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The Comparison of Three Environmental Metrics for Cr, Pb, and Zn in the Agricultural Region of the Mid-Continent of USA

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Abstract

The chemical and physical properties of soil are critical factors that affect human health. The current geochemical study is designed to evaluate the concentrations of heavy metals (Cr, Pb, and Zn) in the soil in Iowa (IA), Kansas (KS), and Nebraska (NE). The basic descriptive statistical results suggest that there are some limited levels of the heavy metals in the soils that come from anthropogenic inputs. The results of three environmental metrics, the enrichment factor (EF), geoaccumulation (Igeo), and potential ecological risk (PERI), have been calculated, evaluated, and compared. EF values show that soils contain minimal enrichment of Cr, Pb, and Zn in the study area. In addition, PERI values presented low risk with Cr, Pb, and Zn. However, Igeo values showed no contamination of Cr, Pb, and Zn in the study area. These results suggest that the elevated levels of these heavy metals are dominated by the historic agricultural inputs derived from long-term anthropogenic applications, especially in the regions with extensive human activities, which means that soil is the sink for heavy metals released into the environment.

Keywords

Chemical Elements, Enrichment Factor, Geo Accumulation, Potential Ecological Risk, Geochemical Maps

1. Introduction

The spatial soil characteristics differ according to many aspects such as geographic location, chemical composition, physical properties, and climate conditions (Rincon-Florez et al., 2013). The soil properties such as soil mineralogy, organic matter content, chemical compounds, pH, moisture levels, and temperature have impacts on contaminants (Estevez et al., 2008). Soil is an important source of heavy metals required for growing plants, animals, and other living forms. The top soil can be used to show the human contributions, while deeper soil (C. horizon) displays the geologic structural substrate of the soil.

Anthropogenic sources such as industrial and agricultural applications can increase the heavy metals in soil above their natural levels. Heavy metals can be accumulated over time in soil and food crops, which can affect the food chain if their concentrations exceed a specific threshold level, therefore, it can become toxic for all the living organisms in the soil (Naveedullah et al., 2013; Barbieri, 2016; Nweke and Ukpai, 2016) and for animals and humans.

Sustainability of the soil is an important global concern. The intense agricultural productivity of the selected region of three states results in many agricultural factories and processing plants, specifically ones devoted to animals and the processing of animals to prepare them for human consumption. Iowa is one of the most agro-industrial areas in the USA because it has a strong agricultural production success of feed ingredients. The questions that must be addressed is if soil actually being maintained, or do additives have a negative impact. How is this measured?

The aim of this study is to estimate potential chemical cumulative loading of Chromium (Cr), Lead (Pb), and Zinc (Zn). This is done using various contamination indices focused on three parameters: 1) enrichment factor (EF), 2) potential ecological risk index (PERI), and 3) geoaccumulation (Igeo), that can be used for determining the most effective tool to evaluate the long-term pollution in the soil (Ismaeel & Kusag, 2015).

Regional Geochemical Mapping (RGM) documents and interprets the surface geochemistry of the Earth. This knowledge is useful in environmental issues and resource exploration. Data may be acquired at different scales (samples per square kilometer), cover different areas (1. small target, 2. state size, 3. country wide), and include different chemicals (40 chemicals is standard today).

Environmental scientists search for metrics to determine relative environmental danger, risk, or hazards from chemicals. Numerous parameters or criteria have been proposed to make such measurements, and several are in frequent use (Wei et al., 2011; Edwin, 2013; Naveedullah et al., 2013; Alghobar & Suresha, 2015; Dartan et al., 2015; Nweke & Ukpai, 2016; Chee Poh & Tahir, 2017; Davoodi et al., 2017). No one parameter has distinguished itself as notably the best, and uncertainty exists as to their relative values.

The present study selects a large area where geological variables are reduced and where potential impacts by men have minimum variability. Thus, study of traditional environmental issues (Desaules, 2012; Edwin, 2013; Alghobar & Suresha, 2015; Nweke & Ukpai, 2016) can be augmented by comparison of chemical contamination metrics. The USA has a National Geochemical Database (https://pubs.usgs.gov/ds/801/), and a recent addition to that data (https://pubs.usgs.gov/ds/801/) is a soil survey containing samples from different soil horizons.

2. Study Area

The area of the study is located in mid-continent of the USA. The states Iowa (IA), Kansas (KS), and Nebraska (NE) are the target of this study to evaluate the chemical loading by the human inputs from different sources. The study area is an agricultural region and the farmland covers 99% of IA, and fewer areas in KS and NE.

The intense agricultural productivity in this region results in many agricultural factories and processing plants, specifically ones devoted to animals and processing of animals to prepare them for human consumption. Iowa is one of the most intense agro-industrial areas in USA because it has a strong production in animals feed ingredients. In Kansas, food processing is the second biggest activity in the state, including flour-milling, animal feed, meat-packing plants. The largest industry in Nebraska is food manufacturing including meat processing (https://www.newsmax.com/fastfeatures/industries-nebraska-economy/).

3. Materials and Methods

3.1. Soil Sampling and Analysis

The data used in this study was extracted from the United States Geological Survey (USGS) National Geochemical Database (Smith et al., 2014). The analyzed data and the chemical methods of analysis of the several heavy metals are available in the link (https://pubs.usgs.gov/ds/801/). The samples were collected from three states: 91 samples from IA, 132 from KS, 130 samples from NE (Smith et al., 2014) and at three different horizons at each site.

3.2. Statistical Analysis of Data and Map Generation

Descriptive statistics of metal concentrations were achieved and compared and an ANOVA multivariate analysis followed by Turkey was used to estimate the variance between the means of the analyzed EF, PERI, and Igeo. Duncan's Multiple Range Test (DMRT) was carried out to test the differences between means (significance level < 0.05). The means and the standard deviations (SD) were determined. Pearsons correlation matrix was employed to identify the relationship between the chemical elements. Thus, differences between values at significance level were $P < 0.05$, which indicates a statistically significant difference between the means of the soil elements among the states and within the states.

Chemical spatial distribution maps of each environmental metric for single metal concentration were created using Oasis Montaj and GIS software to enable the visualization of the data and identify the differences and similarities between the spatial distributions of heavy metals in the soils of the three states (**Figures 4-6**). Simple metal concentration maps are given in the link above.

3.3. Estimation of Contamination Level

In the present study, three states in the midcontinent of the USA have been selected to pursue these questions. Numerous methods are in use to quantify soil chemistry quality. Three of these methods, EF, Igeo, and PERI, in recent use are employed here to compare results. Three metals, Cr, Pb, and Zn have been selected for investigation on the basis of their known toxic potential, and of having a reported MPL (maximum potential limit) and having a past history of contamination.

Three states have been selected, IA, KS, and NE. The intense agriculture of Iowa diminishes in western KS and NE; ranchland and less rain become the situation. No mining of these metals exists today, although Pb and Zn mining did take place in southeastern KS. The selection of background is a variable and a controversy. Global average shale chemistry is a frequent fallback. The data set under use here sampled three soil horizons at each sample site, thus it is fortunate that the C horizon data is present and is what will be used here as background. Histograms and standard statistical parameters lead towards a better understanding. Multivariate statistical analysis illustrates the paragenetic and geochemical groupings inherent in the samples. The three measures of relative contamination are now presented within equations, Table 1 compares their scales of risk measurement and contamination.

3.3.1. Enrichment Factor (EF)

EF is calculated as a ratio of element concentration in the soil normalized to a reference concentration, Ti. The content of heavy metals is measured with mass basis. The enrichment factor is calculated to measure the degree of the element enrichment of heavy metals using the formula expressed as:

$$\text{Enrichment Factor }(\text{EF}) = \frac{(C_i/C_{\text{Ti}})_{\text{sample}}}{(C_i/C_{\text{Ti}})_{\text{background}}}$$

Table 1. Classification of enrichment factor (EF), potential ecological risk index (PERI) classes, geo accumulation (Igeo), giving the degree or classification, the degree of soil chemical loading in terms of four, five, and six categories. Reference: EF: Jiao et al. (2015), Igeo: Muller (1969), PERI: (Darko et al., 2017).

