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RESEARCH ARTICLE

COMPARISON of the DISTRIBUTION of ENVIRONMENTALLY HAZARDOUS ELEMENTS in COAL with KRIGING and IDW METHODS (TEKİRDAĞ-MALKARA COALFIELD)

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ABSTRACT

Coal is a fossil fuel that can have negative impacts on the environment and human health during extraction, transportation, and burning. In this study, samples were collected from eight boreholes in the Tekirdağ-Malkara coalfield and the major-trace element analysis was performed. Lithology data obtained from boreholes constitute well logs. Interpolation forms the basis of log correlation. The study aimed to determine the local areas that may pose a risk after selecting the interpolation method that provides the most accurate results directly in the study area. Among the elements, those that may cause environmental and human health problems were selected and divided into four groups according to their hazard class. The distributions in the whole field were estimated by Kriging and Inverse Distance Wighting (IDW) interpolation methods. These two interpolation methods were evaluated with a selected test probe and the Kriging method was determined to provide the most accurate results. With this method, the accuracy of results obtained with the elements in the hazard class were as follows: Hg and Cr 100%, Se 98.86%, Cd 75%, As 66.2%. After determining Kriging as the method to be applied, a re-classification analysis was carried out, and estimates made in the field were compared with coal from Turkey, the US, China, and the average upper continental crust. As a result of this comparison, the elements with the highest rate of distribution in all averages were determined as Be, Cu, V, and the elements with the lowest distribution rate were Mn, Mo, P, Sb.

Keywords: *Major-trace element, IDW, Kriging, Coal, Interpolation*

1. INTRODUCTION

Different methods are used in mineral exploration with the development of technology [1]. By processing the lithological data obtained from mineral exploration drillings with various software, many analyses such as minefield reserve, seam continuity, and the tectonic effect can be performed [2]. In addition, the distribution estimates in the minefield can be made by processing the laboratory test results applied to the samples taken from the boreholes in this software. One of them is the results obtained by major-trace element analyses. It is possible to create risk areas at the mining site in cases where the elements are above the limit values. Interpolation forms the basis of all these estimation methods. Interpolation, with a simple definition, is the determination of unknown values using known

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values. It can be expressed as the estimation of empty spaces with the help of existing numerical values in cases where the data are scattered or heterogeneous. IDW (Inverse Distance Weighted) is an interpolation technique used to determine cell values of non-sampled points with the help of values of known sample points, and points are detected in unknown areas by going further away from the known point. Since it is an estimation method, the further away and the greater the distance, the less the effect on the cell value calculation will be. Kriging can be defined as the interpolation method used to estimate the measurements of unknown points by using the measured values in proportion to their weight. The measured points and the points to be predicted are determined depending on the distance. An adjustment is made within the whole field based on the regional variation theory. Therefore, it has been observed that the Kriging method is generally used in earth sciences [3]. These two methods were used in the study, and it was aimed to determine which method obtained more accurate borehole sample results.

Spatial surface modeling, groundwater, precipitation, mining and geology studies were carried out to compare different interpolation methods. For the estimation of element distributions in rocks, additions can be made to Geographic Information System (GIS) software with different purpose-oriented software tools. As a result, three results can be derived. The first of these is the derivation of major-trace element interpolation maps and the establishment of structural relationships, the second is the generation of lithological maps in which the geochemical diagrams of the rocks and the main element data are based on geostatistical interpolation, and the third is the questioning of certain parameter estimation by creating interpolation maps [4]. Potential coal sites can be determined with bivariate statistical approaches at mining fields [5]. The Kriging interpolation method has shown realistic results in determining lignite reserves and the amount of stripping [6]. Kriging, IDW, Spline techniques can be used to estimate the distribution of elements such as As, Pb, which are environmentally hazardous elements, and the volume of the cover layer to be removed from these areas can be determined by 3D modeling [7]. In the comparison of three-dimensional stratigraphic models with Kriging, IDW and closest neighbor methods, the closest neighbor model was observed as the most suitable method in stratigraphic modeling, and Kriging was observed as the closest model in three-dimensional prediction [8]. The reason why the accuracy is lower than the numerical tests in the comparisons made in the application of Spline, IDW, Kriging methods in the coal may be the position differences of the lattice center points of the surfaces whose points are simulated [9]. Estimation methods are also used in water resources. It has been determined that the fuzzy Kriging method exhibits less error than the ordinary Kriging, IDW, and Theissen polygons in cases that vary over time such as a groundwater table [10]. Interpolation methods used to estimate the transparency of water resources from data obtained from satellite data have yielded highly accurate results [11]. While the results are limited in the estimation of seawater mixing with groundwater, the results on the quality degradation elements of the water are more accurate [12]. Precipitation estimates were compared using IDW and Kriging methods, and as a result of the study, it was determined that the estimates obtained by the IDW method gave better results [13]. Although precipitation estimates using Kriging, IDW, Spline support the new method, these have significant differences and are unsatisfactory [14]. In another study conducted in earth sciences, the most suitable landfill site in a province was determined by using the Kriging interpolation method and Multi-Criteria Decision Analysis (MCDA) [15].

2. GEOLOGICAL SETTING

The study area is located in the Thrace press in the Thrace Sub-region of the Marmara Region of Turkey (Figure 1). The Thrace basin is an intermountain Tertiary basin containing Middle Eocene-Pliocene aged units [16, 17]. Thrace basin is particularly important in terms of coal potential as well as hydrocarbon potential. Eocene aged sediments consisting of conglomerate, sandstone, siltstone, claystone, shale, tuffite and limestone units overlie the basement rocks in the basin (Figure 2). Oligocene deposits begin with the Mezardere Formation, which consists of sandstone containing claystone and tuffite in places. It continues upwards with the Osmancık Formation, which consists of sandstone, and ends with the Danişmen Formation, which includes layers of shale, claystone, sandstone, conglomerate, and coal. On the outskirts of Istranca, where there are no formations of Osmancık and Mezardere, the Danişmen formation unconformably overlies older units in regions [17]. Over the Danişmen formation respectively Miocene aged volcanics, sandstone, siltstone and limestone deposits, Pliocene aged conglomerate and claystone overlie unconformably.

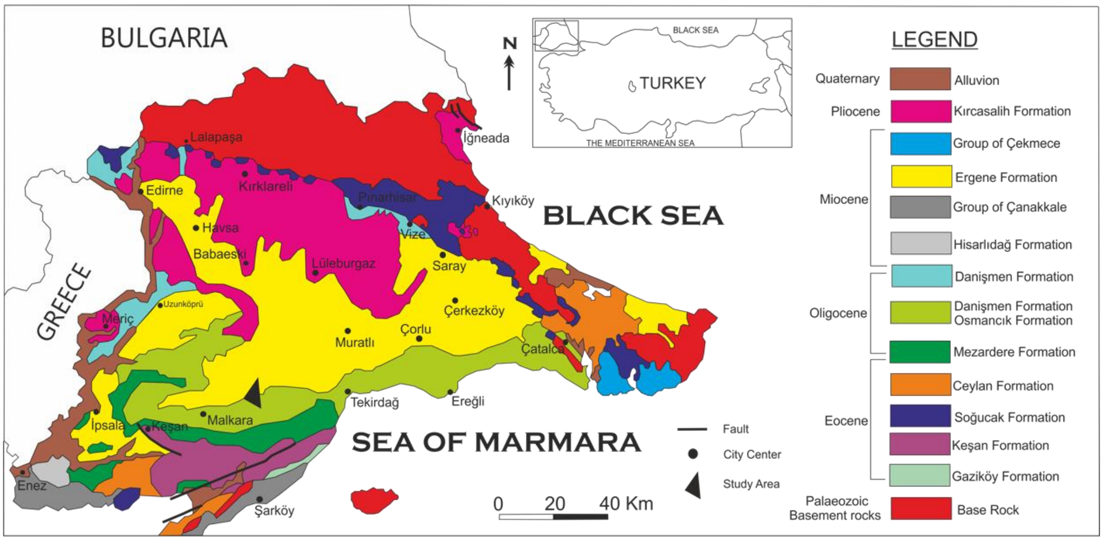

Figure 1. Geological map of Thrace Basin (Modified from [17-20]).

