Spatial distribution and variability of soil agrochemical properties in Botevgrad valley

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Abstract. The paper deals with spatial analysis that evaluates the main agrochemical properties of the Botevgrad valley. The soil samples were taken along a pre-selected grid so as to cover the areas selected for research. The interpolation of the data was done according to geostatistical interpolation method and the output value is using Inverse Distance Weighting (IDW). Spatial distribution is a valuable tool for determining nutrient availability and nutrient management practices to optimize crop production and minimizing environmental impacts. As a general guideline, total nitrogen content in soil is commonly found in the range of 0.1% to 0.2% on a weight basis. Soils with higher organic matter content often have higher total nitrogen levels because organic matter is a significant source of nitrogen. It's important to note that the optimal levels of available potassium and phosphorus can vary depending on the specific soil type.

1 Introduction

Agrochemical properties of soils are related to basic soil functions, such as biomass production, nutrient transformation, etc. Their change can be an indicator of deterioration or improvement of the health status of the soil under the influence of natural and anthropogenic impact. Obtaining new information about soil resources is of particular importance for establishing their current state and quality, for identifying timely destructive processes, forecasting their development and maintaining the soil information system for their timely and scientifically based diagnosis [1].

The present study is a spatial analysis to evaluate the main agrochemical indicators of the Botevgrad valley. The soil samples were taken along a pre-selected grid so as to cover the areas selected for research as evenly as possible. The interpolation of the data was done according to geostatistical methods. The initial value can use Inverse Distance Weighting (IDW) method. IDW is a new type of visual mathematical method for multivariate interpolation with a known number of points. Because IDW is a weighted average interval, the average cannot be as more as than the highest or than the most reduced input. The finest results from IDW are taken when sampling is sufficiently dense with regard to the local

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variation you are attempting to simulate. On the off chance that the inspecting of input data is scanty or uneven, the received values may not sufficiently represent the desired [2].

The methods applied in the studies of the soil cover structure at different hierarchical levels provide valuable statistical information on soil differences and can also be used for monitoring landscape changes. Close to the studied area of the nearby Sofia field, similar studies were made by Kivambo [3] and Dimitrov [4]. They have studied the patterns of soil cover variation and their relationship with soil formation factors.

In the studied area of Botevgrad valley, Fluvisols are the most common, followed by the shallow Leptosols soils, which are mainly located on sloping eroded terrains. Skeletal Regosols occupy significant areas as well. Luvisols and Phaeozems have characteristic of soils in northern Bulgaria. Rendzinas are also widespread in the northern part of the basin mainly on limestone and other carbonate rocks. Antrosols are in urban area occupy about 9% of the area of the valley [5].

2 Materials and Methods

The total survey area is about 150 km², which includes the main arable soil types in the valley area. 29 soil samples were taken from the surface horizon to a depth of 30 cm in the spring of 2022. For this research the software used in mapping the soil agrochemical properties it was ArcGIS 10.5. The Inverse Distance Weighted (IDW) interpolation method of the spatial analyst extension in the ArcGIS 10.5 was used for mapping the soil agrochemical properties in Botevgrad valley. This is IDW assumes that the closest sample point is to the place whose value is to be estimated. The MS Excel 2019 was used for statistic.

