Calcium and Magnesium in Ilam Drinking Water Sources during 2009-2013 using Geographic Information System (GIS)

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ABSTRACT

Physicochemical quality of water from the acceptability point of view is essential for consumers; protecting the health of consumers and maintenance of water supply systems. The aim of this study is to determine temporal and spatial variations of Calcium and Magnesium in Ilam drinking water sources using the GIS system.

This cross-sectional study was conducted on 20 drinking water sources in Ilam city and the 5 years results by water and wastewater company archive GIS software version 3.9 were analyzed via SPSS version 16 as well as one-way variance analysis. Water and wastewater sampling and measurement were conducted in order to verify the data by researchers according to standard methods.

Based on interpolation map, the maximum calcium and magnesium contents are related to western and central regions. ANOVA test showed that there no a significant difference between the mean calcium variable verification test in summer during 2009-2013 and at 95% level. ($P=0.760>0.05$). The one-way analysis of variance showed that there is a significant difference between the average magnesium variable in summer during 2013-2009 years and the verification test at 95% level. ($P=0.019<0.05$).

According to maps 1 and 2, in all areas, the mean calcium content is lower than the maximum allowed. And the water quality is desirable based on the parameters. The results of the verification test in 2015, compared with the international standard WHO, showed magnesium concentrations are higher than is desirable maximum in most sources.

Key words: Calcium and Magnesium, GIS, Water, Ilam

LIST OF ABBREVIATION

GIS: Geographic Information System
WHO: World Health Organization
EPA: Environmental and Protection Agency
RMSE: Root Mean Square Error
IDW: Inverse Distance Weighted

INTRODUCTION

Physicochemical quality of water is essential in terms consumer acceptance, protecting the consumer's health as well as the water network maintenance to control some pollutants concentration in some areas in order to improve the public health. The main objective of maintaining drinking water quality is monitoring public and consumers' health. Adequate and good quality water is essential for human survival [1].

In developing countries, 90% of the patients and 23% of deaths due to contaminated water and the desired time everyone spent an average of 10 percent of water-borne diseases [2]. Water resources include surface water, atmosphere and on the ground [3]. 0.62 percent of earth water is ground water resources [4] and 60 to 65 percent of the water supply have been recognized in urban and rural areas, so the protection of ground water and determining its quality is of considerable importance [5].

Calcium and magnesium cause water hardness. Hard water refers to water having a significant amount of soap needed for the production floor and hot water pipes, radiators, boilers and other heating units that are going to create offense [6].The water having hardness of more than 200 ppm could precipitate a mass in the distribution system and high soap consumption. And On the other hand, water with a hardness of less than 100 milligrams per liter will be highly corrosive to pipes [7].

Usually to determine the suitability of groundwater quality for various uses, after sampling physicochemical and biological tests done on samples and comparing the results with standard values, the water quality is determined for consumption [8].

One way to prevent groundwater pollution is groundwater quality spatial variability analysis, management of water resources and land use [7]. Geographic Information System or GIS is regarded as a fan or tool that can be used to identify the data (thematic maps), analyzing and interpreting and summarizing data, evaluation of the ecological and socio-economic needs for human land use, environmental changes, understanding destruction, waste and pollution, and above all in regional planning and environmental planning in other words used. In fact, GIS bridges between databases, resources and management [9].

Unlike classical statistical methods that consider only the value at different points, geostatistical methods also considered the position with the optimal interpolation value data in locations without the possibility of estimating the variable value to provide a continuous surface turn [10]. The aim of this study was to determine temporal and spatial variations of Calcium and Magnesium in Ilam drinking water sources using the GIS system.

MATERIALS AND METHODS

In this study, a cross-sectional study was used to identify the area of organizational management and planning maps. And sampling wells was determined according to the latitude and longitude on a map. The results of chemical parameters during 2009-2013 are done as seasonal ones for each parameter by water as well as the sewer GIS software and stored in a database. Data collected for 20 drinking water sources of Ilam city. These data were taken monthly in 5 years, from 20 drinking water source of Ilam city, by water and wastewater Co. So, 60 samples analyzed by water and wastewater Co. These primary data delivered from archived data center of water and wastewater Co. In continue in order to verify the archived data, 20 samples were taken and 15 parameters analyzed on each sample as secondary data. The primary data were taken from 2009-2013.