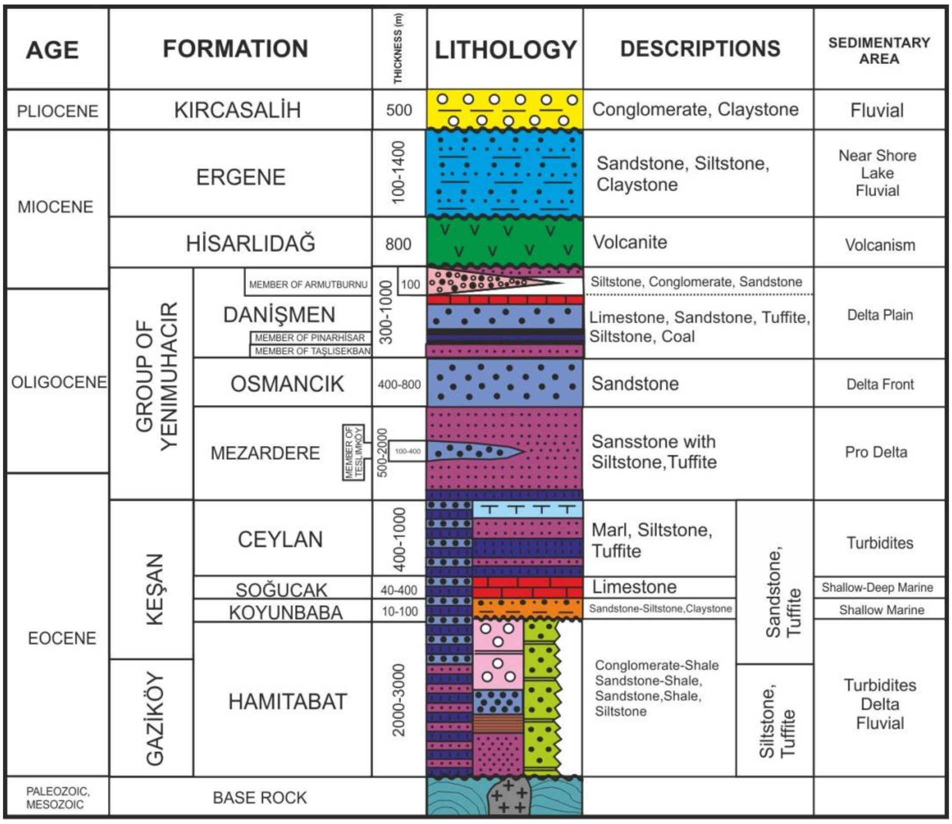

Figure 2. Generalized stratigraphic section of the Thrace Tertiary Basin (Modeified from [21]).

Deltaic and lacustrine environments were formed in the Oligocene with regression in the basin. Coals of the Thrace Basin are also included in the units deposited in these environments [22]. Coal-bearing units that are the subject of the study are found in the Oligocene aged Danişmen formation. Three members have been defined within the Danişmen Formation: Taşlısekban member consisting of conglomerate, sandstone, and marl, Pınarhisar member consisting of limestone and Armutburnu member consisting of conglomerate, sandstone, and claystone. The formation represents the delta plain facies which is at the top unit of the declining delta system. It consists of lake, swamp, flood plain and fluvial sediments [17]. The thickness of the formation reaches 1000 m in places. Different researchers have assigned different ages to the formation: Early Oligocene [23], Middle Oligocene [24-26], Late Oligocene [27, 28], Late Oligocene-Early Miocene [29, 30].

When the loggings from the eight boreholes in the study are examined, Coal seams were detected that are cutting sandstone, siltstone, claystone intercalation. These levels are like the general features of the Oligocene aged Danişmen Formation. The type of coal is lignite, and it is partially clayey. Organically dyed lignite fragments and fossils may be present within the siltstone, sandstone and claystone levels at the bottom and ceiling of lignite veins. Lignite veins start at 25 meters and continue to a depth of 550 meters. The thicknesses of lignite veins vary between 25-100 centimeters.

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3. MATERIALS AND METHODS

The study area is located in Malkara, Suleymanpasa, and Hayrabolu districts of Tekirdag province. The area is 15 km^2 and is represented by a triangular polygon. There are 8 boreholes [TD-155 (x:45 34 442 y:05 05 038 z:95), TD-147 (x:45 34 580 y:05 06 670 z:132), TD-151 (x:45 34 398 y:05 07 727 z:157), TD-152 (x:45 34 535 y:05 08 240 z:160), TD-153 (x:45 32 990 y:05 08 120 z:168), TD-133 (x:45 35 960 y:05 07 745 z:90), TD-129 (x:45 37 155 y:05 07 785 z:90), TD-131 (x:45 37 507 y:05 07 817 z:104)] in total in the study area. Borehole selection was made in north-south and east-west section lines to represent the field (Figure 3).

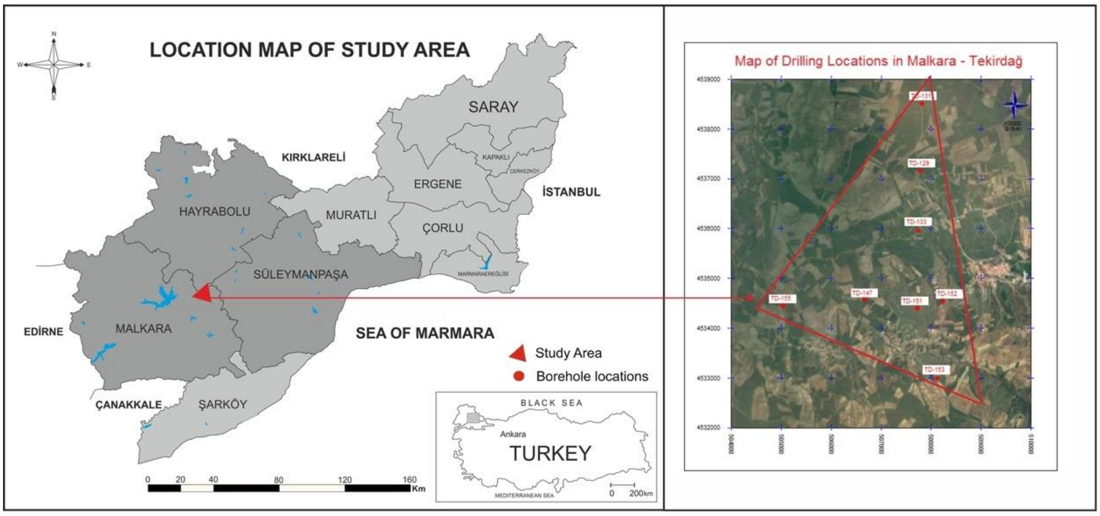

Figure 3. Location map of study area and boreholes.

Well logs were created from the lithological data obtained from eight exploration boreholes in the study area. Since Kriging is the most used interpolation method in earth sciences, NetPro/Mine, which is a correlation software that creates these logs with Kriging, was preferred.

In this study, it was aimed to calculate the proximity values of the actual results obtained from the borehole samples and the results obtained as a result of interpolation. The following method was used in the study. Numerical variables are presented with descriptive statistics such as mean and standard deviation.

Average value change amount = (Maximum value - Minimum value) / Number of class intervals
Difference = Approximate value range average - Actual value
Error Rate = (Difference / Average change amount) * Total number of class intervals
Prediction Accuracy Rate = 100 - Error Rate

If the actual value is lower than the minimum value in the boreholes, then these operations were not performed, and the following formula was used for the difference. The rest of the calculations were made in the same way.

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Difference = Minimum borehole value - Actual value

The reason for calculating the difference in this way is that when interpolated, the minimum and the maximum borehole value range is taken as a basis. For example, while the minimum class range value in As study is 5.98 ppm, the actual value is 3.15 ppm. Since it is impossible to obtain this value, it is more logical to calculate how close it is to the minimum borehole value in a similar situation.

Major-trace element analysis was performed on the samples taken in the ACME analytical laboratory (Canada). Major oxides were determined by the ICP-AES method and trace elements were determined by ICP-MS method. The same procedure was applied to each sample and standardization was achieved. As a result of the analyses, the rates of the elements available in the samples were determined. Borehole averages were calculated from the results obtained for each element. Precision and relative standard deviation (RSD) values were calculated for the quality control elements. (Table 1).