EF	value	Class	Designation of soil quality (enrichment level)	PERI value	PERI class	Designation of soil quality (PERI)	Igeo Value	Igeo Class	Designation of soil quality (Pollution Intensity)
<1	<1	0	no enrichment	<40	0	low risk	≤0	0	Uncontaminated
1 - 2	EF < 2	1	depletion or deficiency to minimal enrichment	≤40 < 80	1	moderate risk	0 - 1	1	uncontaminated to moderately contaminated
2 - 5	EF 2 - 5	2	moderate enrichment	80 ≤ PERI < 160	2	considerable risk	1 - 2	2	moderately contaminated
5 - 20	EF 5 - 20	3	significant enrichment	160 ≤ PERI < 320	3	high risk	2 - 3	3	moderately to strongly contaminated
20 - 40	EF 20 - 40	4	very high enrichment	≥320	4	very high risk	3 - 4	4	strongly contaminated
>40	EF > 40	5	Extremely high enrichment				4 - 5	5	strongly to extremely contaminated
							≥5	6	extremely contaminated

$(C_i/C_{Ti})_{sample}$ is the ratio of mean of the target element to Ti concentration (C_{Ti}) in the soil sample, and $(C_i/C_{Ti})_{background}$ is the ratio in the reference (conservative element) in C-horizon C_{Ti}. Soil Ti concentrations of the C layer is taken as the natural background value instead of its concentration of Ti in the crust or shale for evaluating the level of anthropogenic sources in the topsoil (Barbieri, 2016). The degree of chemical loading is determined using the criteria shown in **Table 1**. Numerical values of EF are then classified into degrees of chemical loading, equivalent to degrees of soil contamination (Jiao et al., 2015).

3.3.2. Potential Ecological Risk Index (PERI)

Potential Ecological Risk Index (PERI) Method is a tool to estimate the degree of heavy metal loading in soils. The equation of PERI can be calculated as a sum of risk index of individual risk indices of heavy metal.

$$\mathrm{PERI} = \sum_{i}^{n} (\mathrm{TRF} \times \mathrm{CF})$$

CF are reported concentrations, and TRF is toxic response factor that is the environmental response to the contaminant. Toxic response factors are known also as relative toxicity for heavy metals are As = 10, Co = 5, Hg = 40, Ni = 6 (Darko et al., 2017), Mn = 1 (Xu et al., 2008; Soliman et al., 2015), Cd = 30, Cr = 2, Cu = 5, Pb = 5, and Zn = 1 (Hakanson, 1980; Jiang et al., 2014; Darko et al., 2017). The degree of ecological risk for each element can be determined according to PERI classification as shown in **Table 1** (Darko et al., 2017).

3.3.3. Geoaccumulation (Igeo)

The accumulative index (Igeo) is a geological assessment that is widely used to measure the magnitude of heavy metal loading related to soils (Muller, 1969). Many researchers applied "Igeo" index by Muller (1969) to assess different heavy metal contaminations (Abrahim & Parker, 2008; Varol, 2011; Nweke & Ukpai, 2016; Izah et al., 2017; Muzerengi, 2017; Huang et al., 2017; Mehr et al., 2017).

The values of geoaccumulation (Igeo) index were determined by calculating the base 2 logarithms of the metal concentration divided by its background concentration. To quantify the degree of heavy metals contamination, the mathematical equation proposed by Muller (1969) is calculated as follows:

$$\mathrm{Igeo} = \log_2 \frac{C_n}{1.5 \times B_n}$$

C_n is the average concentration of metal in the soil (measured concentration of the examined metal), and B_n is the standard concentration of the metal (geochemical background concentration of given metal in the crust or reference value of the metal "n"). The factor 1.5 is the background matrix correction factor for minimizing the impact of possible variations in the standards values. The use of this factor and its value are controversial. Muller (1969) categorized geoaccumulation index into seven class indicators that are used to define the degree of metal contamination. According to the criteria, Igeo ≤ 0 indicates uncontaminated soil. Values 0 - 1 indicate unpolluted to moderately polluted soil, while values 1 - 2 indicate moderately polluted soil. Values of 2 - 3 indicate moderately or strong polluted soil. Values 3 - 4 indicate strongly polluted soil. Values 4 - 5 area sign of strongly to extremely contaminated soil. Values > 5 show extremely polluted soil. The classification of I geo is shown in Table 1.

4. Results of Estimation Contamination Level

Soil chemical processes are significant in the scientific community. National Science Foundation (NSF) stresses special attention to the environmental research for soil chemistry (Sumner, 2000). The main concern is that toxic elements can be accumulated in the soil and therefore in plants as a basis of the food chain that affects humans and animals. The results of environmental indices to evaluate of potential soil contamination are different from one another. Statistical analysis of metal concentrations of the topsoil is given in Table 2. According to Table 3, the observations of EF and PERI of heavy metals are similar and determine with minor pollution, compared to heavy metal concentration calculated using Igeo.

Although Iowa, Kansas, and Nebraska are not considered industrial states when compared to other industrial states, some amounts of chemical pollutants have not originated from natural sources. Toxic maps for Cr, Pb, and Zn are present in the end of this discussion (point source from EPA). Pb and Zn are considered as risky to the human health. This study has revealed that there is direct connection between human agricultural activities and heavy metal loading.

4.1. Enrichment Factor (EF)

The highest value of EF of Pb is observed in KS (1.30) followed by IA (1.26) and NE (1.11). However, the EF of Zn is higher in KS (1.21) when compared to IA (1.19) and NE (1.19). The calculated results of EF are shown in Table 3 and Figure 1. The high values are not in mining areas in KS.

4.2. Potential Ecological Risk Index (PERI)

There are no risks investigated with heavy metals in the soil. All the elements are estimated as low risk assessment according to PERI criteria (Table 3 and Figure 2).

Table 2. A summarized standard statistical analysis was produced showing different calculated values. The measure for spread is represented with the standard deviation (SD). The concentration of metals is measured in mg/kg.

	IA			KS			NE		
Chemical	Cr	Pb	Zn	Cr	Pb	Zn	Cr	Pb	Zn
Max	62	48.5	153	88	450	270	62	110	121
Min	7	8.4	12	7	9.8	12	2	9.1	9
Average	42.48	23.06	81.88	34.31	26.58	68.49	23.02	18.95	47.13
SD	9.99	6.83	26.79	12.91	52.32	36.30	12.49	9.37	22.85

Table 3. Enrichment Factor (EF), potential ecological risk index (PERI), geo accumulation (Igeo) in Iowa, Kansas, and Nebraska. 3 Descriptive statistical analysis of heavy metals in topsoil samples (N = sample numbers, std. Deviation = standard deviation, IA = Iowa, KS = Kansas, NE = Nebraska).