As well as water and wastewater in order to verify the data, from any source samples and chemical analyzes were conducted for water and wastewater Calcium and Magnesium and the results were compared, too. The post-processing parameters results, software, Geographic Information System (GIS) and color zoning are to be described that can be done with this process parameter changes in time or location. Zonation of different parameters is shown in the form of a conceptual model in Fig. 1.

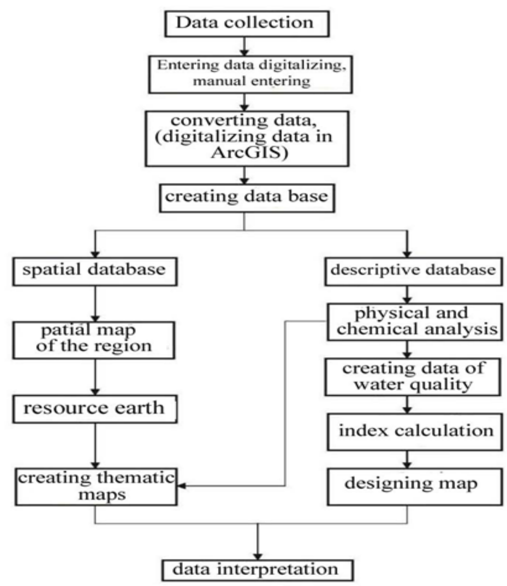

Fig. 1. The Process for Mapping.

RESULTS

Fig.2 (a, b, c and d) show calcium spatial variations in Ilam water supplies in 2009 during different seasons. In accordance to the normal data distribution, the best interpolation method for calcium is ordinary Kriging and the Gaussian model. Based on interpolation map, the highest amount of calcium is related to the western parts; exception is observed for the summer in the eastern regions of highest concentration.

Fig. 2 (a) shows that the concentration of calcium in the western regions is more than the other sites. Calcium concentration is 74.1 milligrams per liter. Calcium is the highest level since the spring. The Root Mean Square Error (RMSE) is 1.07 in spring.