Table 1. The average presence of environmentally hazardous elements in the borehole samples (those marked with * are given in %, other values are given in ppm).

Element Group	**Elements**	**TD-129 (n=8)**	**TD-131 (n=7)**	**TD-133 (n=7)**	**TD-147 (n=9)**	**TD-151 (n=5)**	**TD-152 (n=7)**	**TD-153 (n=4)**	**TD-155 (n=7)**	**RSD %**
Group 1	As	11.52	9.13	7.97	11.10	3.15	5.93	14.35	6.18	
	Cd	0.20	0.25	0.23	0.20	0.15	0.17	0.20	0.20	
	Cr*	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.03	12.86
	Hg	0.09	0.05	0.09	0.11	0.07	0.06	0.11	0.06	
	Se	1.58	1.40	1.40	1.10	0.50	1.70	6.00	1.15	
Group 2A	Mn*	0.03	0.02	0.02	0.03	0.03	0.02	0.03	0.03	
	Mo	2.46	2.10	1.17	1.93	0.55	0.97	1.10	1.13	
	Ni	92.20	69.00	105.33	145.25	122.00	83.00	219.00	87.50	5.94
	Pb	10.50	9.53	8.80	10.50	15.00	8.00	14.90	7.30	
Group 2B	Be	2.00	3.67	4.00	2.50	1.50	2.00	2.50	2.75	12.86
	Cu	31.28	33.13	30.77	36.75	27.85	55.50	42.10	38.10	
	P*	0.08	0.01	0.02	0.02	0.01	0.02	0.02	0.02	
	Th	6.50	5.73	5.00	6.83	9.05	4.70	7.65	4.70	
	U	5.24	2.97	5.00	4.70	2.75	2.50	5.80	3.40	0.92
	V	76.00	102.00	135.00	123.75	113.50	126.67	150.50	90.00	2.12
	Zn	35.60	34.67	33.33	51.50	50.50	39.33	65.50	32.25	
Group 3	Ba	291.80	249.00	234.67	228.75	310.50	268.00	276.50	215.25	1.19
	Co	9.54	12.20	17.73	20.95	15.50	16.67	25.05	14.78	2.32
	Sb	0.38	0.20	0.83	0.35	0.20	0.23	0.50	0.45	
	Sn	1.00	1.00	1.33	1.50	2.00	1.00	1.50	1.25	
	Ti*	0.16	0.18	0.21	0.23	0.28	0.21	0.29	0.18	

Environmentally important elements can be examined in four parts as Group 1, Group 2A, Group 2B, and Group 3 [31]. The most hazardous of these element classes in terms of environmental and human health is Group 1 (Arsenic, Cadmium, Chromium, Mercury, Selenium), and the other element classes from the most to the least hazardous are Group 2A (Boron, Chlorine, Fluorine, Manganese, Molybdenum, Nickel, Lead), Group 2B (Beryllium, Copper, Phosphorus, Thorium, Uranium,

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Vanadium, Zinc), and Group 3 (Barium, Cobalt, Antimony, Tin, Titanium), respectively. Distribution maps of elements evaluated in four different hazard groups as a result of major-trace element analysis were created with Quantum GIS, an open source GIS software.

These element values are known at the borehole points. However, the values of these elements are not known in the areas that are in between and are not borehole. Since the field represents a local area, it is possible to estimate these gaps from the data obtained by boreholes. The interpolation method is used for this purpose. In this study, two interpolation methods were applied and compared. It was aimed to determine the most suitable method for coal element values. IDW and Krigging methods were applied. TD-151, which is located at the intersection of north-south and east-west section lines, was used for testing purposes. Both interpolation methods were used without taking into account the TD-151 borehole samples. Since the element values in this borehole are known beforehand, it was tried to determine which method gave the most accurate value.

After using Kriging as the interpolation method, the maps obtained were converted to Raster data format. With this technique expressed in cells, the range of values each pixel corresponds to was determined using the Reclass (reclassification) technique. The diagram showing the flow of the study is given in Figure 4.

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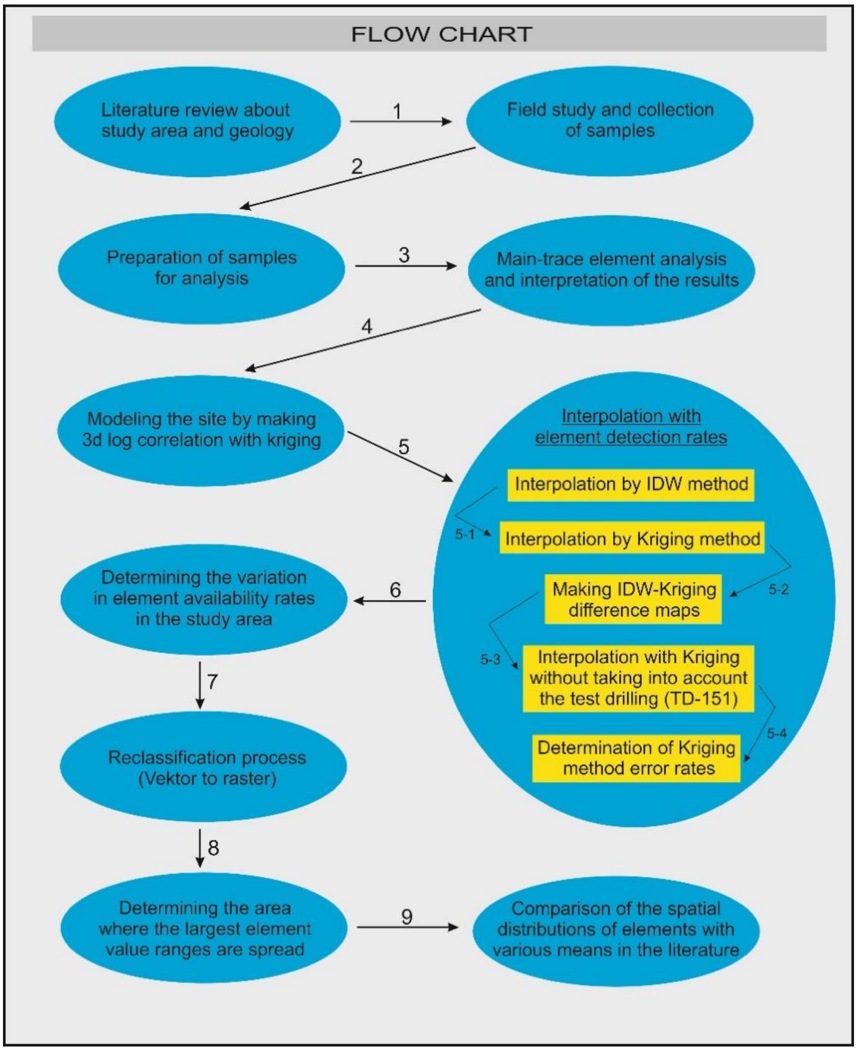

Figure 4. Flow chart of the study.

4. RESULTS AND DISCUSSION

The correlation formed according to the lithology data processed in the NetPro/Mine software was compared with the strut sections. Two section lines were examined on the east-west (Figure 5) and north-south (Figure 6) lines. In the software, similar results were obtained in both section lines, with ceiling lignite at the top, floor lignite at the bottom, and a layer of clayey lignite in between. The accuracy of these findings was tested by comparing them with the seams in the strut sections. Highly accurate results were observed for both section lines. The increase in the number of coal seams on the north-south section line from south to north shows that tectonism has an effect on coal formation in the north of the study area. While the clayey lignite layer was not found in the south of the study area, it was observed that it was formed gradually towards the north. There are more stable deposition

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conditions where tectonism has less effect on the east-west line. It was found that the clayey lignite seam disappeared to the east of this section line.