Element Index	State	N	Mean	Std. Deviation	Degree of EF	Element Index	Mean	Std. Deviation	Degree of PERI	Element Index	Mean	Std. Deviation	Degree of Igeo
EF_Cr	IA	91	1.074	0.303	minimal enrichment	Cr_PERI	2.7182	1.769	low risk	Igeo_Cr	0.355	0.608	Uncontaminated
	KS	127	0.8205	0.191	no enrichment		1.660	0.651	low risk		−0.154	0.493	Uncontaminated
	NE	130	1.075	0.387	minimal enrichment		2.546	2.013	low risk		−0.004	0.713	Uncontaminated
	Total	348	0.982	0.328	no enrichment		2.268	1.640	low risk		0.034	0.643	Uncontaminated
EF_Pb	IA	91	1.266	0.430	minimal enrichment	Pb_PERI	7.384	2.523	low risk	Igeo_Pb	0.455	0.391	Uncontaminated
	KS	127	1.308	1.608	minimal enrichment		6.406	7.426	low risk		0.193	0.508	Uncontaminated
	NE	130	1.114	0.485	minimal enrichment		5.808	1.694	low risk		0.208	0.239	Uncontaminated
	Total	348	1.226	1.040	minimal enrichment		6.438	4.809	low risk		0.267	0.409	Uncontaminated
EF_Zn	IA	91	1.198	0.468	minimal enrichment	Zn_PERI	1.480	0.938	low risk	Igeo_Zn	0.36408	0.613	Uncontaminated
	KS	127	1.214	0.517	minimal enrichment		1.217	0.596	low risk		0.17510	0.511	Uncontaminated
	NE	130	1.109	0.330	minimal enrichment		1.292	0.851	low risk		0.19432	0.637	Uncontaminated
	Total	348	1.170	0.443	minimal enrichment		1.3144	0.798	low risk		0.23170	0.591	Uncontaminated

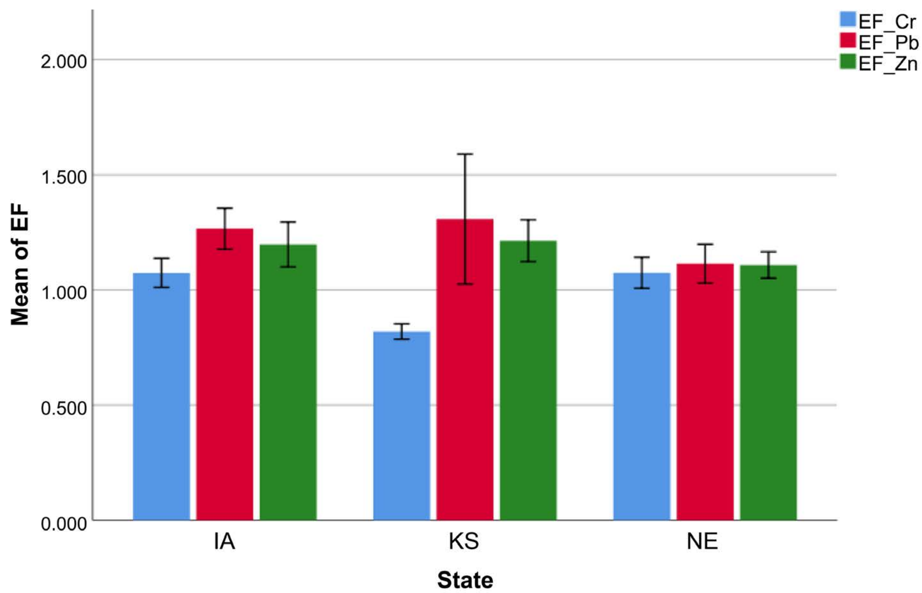

Figure 1. Boxplot showing enrichment factor (EF) values of individual heavy metals in surface soil in the study area.

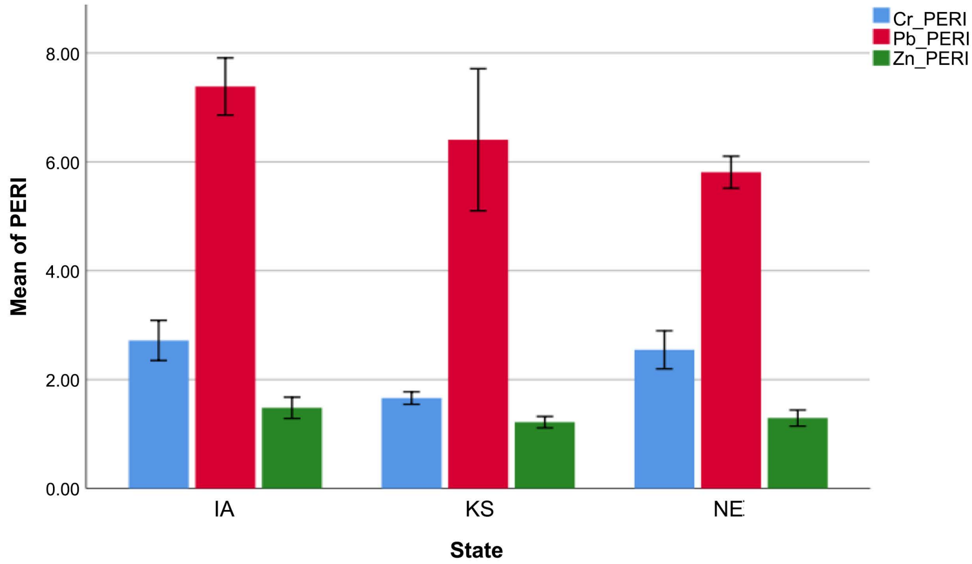

Figure 2. Boxplot showing potential ecological risk index (PERI) values of individual heavy metals in surface soil in the study area.

4.3. Geoaccumulation (Igeo) Index

Results of Igeo showed no contamination in the soil with the heavy metals (Table 3 and Figure 3).

At the initial stage of investigating new data, there are descriptive products which describe the data, and most often there are proposed filters to that data. Histograms and standard statistic parameters, and correlation coefficients, lead towards a better understanding. Multivariate statistical analysis illustrates the paragenetic/geochemical groupings inherent in the samples.

Spatial analysis is initially different. Description, when necessary, initially mimics or is the description of an anomaly map. Description may be carried out in a fashion like a topographic map, describing hills, valleys, etc. From this perspective, the following terms are defined for the generalized description of this special variable, in geology, these interests are called geomorphology.

5. Spatial Distribution Maps of Heavy Metals Using Enrichment Factor (EF)

There is a site specific, circular anomaly. On a fertilizer derived regional plateau dimples may be towns, within which fertilizer nor are additives not applied (negative anomaly). Otherwise, dimples as positive anomalies are point sources due to industrial activity. Some boundaries may consist of large value changes over short distances, as measured in general perpendicular to trend of boundary (sharp). Alternatively, perpendicular to the trend of the shape the rate of change of the measurement is relatively slow.

The spatial distributions of the metals in the soil were evaluated by Kriging are mapped (Figures 4-12) It is important to note that the dunes located in northwest of NE is a large region of wind-blown sand in largely quartz and clay, and is

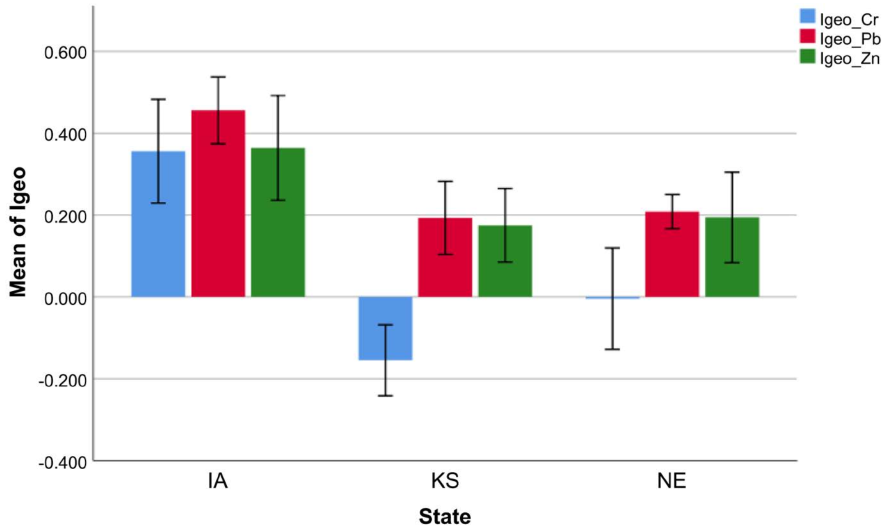

Figure 3. Boxplot showing geoaccumulation (Igeo) values of individual heavy metals in surface soil in the study area.

