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Physical-Chemical Properties and Spatial Distribution of Heavy Metals in Agriculture Soil in Al-Qadisiyah City by using ArcGIS and Multivariate Analysis

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ABSTRACT

Al-Qadisiyah governorate is one of the most important agricultural areas in Iraq, and the study was conducted in different areas of the governorate, including seven areas for sampling. The physical-chemical properties and heavy metals of agricultural soils were examined. The results showed that highest value was Ni (189.9 mg/kg) followed by Cr (124.5 mg/kg), Zn (50.8 mg/kg), Cu (36.9 mg/kg), Pb (35.2 mg/kg) and Cd (1.17 mg/kg). Moreover, Ni and Cr concentration levels were higher than Canadian soil guidelines. Geostatistical analysis was applied to know the sources of heavy metals in agricultural soil and results were revealed that Zn, Cu, Ni, and Cr were the same pollution sources and Cd and Pb also were the same pollution sources indicating these elements impacted by anthropogenic activities. The Pearson correlation coefficients found some physical-chemical properties role in increasing heavy metals in the soil such as EC and Cu, and also TOC, OM and Cr. Therefore, these results are considered useful for the competent authorities in order to reduce and control these pollutants in agricultural soils.

Key words: *Heavy metals, Agriculture soil, GIS, Multivariate analysis, Al-Qadisiyah Governorate*

Introduction

Al-Qadisiyah Governorate is known to have fertile land and is famous for rice cultivation for many years and it is a major source of food consumption not only in Iraq but also exported to the rest of the world. Currently, the soil of agricultural lands in the city is exposed to many environmental conditions such as salinity and drought due to the wrong water policy, as well as exposure to many pollutants such as industrial waste and agricultural activities. In general, salinity in Iraqi soils is a major problem at the present time due to climatic changes, which in turn lead to higher temperatures, which negatively affects the high percentage of salinity in agricultural lands. Moreover, salinity is an intense environmental hazard that impacts the growth of many crops and threat to food safety (Newer *et al.*, 2013; Asfaw *et al.*, 2018).

The main sources of heavy metals in soil outcomes from two polluted: natural processes and anthropogenic activities, which they make the metals accumulate in soils for long times (Fei *et al.*, 2019; Zeng *et al.*, 2011; Ren, 2021). Heavy metals contamination in the agricultural soil is a significant issue due to its cumulative and non-degradable characteristics, and also make an adverse effect on human health by their consumption of the plants (Facchinelli *et al.*, 2001). Toxic metals could make problems to human health through bioaccumulation into different organs, and eventually possible human carcinogens (Kadhum *et al.*, 2015, Jaber and Al-

Mayahi, 2020).

Heavy metals storage in soils is related to the soil physical-chemical properties (Sinha *et al.,* 2006; Dheri *et al.,* 2007). Therefore, understanding the soil quality and the levels of heavy metals in this study is necessary to know Al-Qadisiyah agriculture soils and to manage moreover plans for agricultural productivity, and reduced heavy metal risk assessment in agriculture soil. Multivariate statistical analysis is useful tools to identify natural or anthropogenic sources in soils (Facchinelli *et al.,* 2001; Micó *et al.* 2007; Huang *et al.,* 2007; Luo *et al.,* 2007; Chabukdhara and Nema, 2012), geographic information system (GIS) is a framework geographically to show the managing, manipulating, analyzing related information in the land (Li *et al.,* 2004). Therefore, a set of multivariate statistics and geostatistical analysis could be helpfully applied in describing the spatial distribution of heavy metals and identifying their sources (Lu *et al.,* 2012; Sun *et al.,* 2013; Zhang *et al.,* 2016).