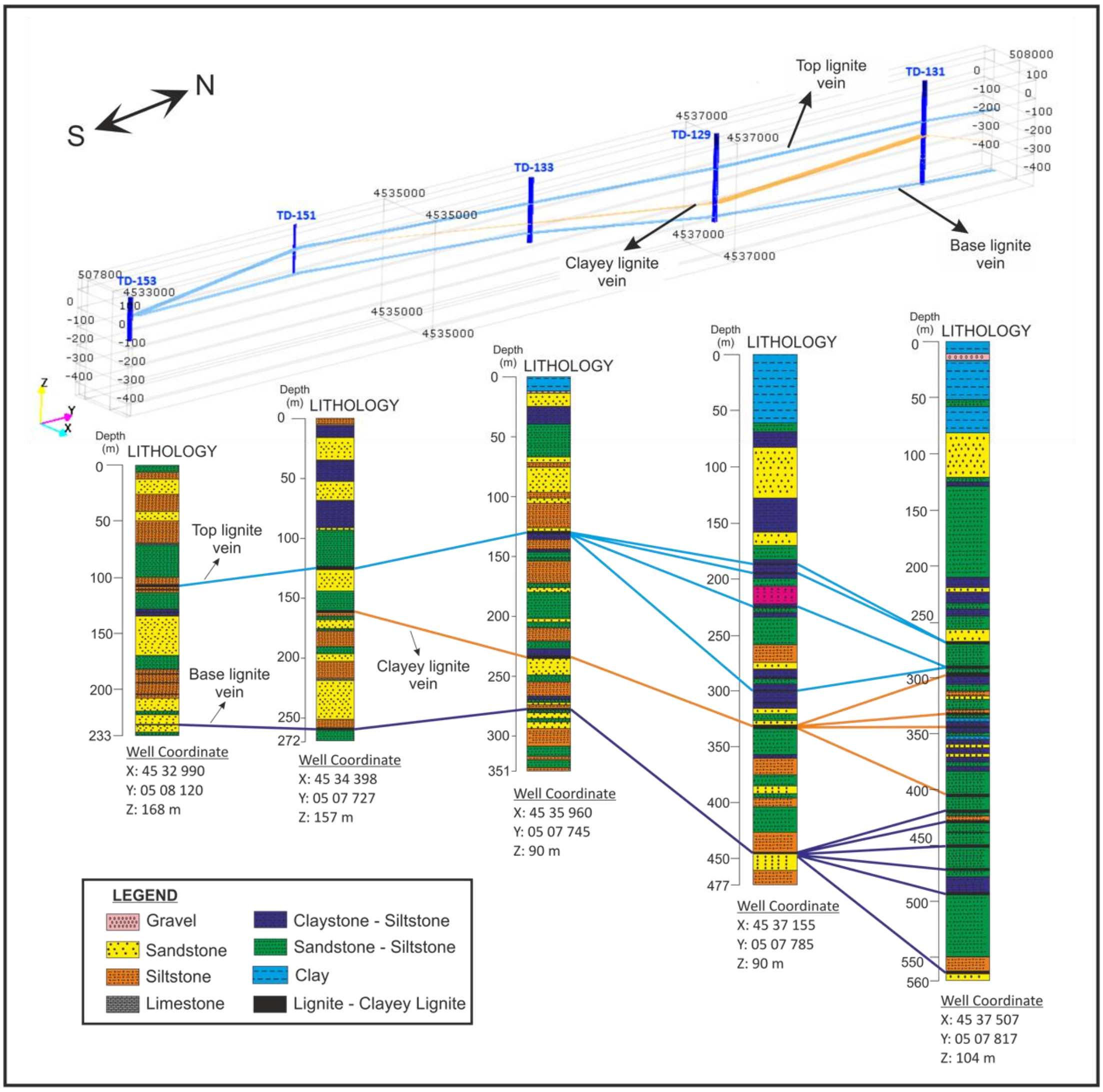

Figure 5. North-south line created with Kriging and strut sections (ceiling, bottom coal lode and clayey lignite lode).

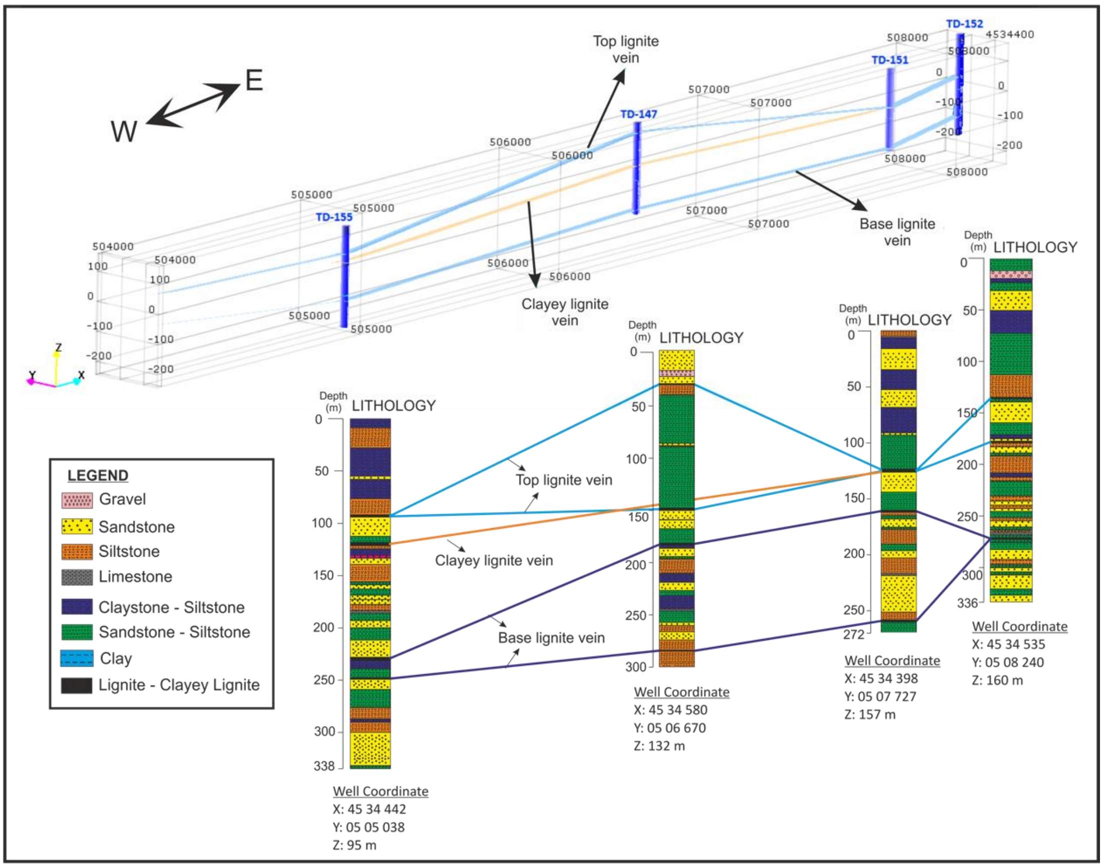

Figure 6. East-west line created with Kriging and strut sections (ceiling, bottom coal lode and clayey lignite lode).

4.1. Estimating Element Distributions

The spatial spread estimates were made by applying IDW and Kriging interpolation methods of the elements. The study was conducted for all element classes including Group 1, Group 2A, Group 2B, and Group 3, and similar results were observed. The spatial spread estimates of Group 1 (the most hazardous element class) elements of As (Figure 7), Cd (Figure 8), Cr (Figure 9), Hg (Figure 10), Se (Figure 11) were made by IDW and Kriging methods.

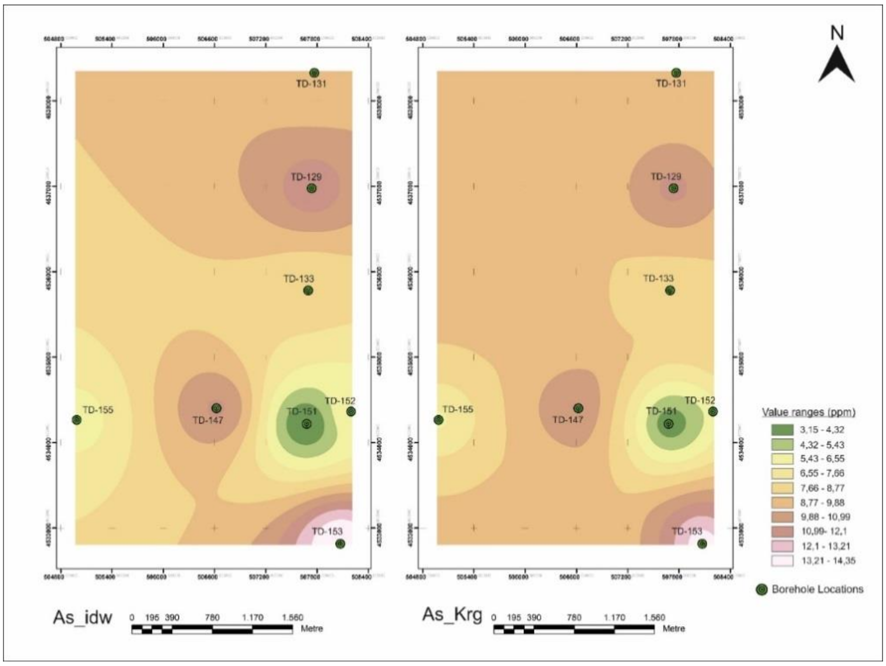

Figure 7. Areal spreading of As by Kriging and IDW.