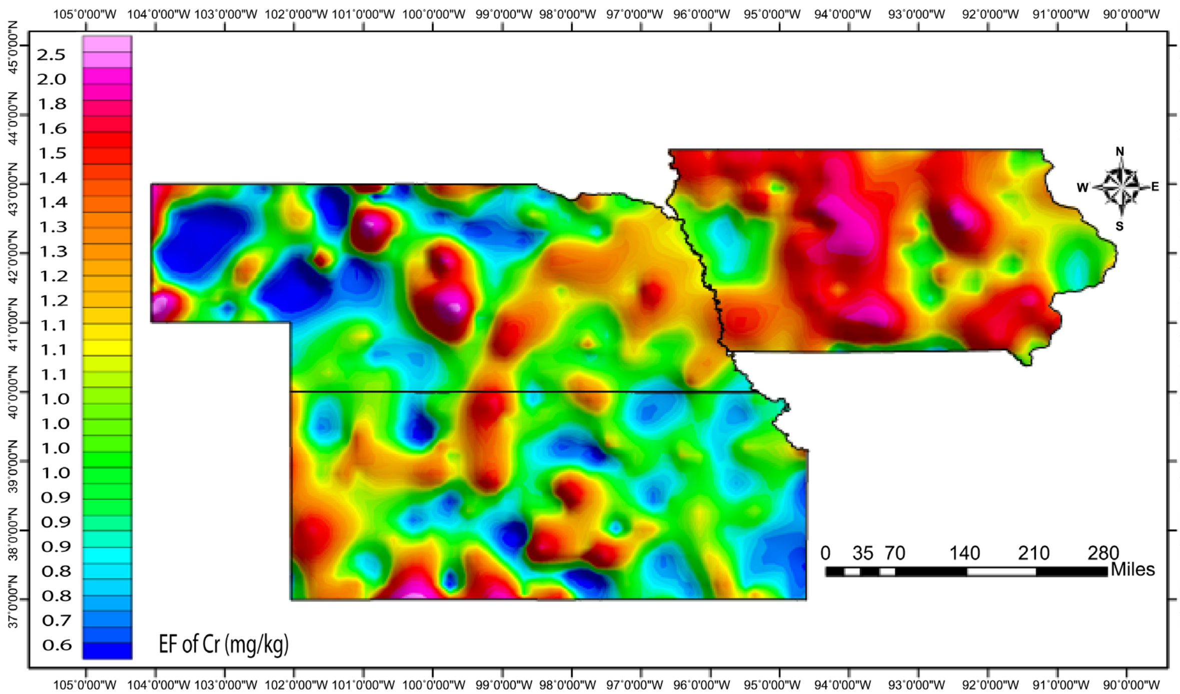

Figure 4. Spatial distribution maps show EF values of Cr in the surface soil in study area.

not and never has been under cultivation. It serves as a region of near zero values for most chemical constituents. This means the ground truths equal zero. Regions of plateaus or regions of broad non-zero, relatively uniform anomalies are interpreted to be of agricultural origin resulting from intensive fertilizer applications, or additives. The results show significant potential sources of high EF values of Cr, Pb, and Zn (2.5, 4.3, and 3.6) (**Figures 4-6**). Parallel Cr ridges or regions are present in the maps and large areas suggest agricultural applications (**Figure 4**). Higher anthropogenic EFs regions of Cr were identified in most of

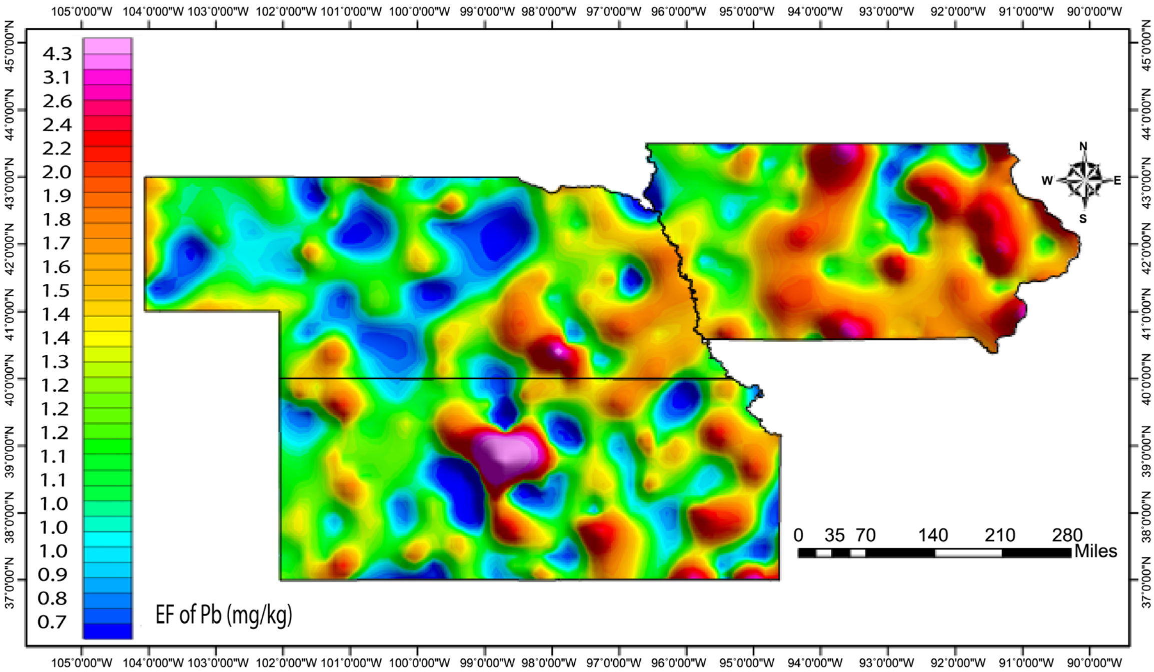

Figure 5. Spatial distribution maps show EF values of Pb in the surface soil in study area.

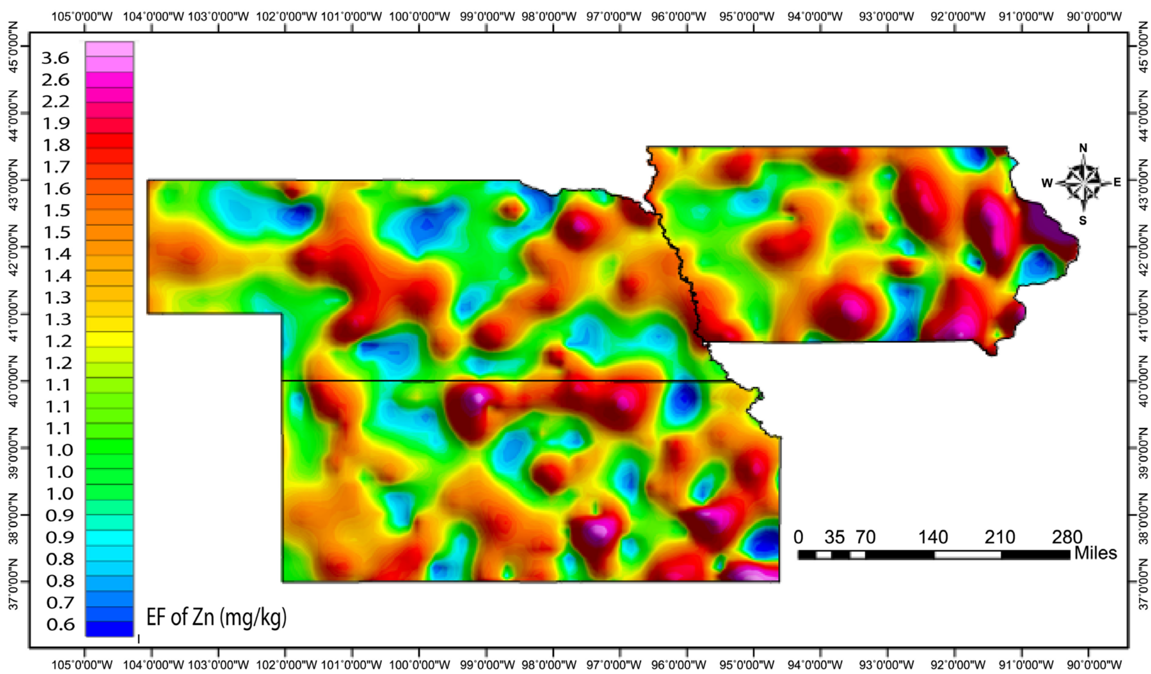

Figure 6. Spatial distribution maps show EF values of Zn in the surface soil in study area.