There are different studies were conducted to search in pollution of heavy metals content in agricultural soils over the world, like the study by Keshavarzi and Kumar, (2019) in agricultural soils of Northeastern Iran were studied the spatial distribution and sources of heavy metals and soil properties, and based on geostatistcal techniques, and contamination indices showed very high enrichment and ecological risks of heavy metals in the soil, and also anthropogenic and natural sources were accountable for metal contents. Likewise, Zhuang *et al.* (2016) found concentrations of Cd and Pb are associated with anthropogenic activities in agricultural soil in Gongzhuling, Northeast of China. Other studies were also explored in the city of Qadisiyah/Iraq and, specifically in the city of Al-Shamiyah, to investigate spatial levels of heavy metals by using geographic information systems and pollution indices in agricultural soil (Al-Khuzaie and Abdul Maulud, 2022). In a study also in Al-Diwaniyah Governorate by AlHamzawi and AlGharabi (2019), different concentrations were found in industrial, residential and agricultural soils in various cities in the governorate. However, we focused in this study on the physical-chemical properties of the agricultural soil of Qadisiyah governorate to know the effect of these properties on the distribution of heavy metals and the investigating of the polluting sources of these toxins through GIS and multivariate analysis which is still unknown. The objectives of this study were (1) to assess and reveal the levels of the heavy metal in agricultural soils (2) to discover the sources and spatial distributions of heavy metals in agricultural soils of Al-Qadisiyah governorate by using multivariate statistics and geostatistical analysis (3) to study the impact of physical-chemical properties on the content of these heavy metals. This work will give an indicator to decision-makers in the environmental issue to reduce the accumulation of heavy metals in agricultural soils and protect the consumer from potential diseases in the long term.

Materials and Methods

Study area

Al-Qadisiyah Governorate is one of the cities of the middle Euphrates in Iraq and is famous for rice cultivation. It also has some factories for the manufacture of rubber and textiles, and after the establishment of many oil facilities in Iraq, it is becoming one of the important cities in storing petroleum. The total area of Qadisiyah Governorate is 8153 km^2 and the population began to increase around 1,320,000 people (Al-Hamzawi, 2017). The latitude and longitude of the city are located between 31°.732N, 44°.692E (Al Hamzawi and Al Gharabi, 2019). The climate of Iraq in summer is dry and very hot with temperatures reach to 50 during July and August. The winter in Iraq is cold with a temperature reach to 4 (Kadhum, 2020; Kadhum *et al.,* 2020). The source of water in agricultural lands in the city of Qadisiyah is the Euphrates River and some springs and wells, which in turn also suffer from salinity and water pollution. The samples were collected from the following sites in Qadisiyah Governorate: Sumer (S1), Hamza (S2), Afaq (S3), AlBdair (S4), Sania (S5), Ghamas (S6), Shamiyah (S7) Figure 1. The coordinates sampling collection from agricultural land with different anthropogenic activities were presented in Table 1.

Soil Samples collection and analysis

Thirty-five soil (10 cm) samples were collected at seven sites in Al-Qadisiyah Governorate between November and December 2021. The samples from agricultural soil were kept in polyethene plastic bags, and labelled, the samples were set in an icebox and brought to the laboratory. The soil samples were dried in an oven within 40 °C and weight (1 g) after sieved through a 75 µm mesh nylon sieve to

Table 1. The coordinates sampling collection from agricultural land

Site	Code	Coordinates	
Ghamas	G1	31.71928547	44.60451042
	G2	31.73140449	44.61902314
	G3	31.73998366	44.59852061
	G4	31.73873881	44.61147883
	G5	31.75859825	44.61962071
Shamia	Sh1	31.95851365	44.58493563
	Sh2	31.96842075	44.60769034
	Sh3	31.96475021	44.59246879
	Sh4	31.95557454	44.60181812
	Sh5	31.96214671	44.59715455
Sania	Sa1	32.07568412	44.77172646
	Sa2	32.06746159	44.78063282
	Sa3	32.0564613	44.77315416
	Sa4	32.06670078	44.76846575
	Sa5	32.06787375	44.77361759
Hamza	H1	31.70889929	44.98283793
	H2	31.74445739	44.9809877
	H3	31.7249906	44.96371718
	H4	31.71969263	44.99351395
	H5	31.72474937	44.97640732
Albdair	Al1	31.96584609	45.42154667
	Al2	31.96736859	45.41482991
	Al3	31.98138694	45.40806562
	Al4	31.96258852	45.41271737
	Al5	31.96660633	45.42123641
Afaq	A1	32.05182146	45.24520918
	A2	32.07007597	45.22740395
	A3	32.07455279	45.247834
	A4	32.06113825	45.26465363
	A5	32.05132155	45.24887873
Sumer	Su1	32.15545929	45.00005274
	Su2	32.14168629	44.99735407
	Su3	32.14954577	45.00536341
	Su4	32.14892666	44.98853507
	Su5	32.14936359	44.99894461

remove suspended solids residues from the soil and after that the sieved samples were digested into a 10 ml solution of a mixture of 10 ml of a 3:1 concentrated HCl/HNO_3 (Karimi *et al.,* 2009; Sparks *et al.,* 1996). The samples were calculated for metals levels using Atomic Absorption Spectrophotometer (AAS) (SHIMADZU AA-7000)