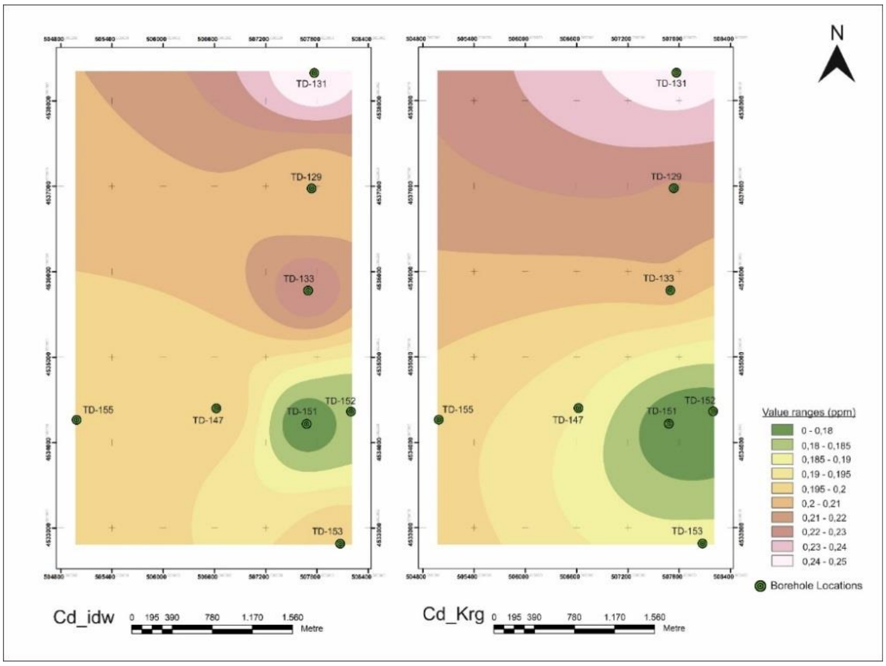

Figure 8. Areal spreading of Cd by Kriging and IDW.

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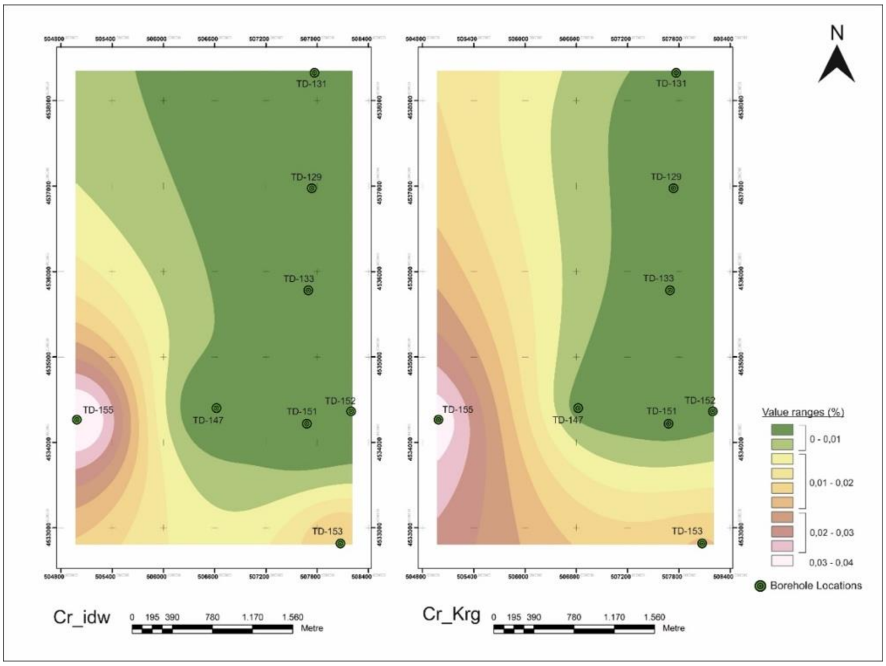

Figure 9. Areal spreading of Cr by Kriging and IDW.

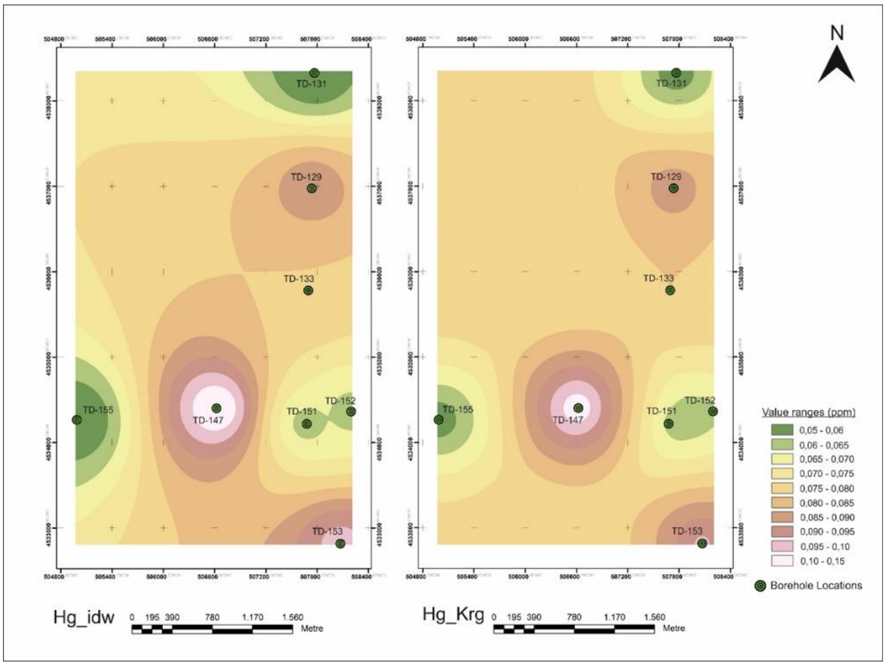

Figure 10. Areal spreading of Hg by Kriging and IDW.

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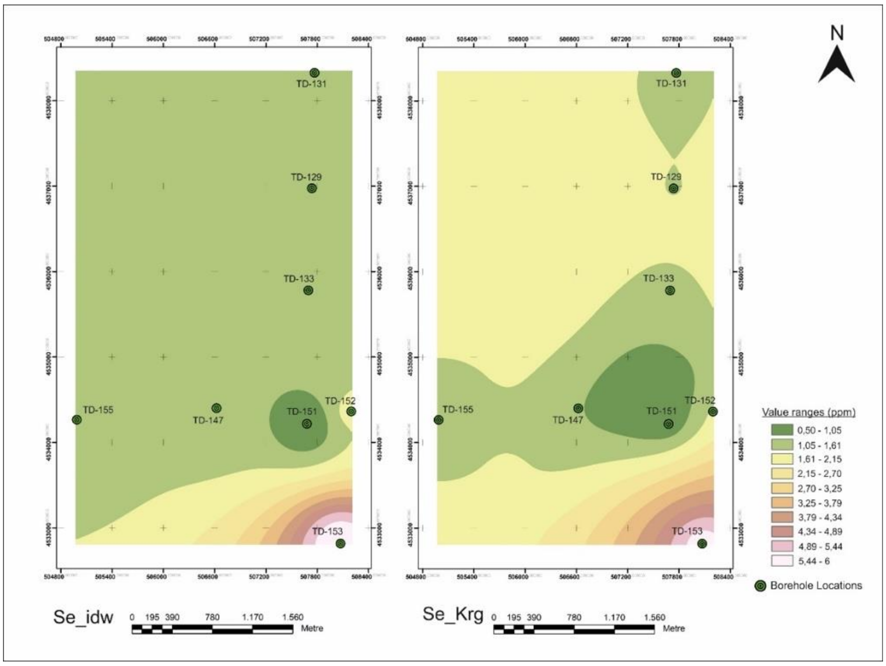

Figure 11. Areal spreading of Se by Kriging and IDW.