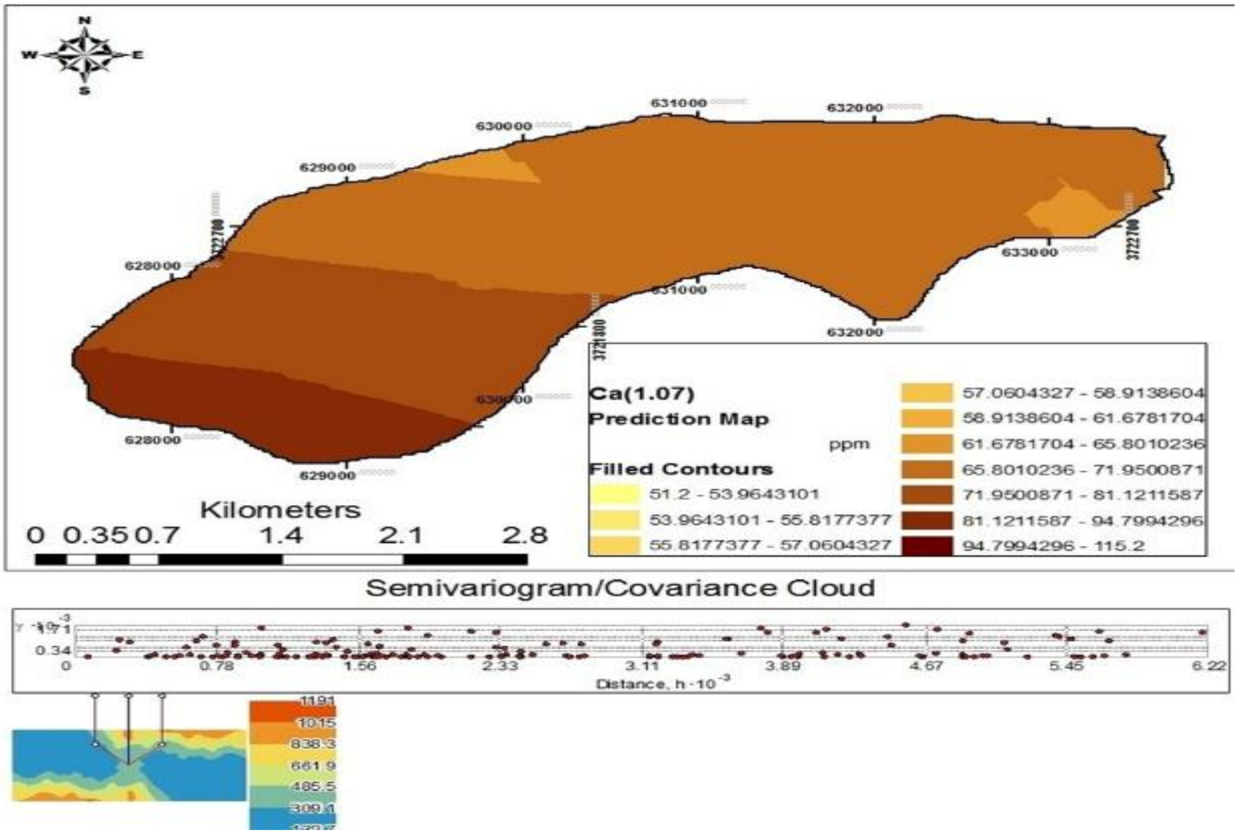

Fig. 2 (a). Calcium spatial variations in Ilam water supplies in spring 2009

Fig. 2(c) shows that the concentration of calcium in the western regions is more than the other sites. The area mean calcium concentration is 70.8mg/L. The Root Mean Square Error (RMSE) is 1.08 in autumn.

Fig. 2 (d) shows that the concentration of calcium in the western regions is more than the other sites. The area mean calcium concentration is 69.8mg/L. The Root Mean Square Error (RMSE) is 0.96 in winter.

Fig. 3 (a, b, c and d) shows calcium spatial variations in Ilam water supplies in 2013during different seasons. Semi-variogram graph on any of the maps shows the spatial correlation between calcium samples. Based on interpolation map, the highest amount of calcium is related to the western parts of the eastern region is higher than in summer. The highest concentration of calcium is in the autumn as well as the lowest in the summer.

Fig. 3 (a) shows that the concentration of calcium in the western regions is more than the other sites. The area mean calcium concentration is 73.6mg/L. The Root Mean Square Error (RMSE) is 1.1inspring.

Fig. 3 (b) shows that the concentration of calcium in the eastern regions is more than the other sites. The area mean calcium concentration is 70.3 milligrams per liter as well as the least amount of calcium in summer. The Root Mean Square Error (RMSE) is 0.68 in summer.

