted interpolation of the results of the 30-60 cm soil samples for SOM – Soil organic matter, SOC – Soil organic carbon, N – Nitrogen and soil pH – H2O

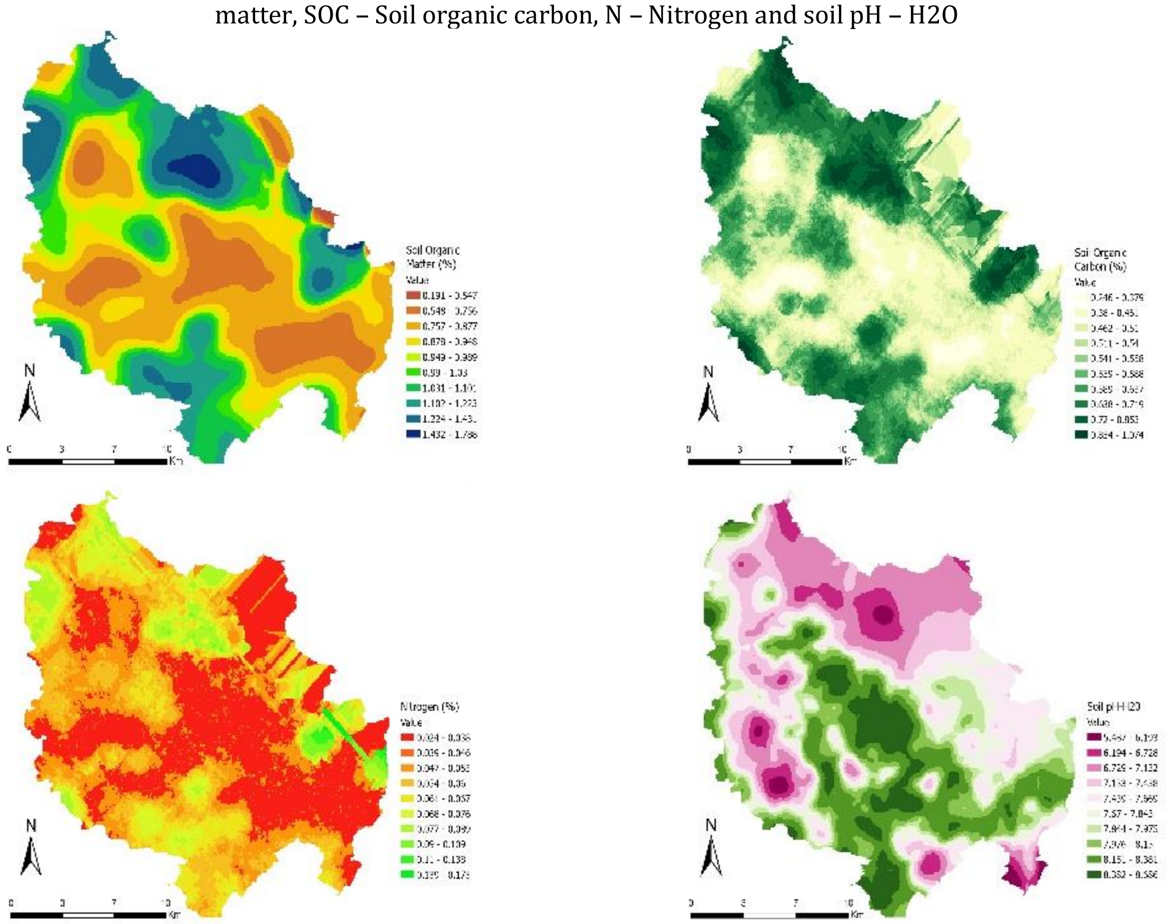

Figure 7. Kriging interpolation of the results of the 30-60 cm soil samples for SOM – Soil organic matter, SOC – Soil organic carbon, N – Nitrogen and soil pH – H2O

Conclusion

The spatial distribution of SOM, SOC, N, and pH content across the study area is shown by Inverse Distance Weighted interpolation and Kriging interpolation technique. The SOC content distribution showed higher values in the area of natural vegetation, in the forest with up to 4.05% and grassland with up to 1.17%, followed by arable land and the lowest SOC content was observed in vineyards with maximum 0.69%. In this study area, the visualization of SOC distribution can help regional farmers in the selection of crops for certain areas for better management of their lands and agricultural production. This study has explained in detail the distribution of SOC, SOM, N and pH using inverse distance weighted interpolation and Kriging interpolation technique that can be applied to different study areas with other soil components. Spatial analyses characterize the current state of the soil for the current year, but do not represent dynamic changes over time, although changes in soil measurements between two depths represent the effect of agricultural practices (human impact). Although based on the analysis we consider that the Kriging method is more spatially accurate compared to IDW as a mathematical method. Due to the unfavourable agricultural practices that are being applied by the farmers of the municipality of Rahovec, it should be taken into account that the farmers need more theoretical and practical trainings such as indoor and outdoor explanations on how to prepare the land for planting or cultivation during the vegetation period in order to protect against further degradation.

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