In line with the differences considered, the areas that gave the same result in both methods are white and in shades of white. This is why the spots where there are boreholes are white or in shades of white. The places that are completely different as a result of the two methods are in black. The fact that the changing colors (gray and its shades) are close to black or white also determines the degree of this difference. The results obtained from the difference maps can also be interpreted as the light-colored places are the most accurate while the accuracy decreases as the color gets darker. In addition, another result that can be inferred is that the accuracy increases as the black color decreases.

When the analysis is made on the basis of elements, it can be said that As is the most accurate estimate because the results were less accurate in two small local areas in the west and east of the study area but similar results were obtained in the remaining area. Cd was observed to be dark in the east of the study area, in the part covering the area of TD-151 and TD-152, and around the TD-129. For Cr, it was determined that there are local differences in the south-west and north-west of the study area. Hg was determined to be dark in two local areas in the south-west of the study area, around the TD-151, and in a single local area in the north-east. Se also differs in two different areas. It was concluded that it was dark and different in a large area in the north-west of the study area and a small local area in the south-east (Figure 12).

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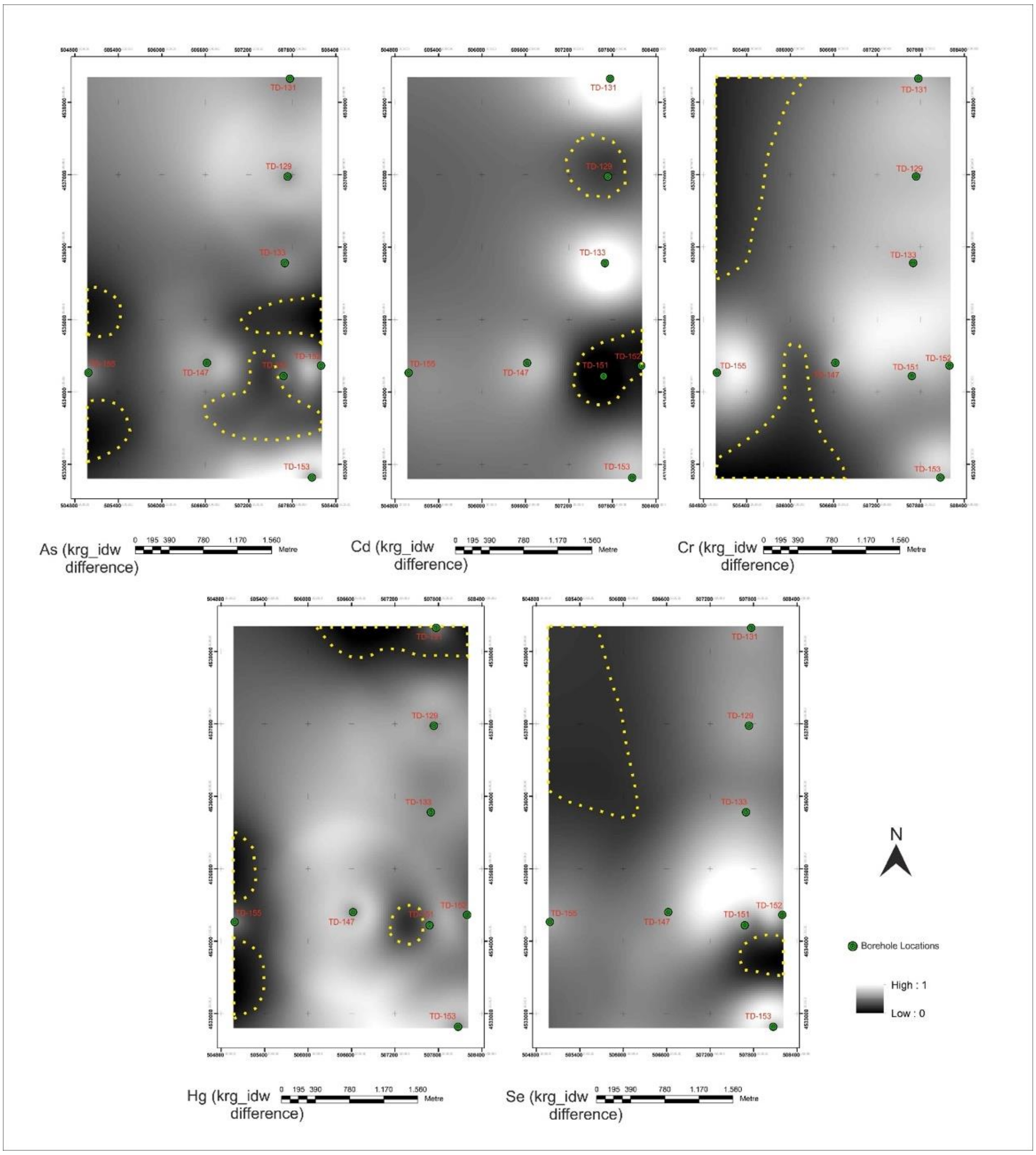

Figure 12. The display of the areas where the group 1 elements were found to differ as a result of two methods (Kriging and IDW).

The well numbered TD-151 was chosen for testing purposes as it is the borehole located on the north-south and east-west section line of the study area. Interpolation was performed for the Group 1 elements over the remaining 7 boreholes. Kriging was chosen as the method. An example map of the element As is given in Figure 13. The same procedures were applied to other elements.

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As a result of the interpolation performed with the Kriging method without adding the TD-151, the value in TD-151 was estimated and compared with the actual value. As a result, the margin of error was determined. Error rates for Group 1 elements are given in Table 2. Cr and Hg gave exact results because the values determined with the actual values coincided with the exact range. 96.86% correct results were obtained in Se and 75% in Cd. The margin of error in As was higher than the other elements, and the accuracy rate of the prediction was determined as 66.2%. The true value of the elements As, Cd, Se is lower than the minimum value in the boreholes. The second evaluation method was used to calculate the differences among these three elements in order to achieve accuracy in interpolation.

Table 2. Error and prediction accuracy rates of Group 1 elements of TD-151 borehole site made by the Kriging method.

Elements	**Error rate (%)**	**Accuracy of estimates (%)**
As	33,8	66,2
Cd	25	75
Cr	0	100
Hg	0	100
Se	9,14	90,86