IA with values 2.5, especially in the middle areas of IA. In NE the high EF regions were determined with one hotspot located in the northwest side and one hotspot in the middle (Figure 4). The range of EF of Cr was 0.6 - 2.5 in three states. However, high EF was observed in southwest KS. The interesting areas additionally were identified as straight line located in northern, and triangle points in the middle of KS.

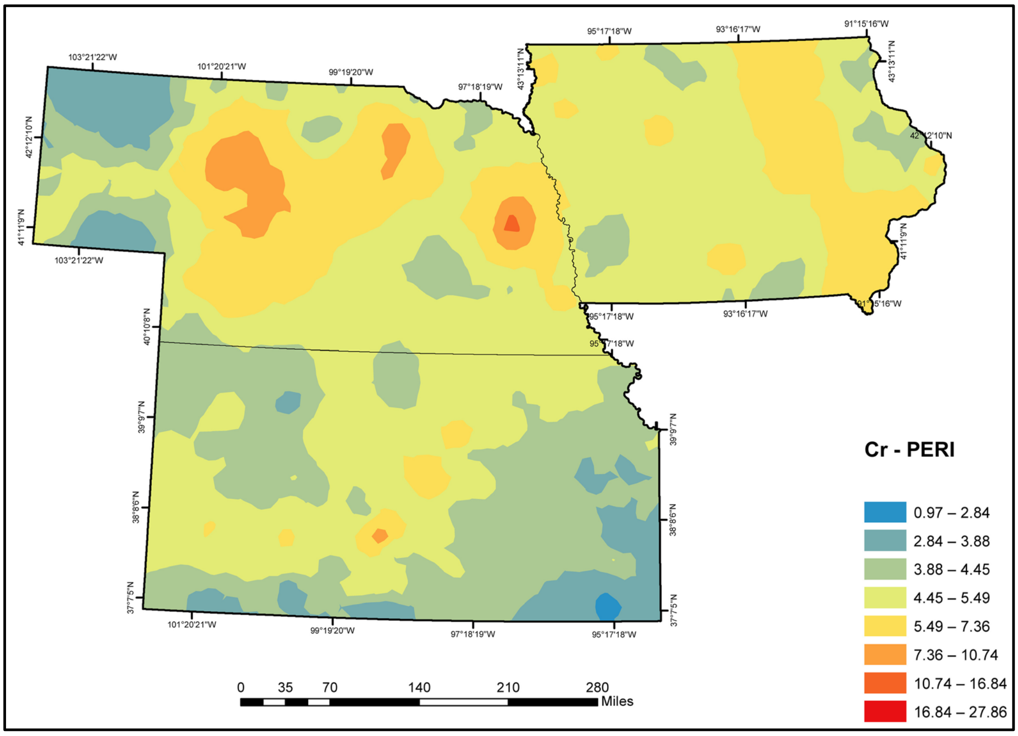

Figure 7. Spatial distribution maps show PERI of Cr in the surface soil in study area.

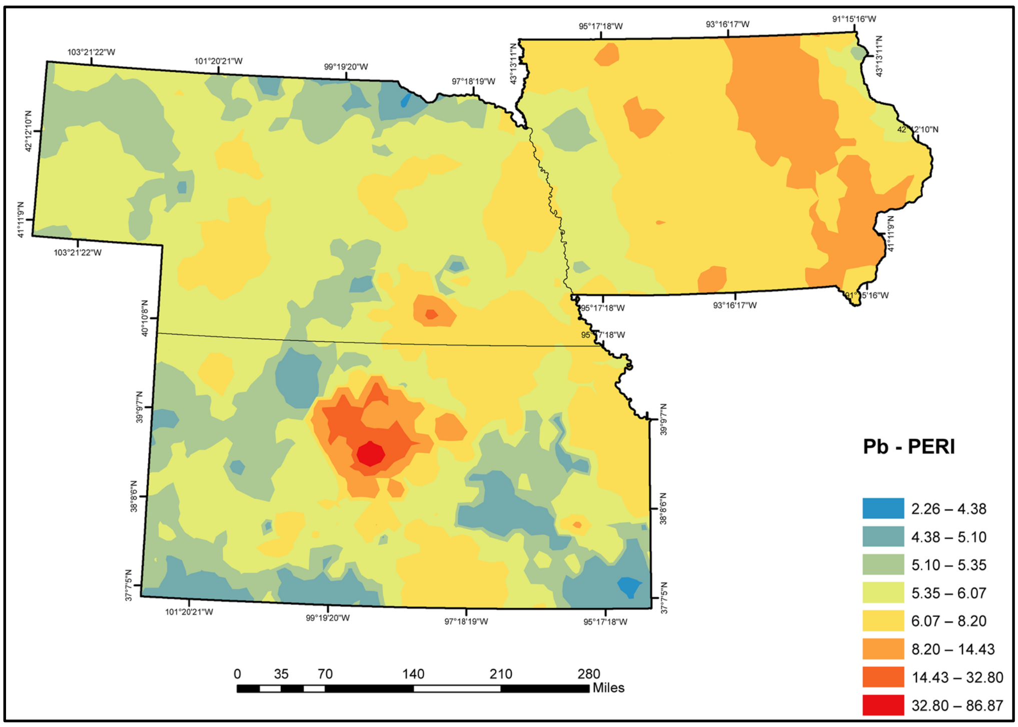

Figure 8. Spatial distribution maps show PERI of Pb in the surface soil in study area.

EF of Pb fluctuated according to the region under concern and the range of calculated EF of Pb was 0.7 - 4.3. The smooth aspect of the map presented anomaly hotspots of Pb located mostly in central KS with high value 4.3. Moreover,