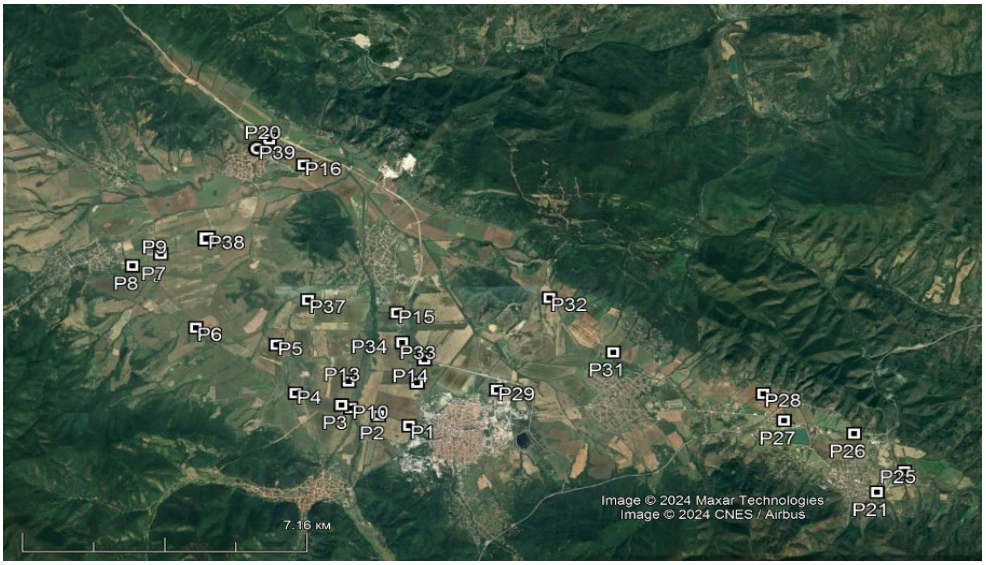

Fig. 1. The Botevgrad Valley (Bulgaria) and sampling points – Google earth.

The following methods for soil analysis were used: Soil Organic Matter (SOM, %) by the Turin method [6]; Total Nitrogen (TN, %) content, by a modified version of the classic Kjeldahl method [6]; P2O5 (mg/100g) and K2O (mg/100g) [7]; NH4 and NO3 [8]; Total P (phosphorus) and Total K (potassium) by performed by decomposition with “aqua regia” (ISO 11466:1995) and ICP-OES determination.

3 Result and Discussion

Agrochemical assessment of soil indicators requires knowledge of the initial state, the natural variation, the sensitivity of the indicators to certain impacts and the critical values that indicate a transition to another state. Nitrogen is the element in the soil that is most often in short supply in the area of Botevgrad valley. In arable lands, the intensive cultivation of crops contributes to this. The east parts of the valley have low amount of total nitrogen (fig 2).

Table 1. Descriptive statistic of soil agrochemical properties.

	NH_4^+	NO_3^-	P_2O_5	K_2O	Total N	Total P	Total K	SOM
	mg/kg	mg/kg	mg/100g	mg/100g	%	%	%	%
Mean	26.96	21.99	5.11	16.12	0.16	0.08	0.51	2.21
St/ Error	2.12	2.93	1.00	2.10	0.01	0.00	0.04	0.15
Median	27.20	20.40	3.41	13.20	0.16	0.08	0.48	2.10
Mode	35.42	0.01	4.28	12.30	0.16	0.08	1.12	2.10
Sta Dev.	11.42	15.76	5.36	11.33	0.04	0.02	0.23	0.82
Range	61.49	72.81	24.38	56.90	0.21	0.07	0.90	4.08
Minimum	9.07	0.01	1.19	7.50	0.10	0.05	0.22	0.97
Maximum	70.56	72.82	25.57	64.40	0.32	0.12	1.12	5.05
Samples	29	29	29	29	29	29	29	29

The mean value for total nitrogen is about 0.16 % that is also low (table 1). Total nitrogen content in soil is commonly found in the range of 0.1% to 0.4% in Bulgaria. The studied region is known with poorest soils of Bulgaria.