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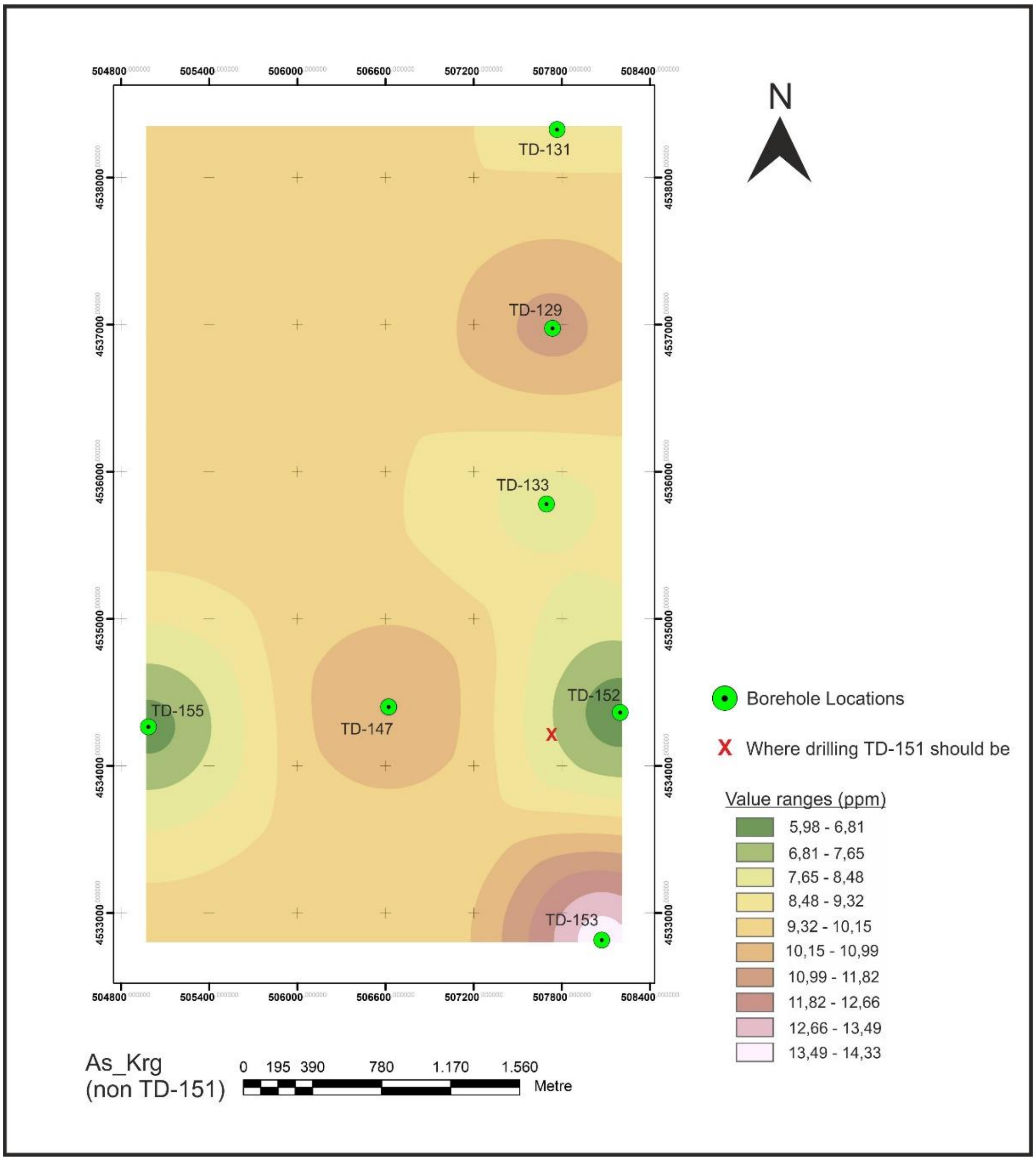

Figure 13. Kriging interpolation method of As without adding TD-151 borehole.

4.2. Determination of Environmentally Sensitive Element Distributions with Kriging Method

The average values of the element concentrations of 54 samples taken for a total of 8 boreholes were taken. It is very important to carry out this study especially for the 25 environmentally sensitive elements. The individual average values of the samples taken from each borehole were examined for environmentally sensitive elements. The elements examined in 4 groups were classified as Group 1, Group 2A, Group 2B, and Group 3.

Cr, As, Cd, Hg, Se are in the 1st group and are considered the most hazardous class. When the average values on the basis of boreholes were examined, it was determined that the Cr, Cd, and Hg elements did not show a great change and were in close concentration in 8 boreholes. It was determined that Se and As varied in borehole averages. It was observed that the As gave the lowest value in the average of the TD-155, which is located in the farthest part of the study area, and the highest value in the average of the TD-153 located in the south of the north-south section line. Although the values for the Se element also varied, it was determined that the lowest borehole value average was in the TD-151, and the highest average value of the borehole was in the TD-153 located to the south of the north-south section line.

Group 2A consisted of less hazardous elements than Group 1 and was examined in terms of Mn, Mo, Pb, Ni. It was determined that the Mn gave the lowest borehole average value in the TD-133 and the highest average value in the TD-151. The lowest borehole average value for Mo was in the TD-151 and the highest average value was in the TD-129. When the Pb was examined, the lowest average value of the borehole was seen in the TD-152, located at the intersection of the north-south and east-west section lines, and the highest average value was seen in the TD-153 located to the south of the north-south section line. Ni gave the lowest average value in the TD-155, located in the far west of the study area, and the highest average value in the TD-153, located in the south of the north-south section line.

Group 2B did not vary in the borehole averages and gave close values in 8 boreholes. Be gave the lowest average value of the borehole in the TD-152, located at the intersection of the north-south and east-west lines, and the highest average value in the TD-147. Th gave the lowest average borehole value in the TD-152 and the highest value in the TD-153. It was determined that the Mn gave the lowest borehole average value in the TD-133 and the highest average value in the TD-151. V gave the lowest borehole average value in the TD-155 in the west of the study area and the highest value in the TD-131 at the far north of the study area. Cu gave the lowest borehole average value in the TD-133, and the highest average value in the TD-153. Zn gave the lowest borehole average value in the TD-152 and the highest average value in the TD-153.

Group 3, which is environmentally sensitive but the least hazardous compared to other group elements, consists of Ti, Ba, Co, Sn, Sb. Ti gave the lowest average value in boreholes TD-152 and TD-155, and the highest average value in the TD-153. Ba gave the lowest borehole average value in the TD-155 and the highest average value in the TD-147. Co gave the lowest borehole average value in the TD-129 and the highest average value in the TD-152. Sn gave the lowest borehole average value in TD-152 and the highest average value in the TD-147. It was determined that the Sb gave the lowest borehole average value in the TD-151 and the highest average value in the TD-133.

According to these results, local concentrations of environmentally sensitive elements in the study area were determined. According to the findings, the TD-153 had the highest concentration average in the field in terms of As, Cu, Ni, Pb, Se, Th, Ti, Zn elements. When the averages of the TD-147 were examined, Be, Ba, Sn elements had the highest value. Mo and U elements gave the highest value in the average values of the TD-129. In the other four boreholes, one element had the highest value in each. It was determined that the highest concentration of Mn was in the TD-151, V in the TD-131, Co in the TD-152, and Sb in the TD-133.

When the lowest value concentrations were examined, the averages of the TD-153, TD-147, and TD-131 did not give the lowest value in any borehole. TD-152 is the borehole with the lowest concentration of elements. Pb, Be, Th, U, Zn, Ti, Sn elements gave the lowest value according to the borehole averages in this borehole. As, Ni, V, Ti, Ba had the lowest mean value in the TD-155. It was determined that TD-151 had the lowest value for Mo, Se, Sb, TD-133 for the Cu and Mn, TD-129 for Co.

According to all these findings, an increase was observed in As, Cu, Ni, Pb, Se, Th, Ti, Zn values in the southernmost of the study area. It was determined that the concentrations of Co, Sb Mo and U increased, respectively, further towards the north on the north-south section line. It was determined that the V element concentration value was high in the northernmost part of the study area. Mn value increased further from east to west on the east-west section, and Be, Ba, Sn increased gradually.

The lowest environmentally sensitive element values in the study area show that these areas are less hazardous. When examined from this point of view, Pb, Be, Th, U, Zn, Ti, Sn elements at the intersection point of north-south and east-west section lines gave the lowest value in the whole field. It was determined that the Mn and Cu gave the lowest value further north from this point, and Co in a little further north. It was determined that further towards the west from the same intersection, primarily Se, Mo, Sb, and As, Ni, V, Ti, Ba element concentrations at the farthest point gave the lowest value compared to the field average (Figure 14).