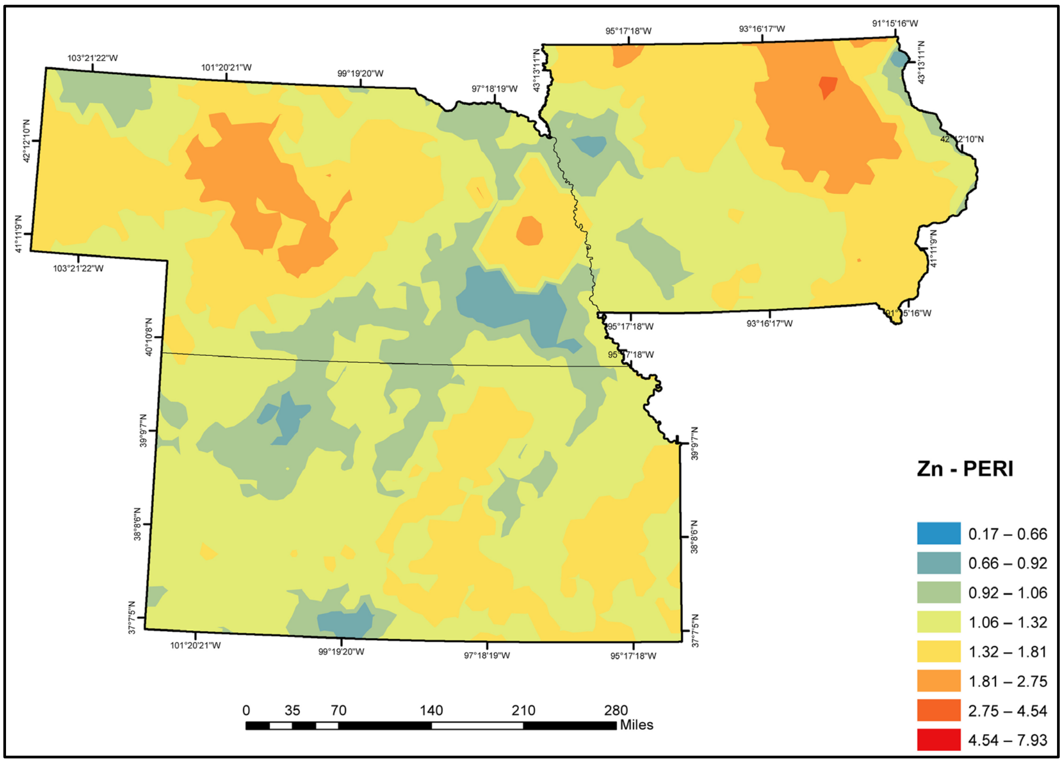

Figure 9. Spatial distribution maps show PERI of Zn in the surface soil in study area.

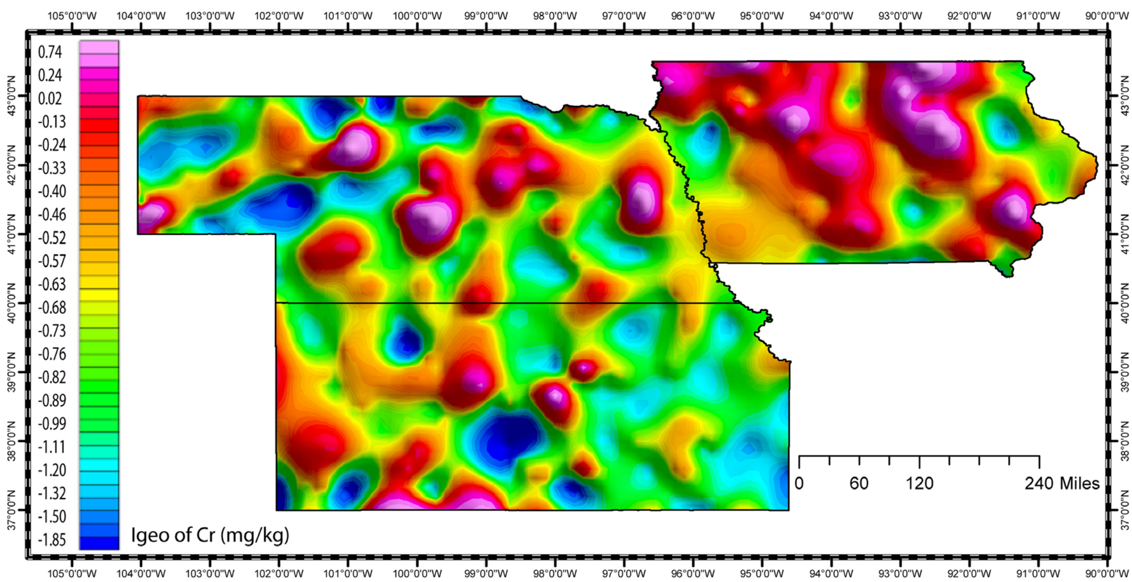

Figure 10. Spatial distribution maps show Igeo values of Cr in the surface soil in study area.

there is a large regional plateau of Pb (**Figure 5**). EF map of IA showed a moderate enrichment in extended points in east, north and south of the state. The low values of EF values are existed in some areas of the EF map especially in northwest of NE (Sand Hills). However, one small hotspot was perceived only in southeast of NE (**Figure 5**).

Distribution of Zn loading on EF maps ranged with values 0.6 - 3.6 that are

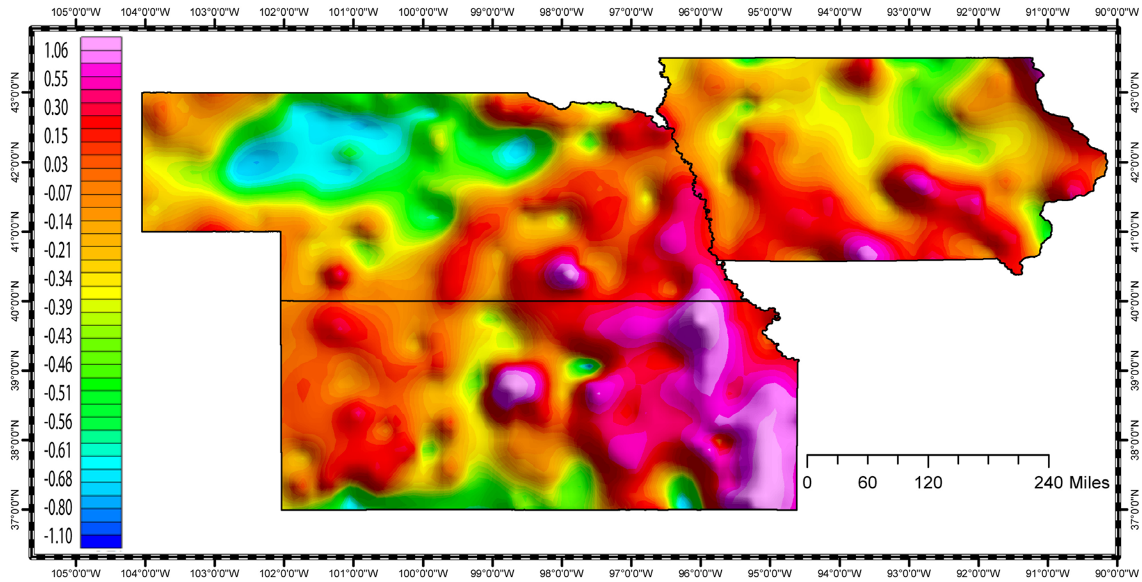

Figure 11. Spatial distribution maps show Igeo values of Pb in the surface soil in study area.

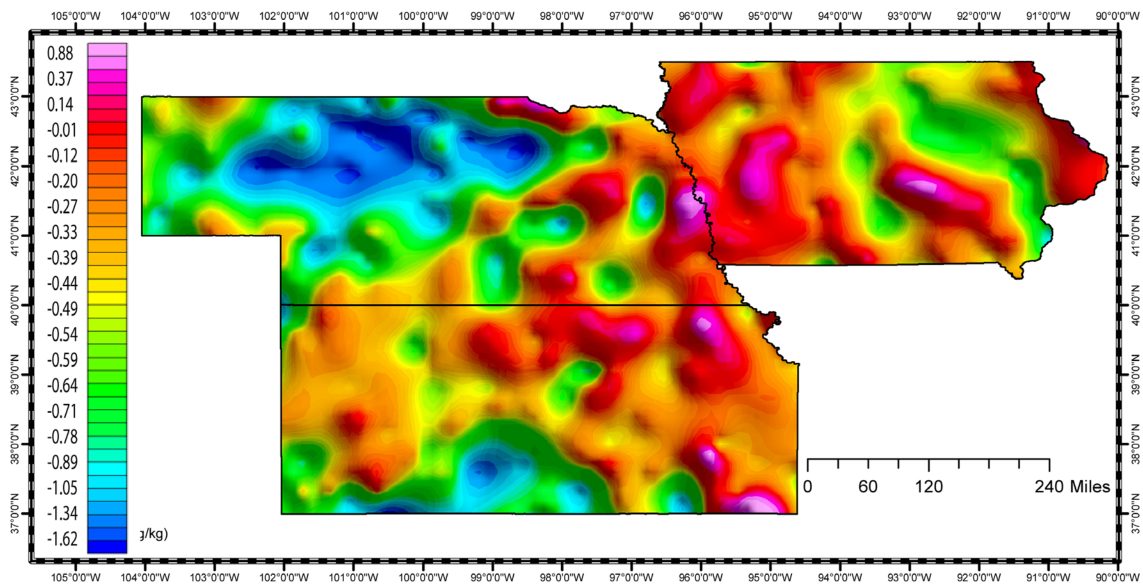

Figure 12. Spatial distribution maps show Igeo values of Zn in the surface soil in study area.

classified as significantly moderate enriched includes large regional plateau. The maps show high values of EF, which may result in different potential anthropogenic sources of Zn (**Figure 6**).