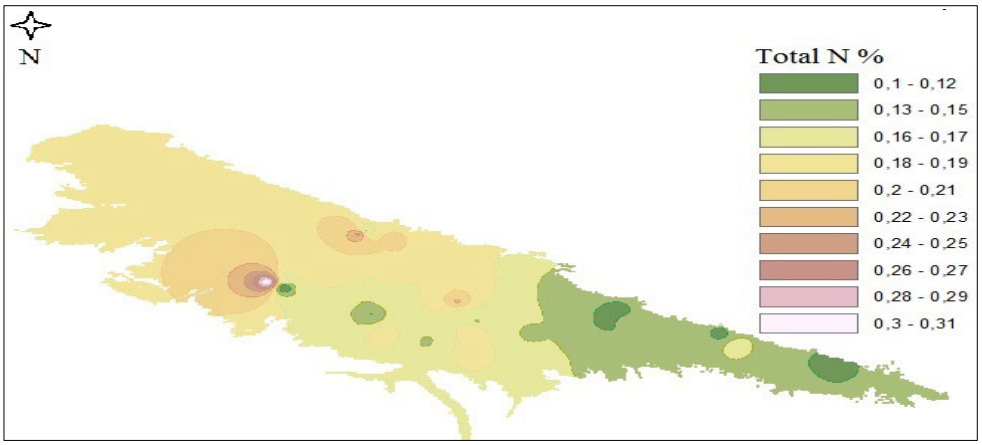

Fig. 2. Interpolation map (IDW) of total nitrogen content in Botevgrad valley

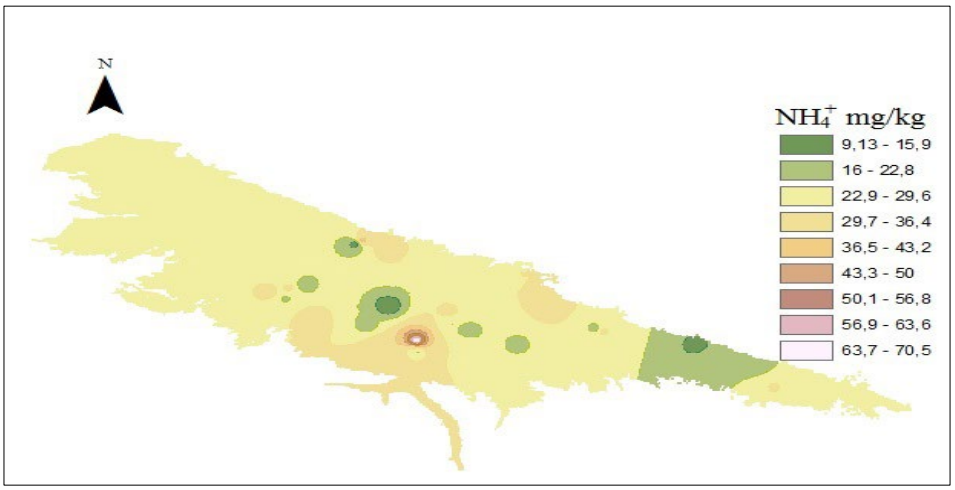

Fig. 3. Interpolation map (IDW) of ammonium content in Botevgrad valley

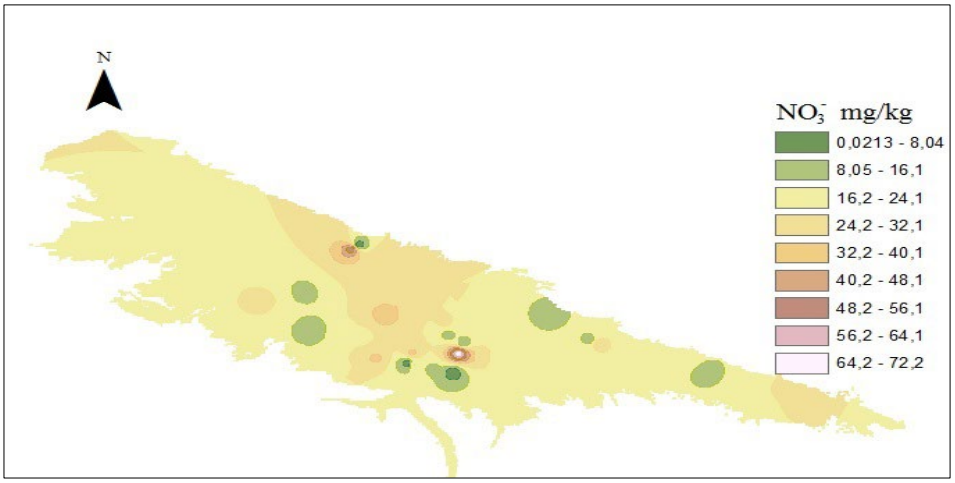

Fig. 4. Interpolation map (IDW) of nitrate content in Botevgrad valley

The levels of ammonium (NH_4^+) and nitrate (NO_3^-) in soil are important indicators of soil fertility and nutrient availability for plants. Both ammonium and nitrate are forms of nitrogen are in low qualities in studied soils, especially nitrate form [9]. In soil, nitrate (NO_3^-) is generally more mobile than ammonium (NH_4^+). The mobility of these nitrogen forms is influenced by their chemical properties and interactions with soil components that is the reason why it is in lower qualities (table 1 and fig. 3 and fig. 4).