Physicochemical properties

The physico-chemical properties such as pH, EC, TOC and the total organic matter were determined for 35 soil samples. The pH was calculated in soil by using the method (Ryan *et al.,* 2001). The organic matter was measured by following the method (Ben

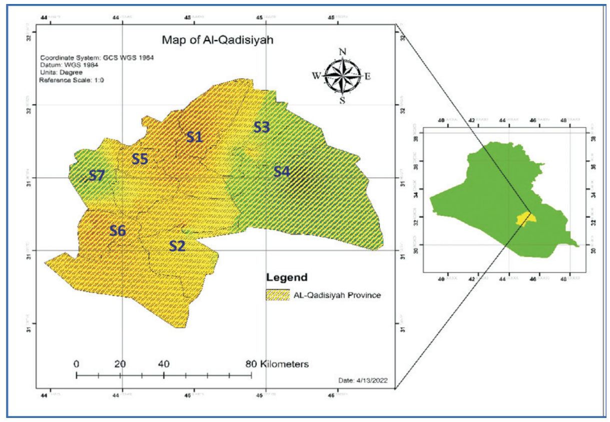

Fig. 1. Iraq map and Al-Qadisiyah Governorate

Dor and Banin, 1989) as a loss on ignition by measuring the difference between the dry weight of soil samples before and after ashing in a muffle furnace at 550 °C for 5 h. The EC of the samples were determined using the method (Ryan *et al.,* 2001).

Statistical and geostatistical analysis

Multivariate analyses were applied in agricultural soil of Qadisiyah cities by using SPSS 20.0 (SPSS Inc., USA), principal component analysis (PCA) was carried out to estimate the pollution sources in the agricultural soils of Qadisiyah Governorate through using varimax rotation and Kaiser Normalization were employed the rotation method in the analysis (Zhang *et al.,* 2016). The Inverse distance weighting (IDW) interpolation was applied on the concentrations of agriculture soil heavy metals using ArcGIS software (Version 10.7.1, ESRI, Inc., Redlands, CA, USA).

Results and Discussion

Heavy metals and Physico-chemical properties

The total mean concentrations of heavy metals and physical-chemicals properties in the agricultural land of the Qadisiyah Governorate from all the sites are presented in Table 2. It is notified that some metals such as nickel (Ni) and chromium (Cr) were the high pollution levels in the soil followed by Zn, Cu, Pb and Cd, it has shown that agricultural soil in the Qadisiyah Governorate was significantly contaminated as compared with average shale (Turekian and Wedepohl, 1961) with exception Zn was lower than average shale. The Cd and Pb were ranged between 0.61 to 1.57 mg/kg and 20.58 to

52.30 mg/kg respectively and these elements are toxins due to impact on human health such as carcinogens (Rajaganapathy *et al.,* 2011), while the content of Ni and Cr were ranged from 170.51 to 233.96 mg/kg and 108.98 to 140.50 mg/kg respectively and these results were polluted based on average shale and Canada soil guidelines due to agriculture activities such organic phosphate and fertilizers. The Canada soil guidelines (1997, 1999) for residential/parkland landuse, industrial landuse, commercial and agricultural were used as a standard to our results because there are no found soil guidelines in Iraq. There are only two elements like Cr and Ni were above the various maximum permissible limits (Table 2), suggested that anthropogenic such as agricultural and industrial activities for the long-term may increase the content of heavy metals in soils (Zhang *et al.,* 2016).

The mean values of pH, OM, TOC, EC and salinity were presented in Table 2. The pH value was found in the range between 7.7–8.1 from different soil locations of Qadisiyah Governorate. The pH results in the soil were slightly alkaline nature pH which plays a vital role in decreasing the mobility of heavy metals in the soils (Tian *et al.,* 2016). The EC results were ranged between 2.9 to 8.8 µS/cm and based on Lamond, and Whitney (1992), the electrical conductivity (EC) was moderate to high in agriculture soil.