6. Spatial Distribution Maps of Heavy Metals Using Potential Ecological Risk Index (PERI)

The data analysis of PERI showed visual variances with high and low concentrations of the heavy metals in the surface soils. The unique spatial distribution was observed at the local scale categorized by the localized hotspots. The spatial distribution of some heavy metals in chemical maps showed many spatial anomalies. Map of PERI produced smoother figures and the variations of chemical anomalies that come and go away. The spatial distribution patterns showed some similarity with enriched concentrations trending Cr (8.13 - 14.57) and Zn (4.54 - 7.93) northeast of Iowa and northwest of Nebraska (**Figure 7** & **Figure 9**).

No extreme anomalies of Zn are observed. A broad plateau is located in Nebraska and Iowa and there is a point anomaly spot in far in east central Nebraska at Omaha. In addition, Zn is broad elevated in region of Dunes, but poorly defined. A broad, amorphous slightly elevated region located in south and central Kansas, near Platte. It is important to note that Zn level in the river drainage is low. The lowest concentration of heavy metals was identified in spatial distribution map of Zn with value range (4.54 - 7.93) (**Figure 9**).

No extreme anomalies of Cr occur, except in Omaha. Dunes and east are broad anomalies; in east Iowa is broad northsouth ridge, south central Kansas and a big Cr anomaly, and high concentration of Cr on the Arkansas River. Other hotspots of Cr were distributed in northeast of Iowa that are associated to the farming in this region. However, two big areas of Cr are located in east, north middle, south middle of Nebraska, and small area in the west of the state (**Figure 7**).

Extreme values of Pb are observed in the very center of Kansas. However, linear anomalous features of positive (ridges) or negative (basins) values are observed. It is clearly seen a high anomaly of Pb in northeast, and northwest ridge running through southeast Iowa in addition to spot anomaly in southeast in Nebraska, but no point anomaly in central of Nebraska. High concentrations of the heavy metals were observed include Pb (32.80 - 86.87) presents high concentrations in the soils (**Figure 8**).

7. Spatial Distribution Maps of Heavy Metals Using Geoaccumulation (Igeo)

Igeo of Cr showed no significant values and the spatial variations range min to max values −1.85 - 0.74 in IA, KS, and NE. Geochemical distribution was heterogeneous in IA, KS, and NE. The 0.74 value spots were randomly distributed (**Figure 10**). In the east of KS, there were recorded significant concentrations of Cr. There are embayments and grabens, and ridges of Pb and Zn in IA and NE, embayments into a regional plateau or other features, however, dunes and zero background of Pb and Zn are well displayed in northwest NE. The values of Igeo of Pb were located within class 2 in Muller's classification (Muller, 1969) with maximum value 1.06. Extended areas are observed that present anthropogenic contribution to the contamination load with small hotspots located in south of IA and KS. Most of the population density centers are located the cities in west of IA. Two large domains were observed in east and middle of KS soils (**Figure 11**). In addition, Zn distribution map reflects this Pb plateau, but rougher. The huge domain located in southeast of KS suggests human activity where is Zn mines are located rather than natural geological processes. Igeo of Zn value was lower than its corresponding average C-horizon value (background). Igeo values of Zn were categorized in the range < 1 that indicate to no significant pollution or chemical loading in the study area. Most of the regions in IA, KS, and NE presented high concentrations values of Zn except Sand Hills in NE as shown in Figure 12. From the view of point, EF and PERI tools used to estimate the soil contamination are more effective measurements compared to Igeo. In another word, Igeo index is less effective to be used as tool to evaluate a soil contamination because it depends on the soil origin or the bedrock source that differs from one place to another according to the geographical location.

The spatial pattern of anthropogenic applications revealed that hot spots in ToxMaps are not associated with the geochemical maps (Figures 13-15). To estimate the anthropogenic inputs in the soil, the point sources of soil and land maps are overlapped with spatial chemical maps to identify the anomalous metals contributions (Figures 13-15). The land use pattern has regions with significant high accumulation of heavy metals. The concentrations of the metals are not associated with the land and soil maps as it shown in Figures 13-15 (https://epa.gov/toxics-release-inventory-tri-program). It has been noted that the hot spots of the metal are associated to the intensive farm area with high agrochemicals, specifically fertilizer inputs, and sometimes are located in the areas far from the urban and industrial regions.

Point source maps of the three chemicals given in Figures 13-15 had a little to zero influence on the maps generated here. The maps derived from the soil chemistry (Smith et al., 2014) can be described in a manner similar to topographic maps; that is hills valleys and other features. Data must be considered with the histograms at hand. The most important features in the present work are regional plateaus. These plateaus will be interpreted as agricultural addition to the soil because of the widespread uniform properties.

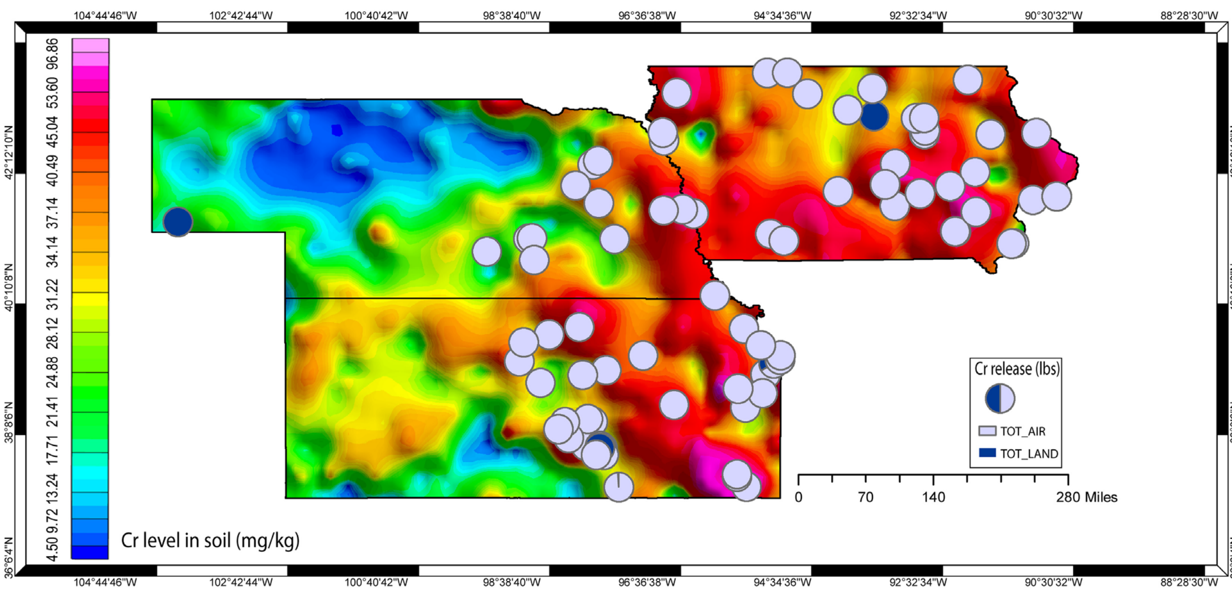

Figure 13. Map of air and land emissions super imposed on soil geochemical background map of Cr.