Phosphorus in the soil is found in organic compounds and in minerals. However, the amount of readily available phosphorus is very low compared to the total amount of phosphorus in the soil. Typically, soils with less than 0.1% total phosphorus are considered low in phosphorus [10]. The results shows that mean values of total phosphorus are about 0.08% (table 1 and fig. 6).

Available phosphorus in soils refers to the portion of total phosphorus that is soluble. The fact here is that total phosphorus correlates with available phosphorus (table 2) and fig 5 and 6. As we can see on the both figures the amount of phosphorus is low. The mean value and the mode are close 5.1 and 4.8 mg/100g, which is insufficient. In past years, the fertilizers are very expensive and many farmers did not use phosphorus and potassium fertilizers.

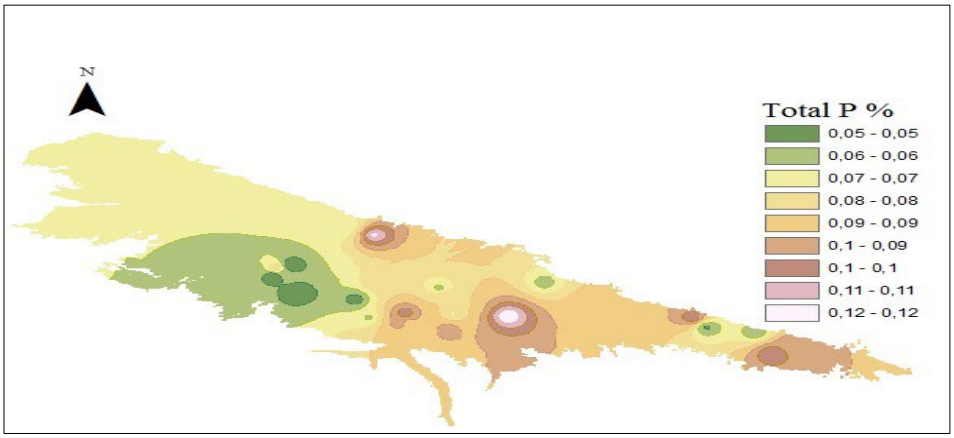

Fig. 5. Interpolation map (IDW) of total phosphorous content in Botevgrad valley

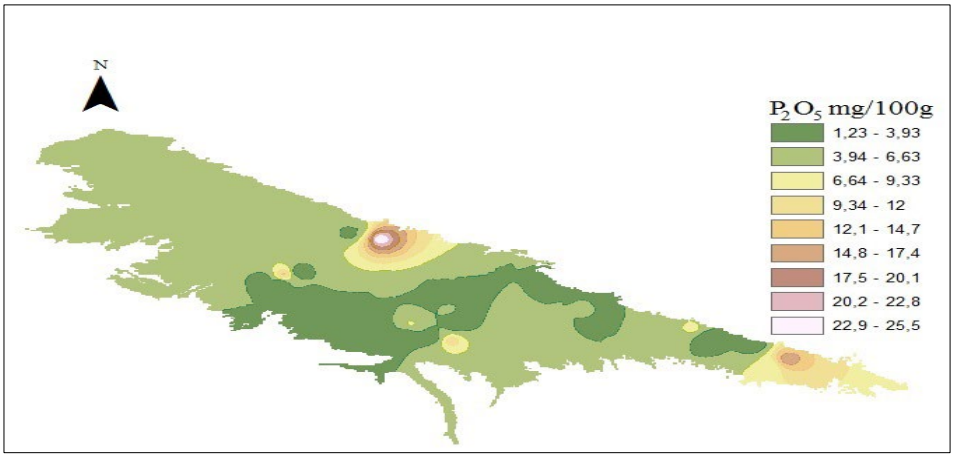

Fig. 6. Interpolation map (IDW) of available phosphorous content in Botevgrad valley