(a) average shale (Turekian and Wedepohl 1961); (b) Canada soil guidelines (1999) for residential/parkland landuse; (c) Canada soil guidelines (1999) for industrial landuse; (d) Canada soil guidelines (1999) for commercial; Canada soil guidelines (1999) for Agricultural; (*) Canada soil guidelines (1997) for residential/parkland landuse, industrial landuse, commercial and Agricultural respectively.

Multivariate statistics

Principal components analysis (PCA)

Principal components analysis (PCA) was applied to discover the origin of heavy metals in agricultural soils (Rodríguez Martín *et al.,* 2006; Lu *et al.,* 2012; Niu *et al.*, 2013; Sun *et al.*, 2013; Zhang *et al.,* 2016). The principal component analysis results of total heavy metal contents in soils are illustrated in Table 4. Principal components were selected based on their eigenvalues which should be greater than 1.0 (kadhum *et al.,* 2017) and the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) value was 0.638 where Bartlett's Test of Sphericity was statistically significant ($p < 0.000$). A total of three principal components (PC1, PC2, and PC3) were extracted which accounted for 72.810% of the total variance. The first component has consisted of Zn, Cu, Ni, and Cr (Fig. 2), indicating that the metals originate from the same sources and these metals may come from anthropogenic sources such as agricultural activities and industrial processes around the area. The second component included the physical-chemical properties such as EC, OM and TOC. The second component included the physical-chemical properties such as EC, OM and TOC, this indicates that the physical and chemical properties were affected by each other. The third component loaded only Cd and Pb. Hence, Cd gathering in agricultural soils due to frequently using of phosphate (P) fertilizers, the other metals in the first component may also be much impacted by farming activities (Shan *et al.,* 2013).

Pearson correlation coefficients

Relationships between heavy metals and physical-chemical properties in the soil can supply informa-

Table 2. Physico-chemical properties and heavy metals concentrations in agriculture soil of Qadisiyah Governorate

Elements	Units	Min	Max	Mean	SD	Var	A.V[a]	CCME[b]	CCME[c]	CCME[d]	CCME[e]
pH		7.7	8.1	8	0.1	0					
OM	%	4.3	8.2	6.70	1	1.3					
TOC	%	2.8	4.7	3.80	0.6	0.4					
EC	µS/cm	2.9	8.8	21.8	6.02	36					
Cd	Mg/kg	0.61	1.57	1.17	0.39	0.18	0.30	10	22	22	1.4
Cr	Mg/kg	108.98	140.50	124.50	13.08	171.1	90	64*	87*	87*	64*
Ni	Mg/kg	170.51	233.96	189.99	21.37	533.02	68	50	50	50	50
Zn	Mg/kg	44.40	58.36	50.18	5.45	34.67	95	200	360	360	200
Cu	Mg/kg	32.64	46.81	36.90	5.14	30.82	45	93	91	91	63
Pb	Mg/kg	20.58	52.30	35.25	11.21	146.76	20	140	600	260	70

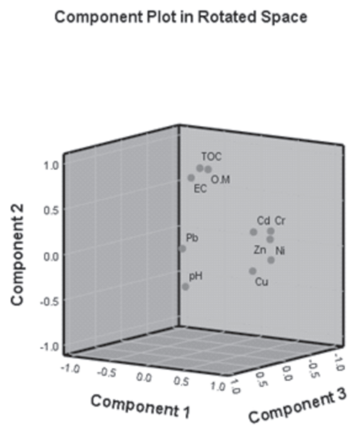

Fig. 2. PCA loading plot of heavy metals and physical-chemical properties in agriculture soil

tion about their sources (Oliva and Espinosa, 2007), and how do soil properties impact the distribution of the heavy metals?