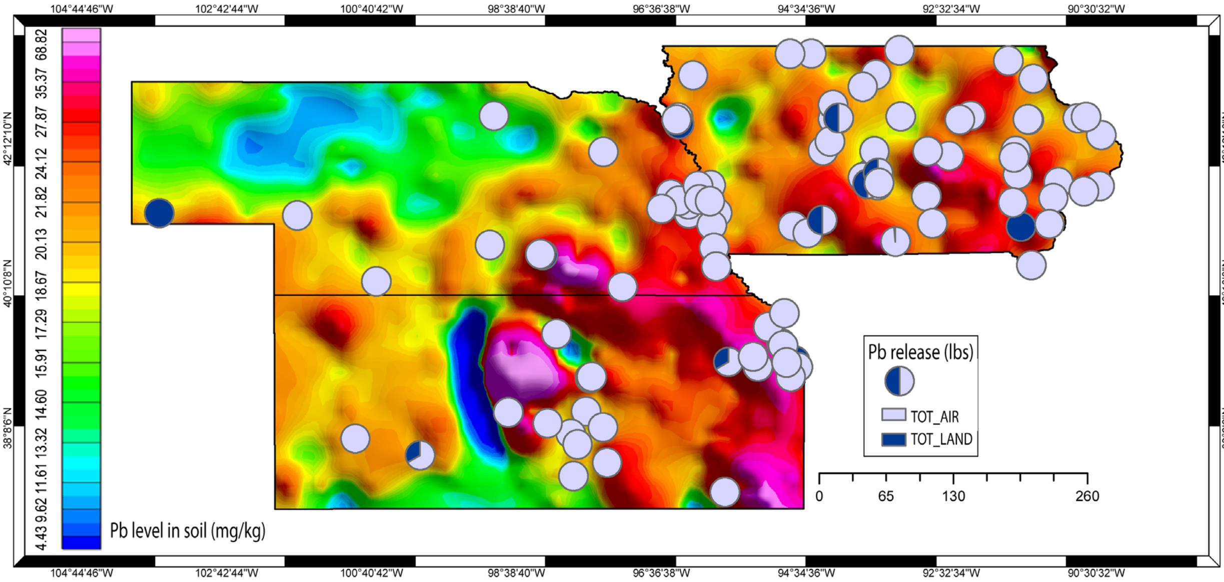

Figure 14. Map of air and land emissions super imposed on soil geochemical background map of Pb.

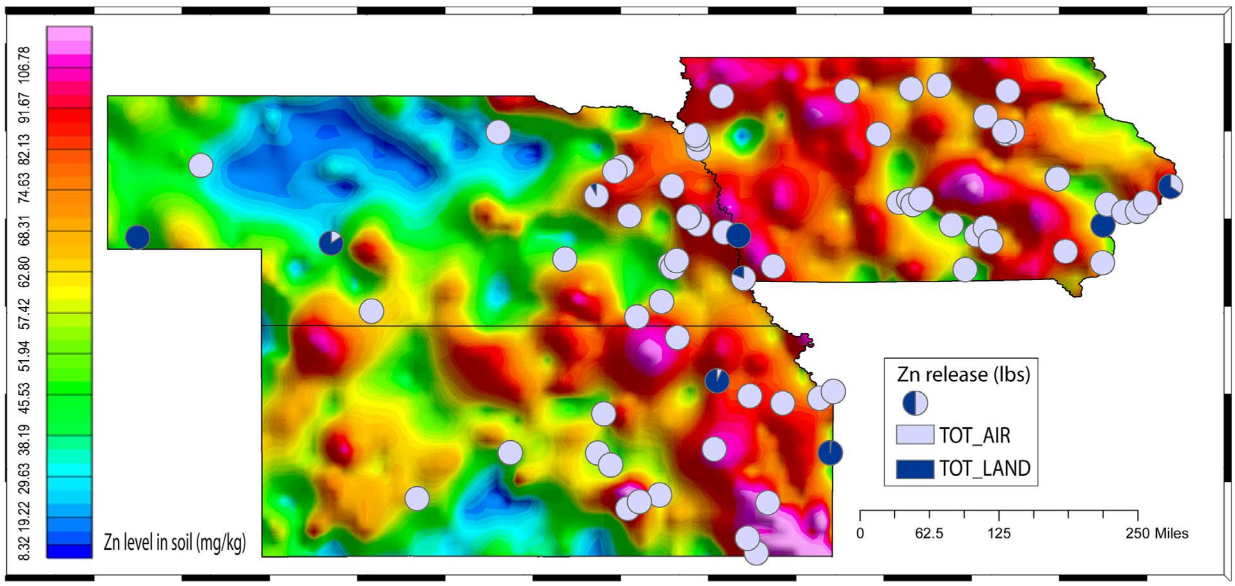

Figure 15. Map of air and land emissions super imposed on soil geochemical background map of Zn.

8. Discussion

The importance of this research to determine some of the heavy metals on the surface soil of IA, KS, and NE. The combination of using three approaches for evaluating soil metal contamination is useful to understand the changes of the soil properties. Based on the EF, PERI, and Igeo indexes data, the soils are classified as minimal enrichment, low risk, and uncontaminated respectively. Anthropogenic applications such as additives that contain heavy metals can contribute to the soil contamination. There is irregular distribution of the heavy metals in soils from numerous locations. EF values for all metals in the topsoil showed minimal enrichment Pb > Zn > Cr (1.226 > 1.170 > 0.982) while Igeo indicates low risk Pb > Zn > Cr (0.267 > 0.231 > 0.034) respectively. However, the results of Igeo showed uncontaminated soil with low values in the study area (Pb = 0.267, Zn = 0.231, Cr = 0.034).

It is important to note that there is an area where zero or close to zero chemical concentrations are present that indicate to the background equal zero. This was the case in the Dunes in northwest Nebraska. This large region of wind-blown sand in largely quartz and clay, and is not and never has been under cultivation. It serves as a region of near zero values for most chemical constituents. However, sometimes unexplained anomalies exist, such as Se! Moreover, regional plateaus show that regions of broad non-zero, relatively uniform, anomalies are interpreted to be of agricultural origin, from fertilizers and additives. Ridges and basins are linear anomalous features of positive (ridges) or negative (basins) values. Beside these features, there are grabens and horsts that are alternative parallel valleys and uplifts. Embayments are entries into a regional plateau or other feature. It is important to note that there are dimples such as site specific, circular anomaly. On a fertilizer derived regional plateau dimples may be towns, within which fertilizer nor additives are not applied (negative anomaly). Otherwise, dimples as positive anomalies are point sources due to industrial activity. Furthermore, boundaries may consist of large value changes over short distances, as measured in general perpendicular to trend of boundary. Alternatively, perpendicular to the trend of the shape the rate of change of the measurement is relatively slow.

9. Conclusion

It is essential to determine and identify the natural and anthropogenic contamination resources that affect chemical concentrations in the soil. The environmental indices include EF and PERI used in this study showed similar results while I geo showed different results compared to the first two indices. The results of this study investigated minimal pollution presented in the study area. Mean values of heavy metals Cr, Pb, and Zn using EF as pollution index showed minimal enriched soils while showed low risk using PERI as a pollution index. However, estimation of soil contamination using Igeo revealed no contamination in the study area.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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