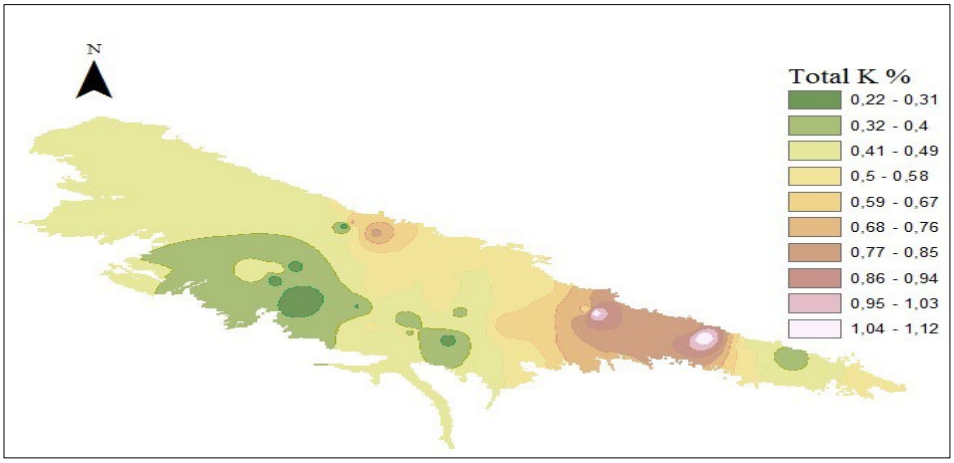

Fig. 7. Interpolation map (IDW) of total Potassium content in Botevgrad valley

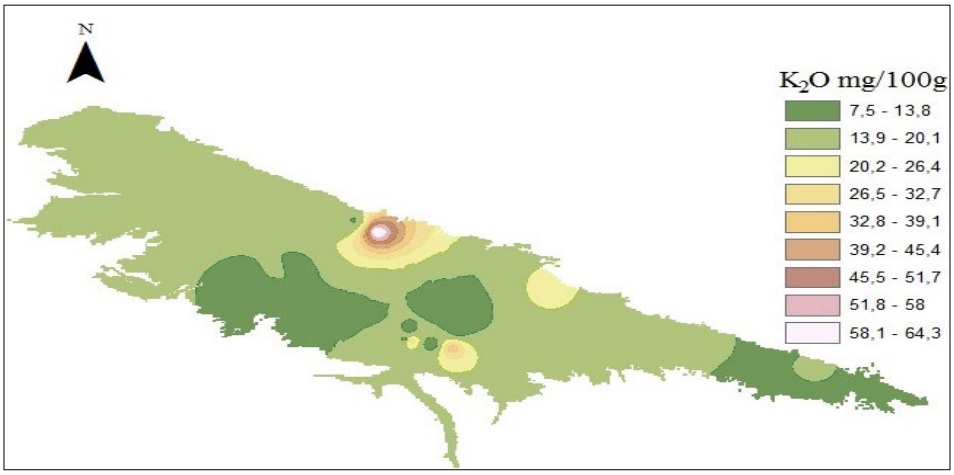

Fig. 8. Interpolation map (IDW) of available Potassium content in Botevgrad valley

Together with nitrogen and phosphorous, potassium is a primary nutrient that facilitates the optimal growth. Unfortunately in modern rural agriculture, potassium as a nutrient is underestimated, and the timing and rates of fertilization are often based on optimal nitrogen supply [11]. The total potassium content in the surface horizons of Bulgarian soils is usually between 1.0 and 2.5% of the soil mass. In some clay soils, the potassium content can reach up to 3 - 4%, and in sandy soils, as well as in peat soils, below 0.5 [12]. In our results total potassium is between 0.22 – 1.12 %, which is lower than other soils (table 1 and fig 7). It's important to note that the optimal levels of potassium can vary depending on the specific crop being grown, soil type, and other factors.