Pearson correlation coefficients were applied to show the relationship between metal and physical-chemical properties in the soil, the results were presented in Table 4. Zn had positive relations with Ni (r=0.829; P≤0.01), Cu (r=0.754; P≤0.01), and Cr (r=0.760; P≤0.01), in addition, Cr results showed a positive relationship with Ni (r=0.754; P≤0.01) and Cu (r=0.567; P≤0.01), which might suggest the same source due to anthropogenic sources. Pb and Cd had not presented any correlation with other metals and even physical-chemical properties in the soil, which were suggested from different sources. pH was negative correlation with Zn (r=-0.342; P≤0.05) in soil, and EC had negative correlation with Cu (r=-0.433; P≤0.01); TOC and OM had positive correlation with Cr (r= 0.363, 0.408 ; P≤0.05) respectively, indicating that EC, TOC and OM impact in increasing of Cu and Cr levels in agricultural soil due to sorb and attractive between Cu, Cr and EC, OM and TOC. The sources of heavy metals in agricultural soils contaminated could come from fertilizer and

Table 3. Principal component analysis between heavy metals concentrations physical-chemical properties in agriculture soil

	Initial eigenvalues			Extraction sum of square loadings			Rotation sum of square loadings		
Component	Total	% of variance	Cumulative (%)	Total	% of variance	Cumulative (%)	Total	% of variance	Cumulative (%)
Total variance explained									
1	3.554	35.536	35.536	3.554	35.536	35.536	3.361	33.615	33.615
2	2.449	24.494	60.030	2.449	24.494	60.030	2.577	25.766	59.381
3	1.278	12.780	72.810	1.278	12.780	72.810	1.343	13.430	72.810
4	0.981	9.808	82.619						
5	0.805	8.053	90.671						
6	0.351	3.514	94.185						
7	0.297	2.967	97.152						
8	0.143	1.432	98.584						
9	0.095	0.954	99.538						
10	0.046	0.462	100.000						
Variables	Component matrix			Rotated component matrix					
	PC1	PC2	PC3				PC1	PC2	PC3
Component matrix									
Cd	0.029	0.156	**0.796**				0.117	0.100	**-0.797**
Zn	**0.935**	-0.103	0.116				**0.921**	0.220	0.033
Pb	0.330	-0.022	**-0.654**				0.197	0.140	**0.692**
Cu	**0.772**	-0.409	-0.087				**0.836**	-0.108	0.247
Ni	**0.846**	-0.316	0.156				**0.917**	-0.012	0.008
Cr	**0.860**	0.001	0.226				**0.837**	0.284	-0.099
EC	-0.169	**0.839**	0.202				-0.398	**0.712**	-0.329
pH	-0.319	-0.327	-0.070				-0.200	-0.412	0.064
O.M	0.448	**0.806**	-0.133				0.125	**0.918**	0.093
TOC	0.431	**0.829**	-0.239				0.083	**0.942**	0.191

agrochemicals (Huang *et al.*, 2007; Atafar *et al.*, 2010). For physical-chemical properties, TOC had positive correlation with OM (r=0.927; P≤0.01) and EC (r=0.496; P≤0.01) in agricultural soils.

Cluster analysis

Cluster analysis was applied to heavy metals and physical-chemical properties in agricultural soils by using between groups linkage, and the interval among variable of metals and physical-chemical properties were used as Persons Correlation Fig 4. The Dendrogram showing three clusterings, Cluster 1 contained Cr, Cu, Zn, Pb and pH. These elements were mainly affected by pH and human activities and gain the pollution from anthropogenic sources. Cluster 2 included only Cd and cluster 3 comprised EC, OM and TOC. Moreover, the cluster analysis (CA) was also carried out on the agricultural soil as spatial variables because know the levels of heavy metals pollution between similar sites of the study Fig (3). The Wards method with interval Euclidean distance were used to classified seven sampling sites into three clusters. Cluster 1: comprised of Shamiya, Sania sites, Cluster 2: included Hamza, Sumer, Ghamas sites, Cluster 3: included Albdair, Afak sites. Hence, the Cluster analysis results showed different anthropogenic activities between sampling sites, and also the physical-chemical properties have impacted some heavy metals distribution.