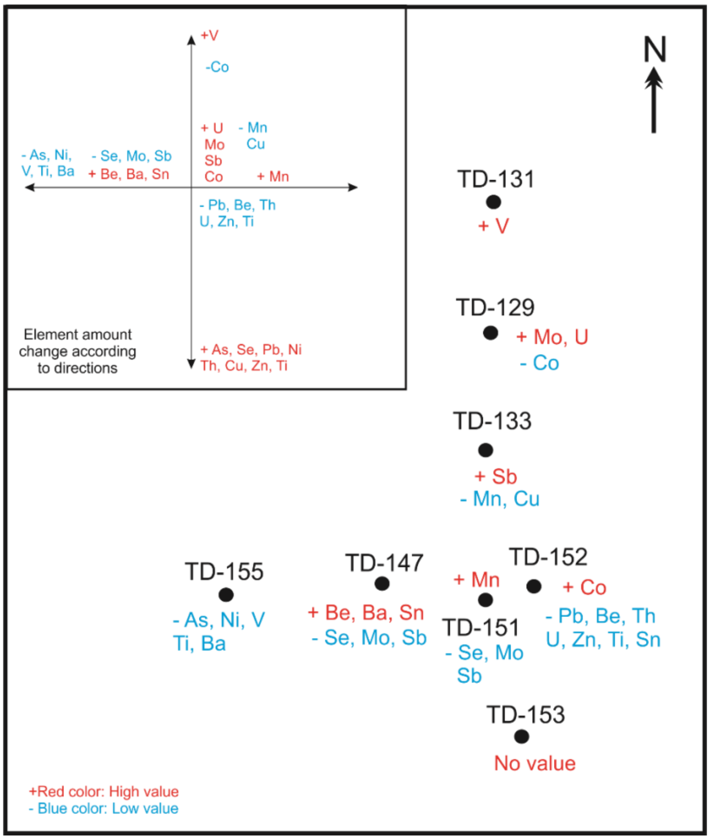

Figure 14. Change of elemental presence rates according to borehole locations.

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4.3. Spatial Spread of Element Distributions

Based on the fact that the total area is the same in each map, it was determined how many square meters each value range (color) covered (Figure 15). The list of methods applied to environmentally important elements in groups is included in Table 3 below.

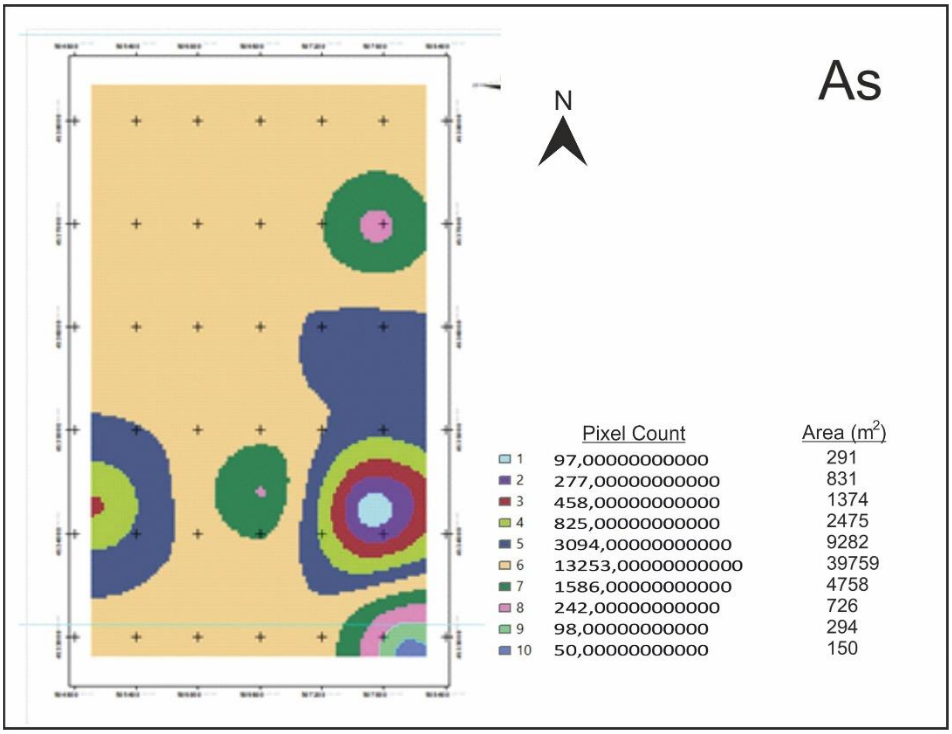

Figure 15. A sample reclassification study of As.

Table 3. The largest area spread by the elements according to their value range (those marked with * are given in %, other values are given in ppm for value range column).

Element	Largest Area (m^2)	Value range	Group
As	39759	8.77-9.88	Group 1
Cd	9183	0.19-0.20	
Cr*	18900	0-0.01	
Hg	34815	0.075-0.08	
Se	35814	1.61-2.15	
Mn*	33636	0.02-0.03	Group 2A
Mo	10344	1.30-1.40	
Ni	16650	92.55-101.68	
Pb	21867	7-7.5	
Be	54612	2.50-2.74	Group 2B
Cu	54129	36.15-38.83	
P*	37089	0.01-0.015	

Th	54297	6.01-6.43	
U	30258	4.15-4.48	
V	16398	105.96-113.37	
Zn	27870	32.25-37.1	
Ba	53493	229-236	
Co	11088	14.21-15.76	
Sb	37158	0.35-0.40	Group 3
Sn	53928	1.31-1.41	
Ti*	14760	0.17-0.19	

Results of the values obtained as a result of calculations were compared with the average values of Turkey, the US, China coals, and the average upper continental crust. The evaluation was made on 21 elements. Figure 16 contains the percentage values of the areas above the average value. Be, Cu, V remained completely above all limit values in the study area. It was observed that Mn, Mo, P, Sb were completely below all limit values in the study area. Be, Cu and V are associated with organic matter in coal. However, Be is associated with quartz and clay minerals [32], V is associated with clay minerals [33-35] and Cu is associated with sulfides [35-37].

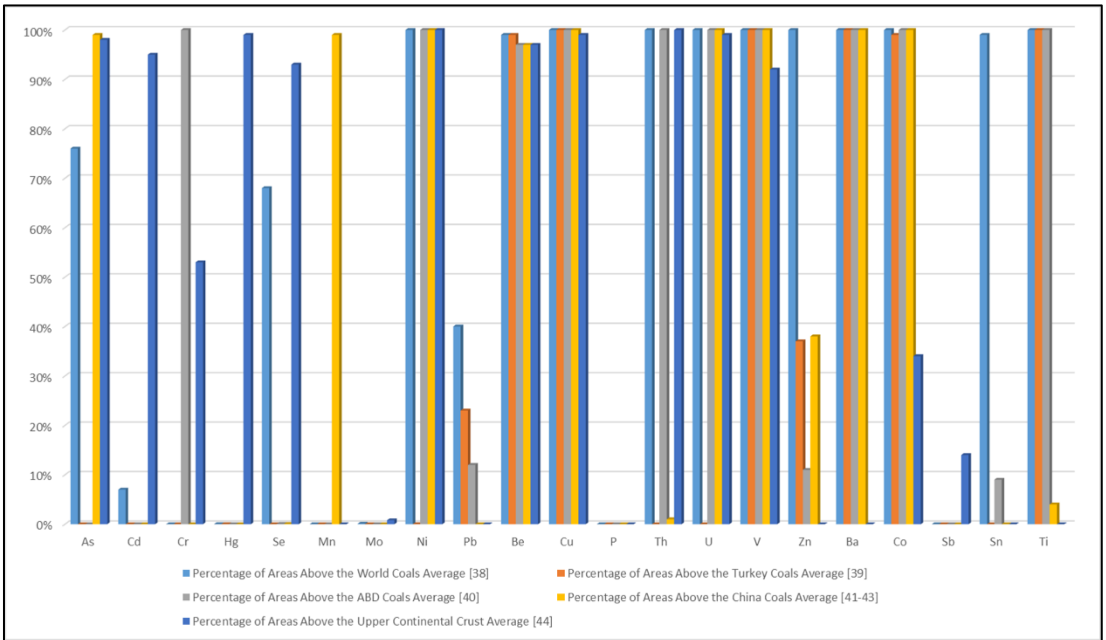

Figure 16. The comparison of areal extent of the elements with world, Turkey, USA, China and the upper continental crust.

5. CONCLUSION

The difference between methods IDW and Kriging methods was determined by maps. It was determined that the method that gave the most accurate result to the test borehole TD-151 was Kriging. According to the results obtained from the elements of the most hazardous class Group 1, the accuracy of Cr and Hg was 100%, that of Se was 90.86%, Cd was 75%, and As was 66.2%. Class ranges determined by Kriging interpolation method were re-mapped and converted into Raster (cellular) data format. As a result of the comparison of values in each cell with the average values of the world, Turkey, USA, China, and the upper continental crust, it was determined that Be, Cu, V elements were completely above the limit values, and Mn, Mo, P, Sb elements were completely below the limit values. Applying the same method with different interpolation methods in different coalfields and other mines other than coal will contribute to the literature.

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