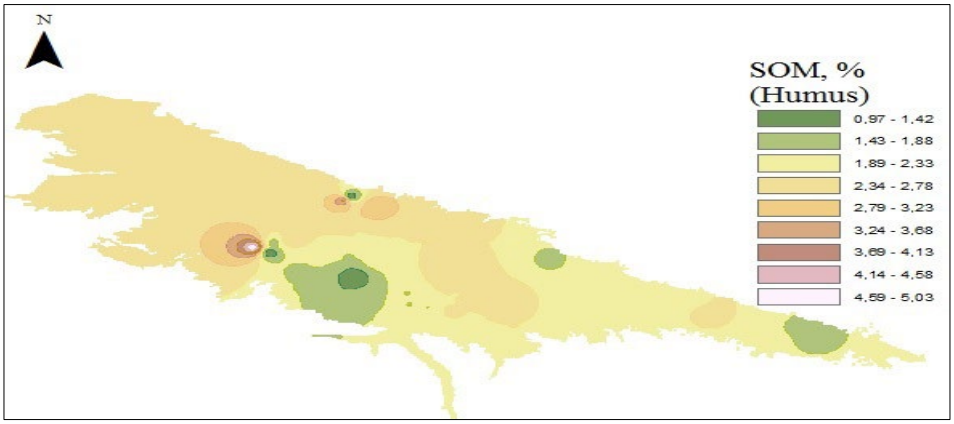

Fig. 9. Interpolation map (IDW) of soil organic matter content in Botevgrad valley

Available potassium in the soil refers to the portion of total potassium that is in a form readily accessible for plant uptake. Unlike total potassium, which includes both soluble and insoluble forms, available potassium represents the pool of potassium that plants can use for their growth and development. Obtained results of available potassium show satisfactory content form 7.5 up to 64.40 mg/100g with mean value about 16.1 mg/100g . The reason for this the fact that weathering minerals have good amounts of potassium and it may come naturally.

Table 2. Statistical correlation analysis of agrochemical properties

	NH_4^+	NO_3^-	P_2O_5	K_2O	total N	total P	total K	SOM
NH_4^+	1							
NO_3-	-0.007	1						
P_2O_5	0.163	0.012	1					
K_2O	0.072	-0.005	0.760	1				
total N	0.128	0.306	-0.025	0.113	1			
total P	0.195	0.010	0.627	0.405	-0.156	1		
total K	-0.080	-0.047	0.071	0.218	-0.106	0.206	1	
SOM	-0.164	0.250	0.080	0.187	0.819	0.054	0.088	1

The content of soil organic matter (SOM) is important indicator for soil fertility. It contains about 98–99% of the total amount of nitrogen in the soil, up to a third of the phosphorus and potassium humates in humic acids [13]. The relation between SOM and total nitrogen can be seen in statistical correlation analysis and it is about 0.819 (table 2). The amount of SOM is close to the values which are typical for arable lands in Bulgaria between 2 – 3 % and it is the same in figure 9. The lowest values are in the urban area. The highest values are in the place with marshes, where Gleysols are spread.

4 Conclusion

The agrochemical assessment of soil was made with gird of 29 sample points and interpolation method of Inverse Distance Weighted (IDW). The studied area is with low fertility status in Bulgaria. The amount for total nitrogen is too low about 0.16 %. The available nitrate and ammonium nitrogen are low quintiles between 27 to 30 mg/kg.

Other agrochemical components such as phosphorous and potassium are also too low, possible reason for that is the absence of fertilizing application in studied area, because of high cost. In spite of that natural content of potassium helps to improve its shortage, but phosphorous needs appropriate addition.

Soil organic matter is also in lower quantity in arable land, between 2 – 3 %, but these values are something typical for whole agricultural lands in Bulgaria. The areas without agriculture in Botevgrad valley usually have soil organic matter about 5. %.

Spatial distribution analysis is a valuable tool for determining nutrient availability and nutrient management practices to optimize crop production with minimizing environmental impacts.

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