Geostatistical analyses

IDW is useful to map the geographic distribution of heavy metals in the soil. This interpolation approach works better with uniformly distributed points (Liang *et al.*, 2019). Moreover, the IDW is easier to

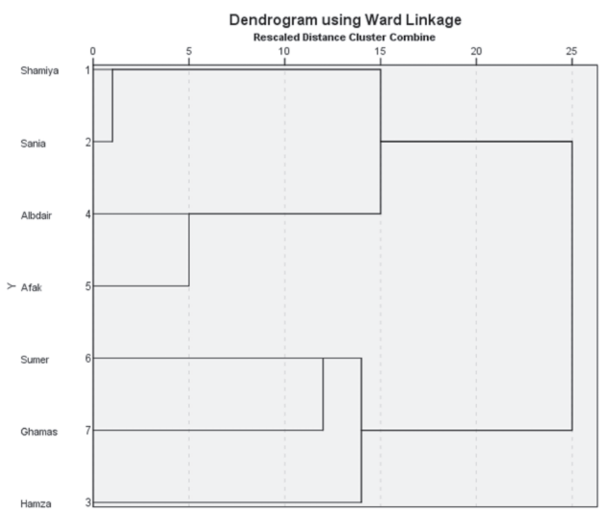

Fig. 3. Dendrogram showing clustering of the agriculture soil sampling

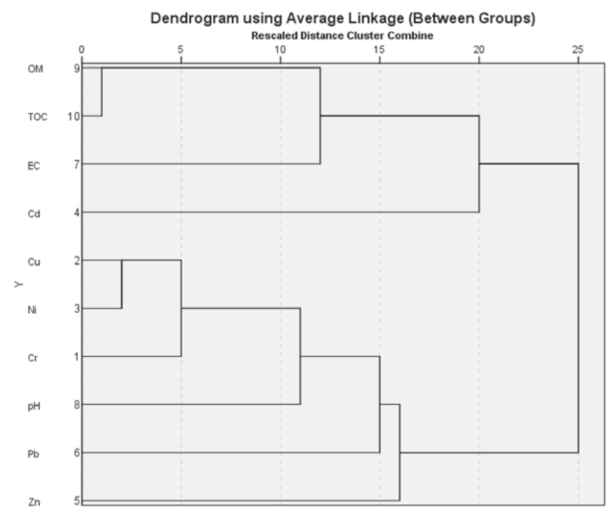

Fig. 4. Dendrogram of the cluster analysis of metals concentrations and physical-chemical properties in agriculture soil

Table 4. The correlation coefficient between metals concentrations and physical-chemical properties in agriculture soil

	Cd	Zn	Pb	Cu	Ni	Cr	EC	pH	O.M	TOC
Cd	1									
Zn	0.062	1								
Pb	-0.161	0.218	1							
Cu	-0.123	0.754**	0.256	1						
Ni	0.092	0.829**	0.234	0.655**	1					
Cr	0.121	0.760**	0.037	0.567**	0.754**	1				
EC	0.223	-0.167	-0.167	-0.433**	-0.322	-0.152	1			
pH	-0.058	-0.342*	-0.062	-0.199	-0.090	-0.090	-0.261	1		
O.M	0.074	0.281	0.185	0.015	0.095	0.408*	0.478**	-0.171	1	
TOC	-0.071	0.261	0.199	0.002	0.061	0.363*	0.496**	-0.307	0.927**	1

**P≤0.01; *P≤0.05

perform in the program and not needed for pre-modelling and individual assumptions as compared with other tools (Jumaah *et al.,* 2019). IDW is classified as classes ranging by colour from minimum to maximum value Figure 5. The value distributions were arranged from the dark green to red colour where heavy metals high contaminated in soils. The spatial distribution of Ni, Cr, Zn, Cu and Pb were highest in Ghamas city which is clearly different from other locations with exception the spatial distribution of Cd where highest concentration in Afaq city. Moreover, the hotspot with Cr and Cu concentrations were also high in Sumer city. The Cd levels was also high in Albdair city. The discrepancy in the concentration levels of heavy metals between the regions of Al-Qadisiyah Governorate has significantly affected the agricultural areas, which may pose a threat to plants through the accumulation of these toxins in the plant tissues, and thus will inevitably affect human health in the near and far future.

The reason for the increase of these toxins may be due to the presence of industrial plants and car smoke around the agricultural areas, in addition to that, the excessive use of pesticides and fertilizers for plants may affect the increase of metals in agricultural soils.

Conclusion

The objective of this study was to discover the six metals sources and to determine concentrations it in agriculture soils. The results found that mean concentrations of Ni and Cr were higher than Canada soil guidelines and average shale. These Elements (Cr and Ni) may impact the integrity of agricultural production in the soil of Qadisiyah Governorate as well as human health. Thus, it is necessary to pay attention to these elements in the future. Moreover, multivariate analyses revealed that Ni and Cr was associated with man-made activities, such as the aerosols of bricks manufacturers, automobile smoke and the use of fertilizers, and livestock in the soil. The geostatistical found Ni, Cr, Zn, Cu and Pb were highest concentrated in agricultural soil of Ghamas city. Therefore, these results are important for future

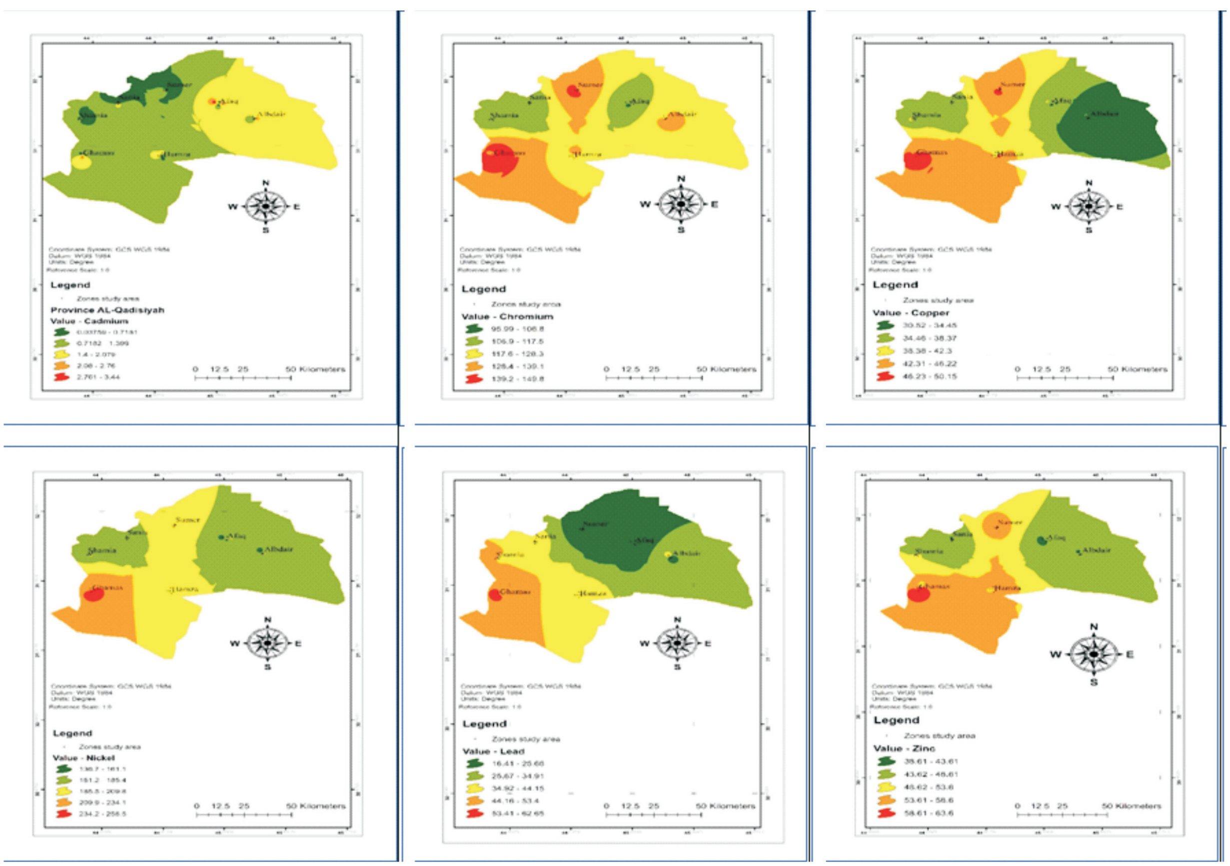

Fig. 5. Spatial distribution of heavy metals in agricultural soil in Al-Qadisiyah Governorate

studies in order to develop appropriate solutions and to limit the deterioration of agricultural soils and reduce environmental risks.

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