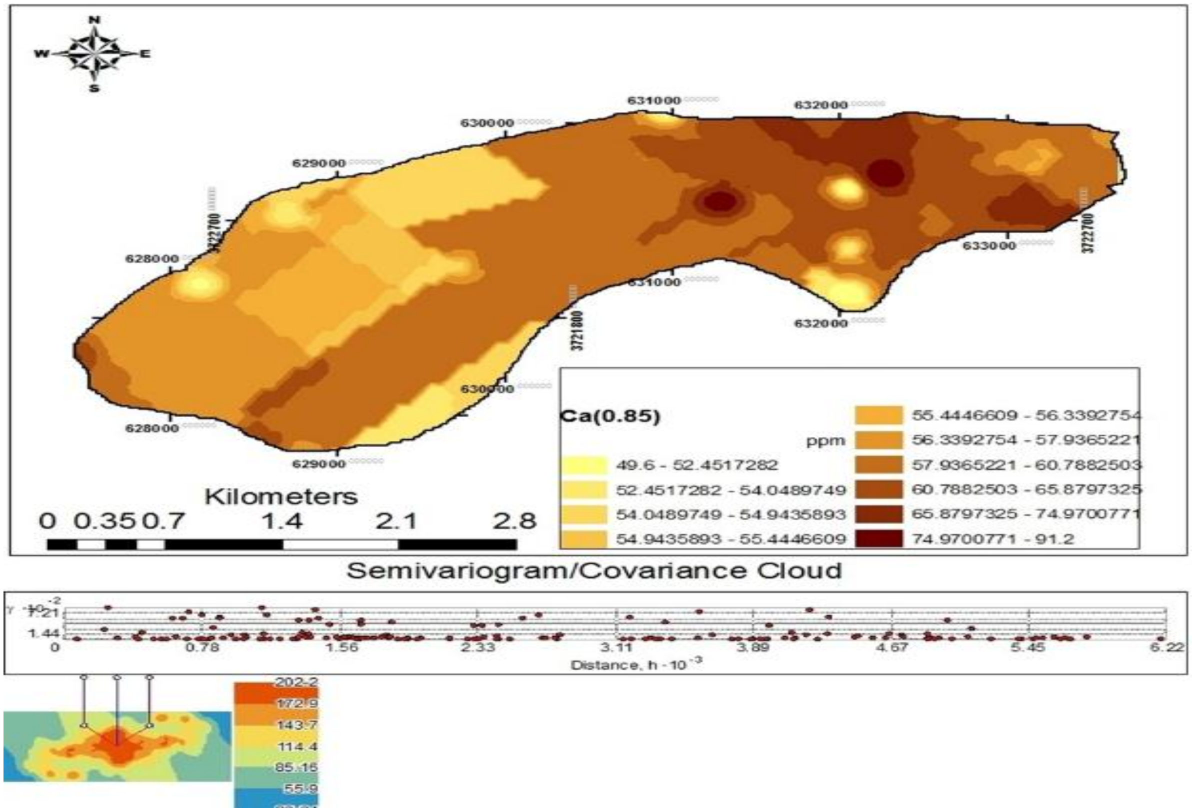

Fig. 2 (b). Calcium spatial variations in Ilam water supplies in summer 2009

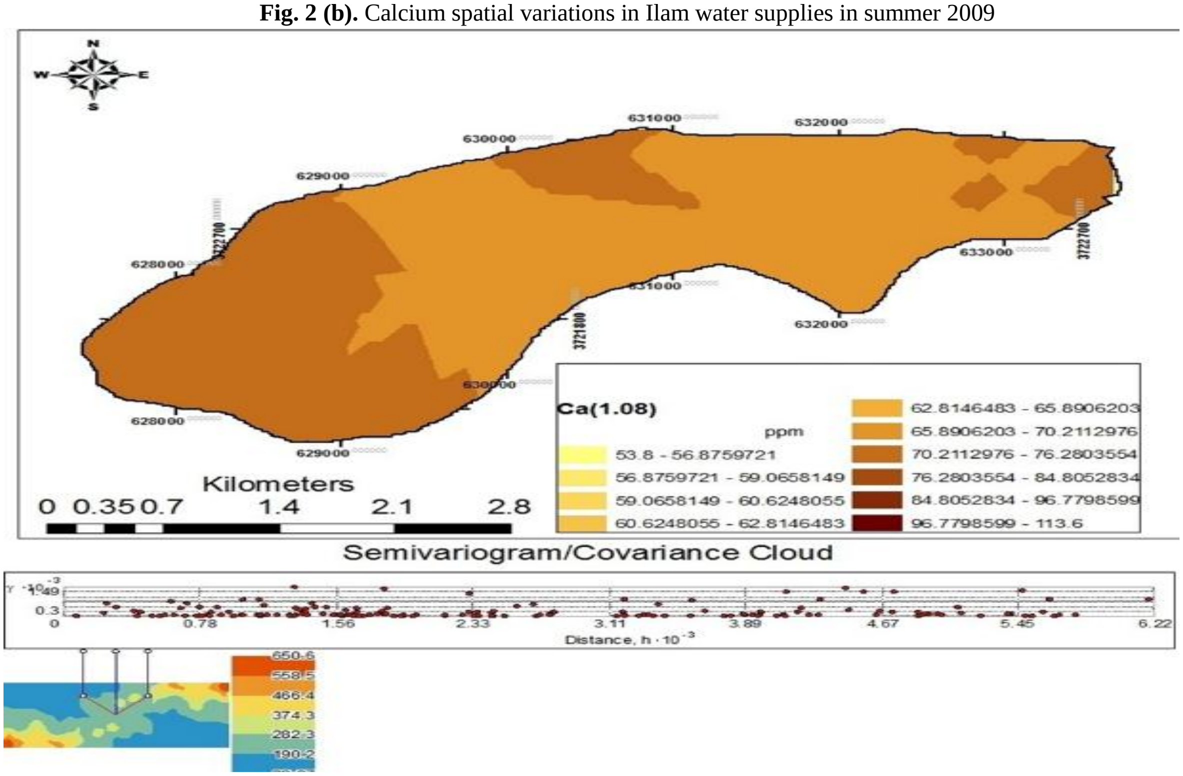

Fig 2 (c). Calcium spatial variations in Ilam water supplies in autumn 2009

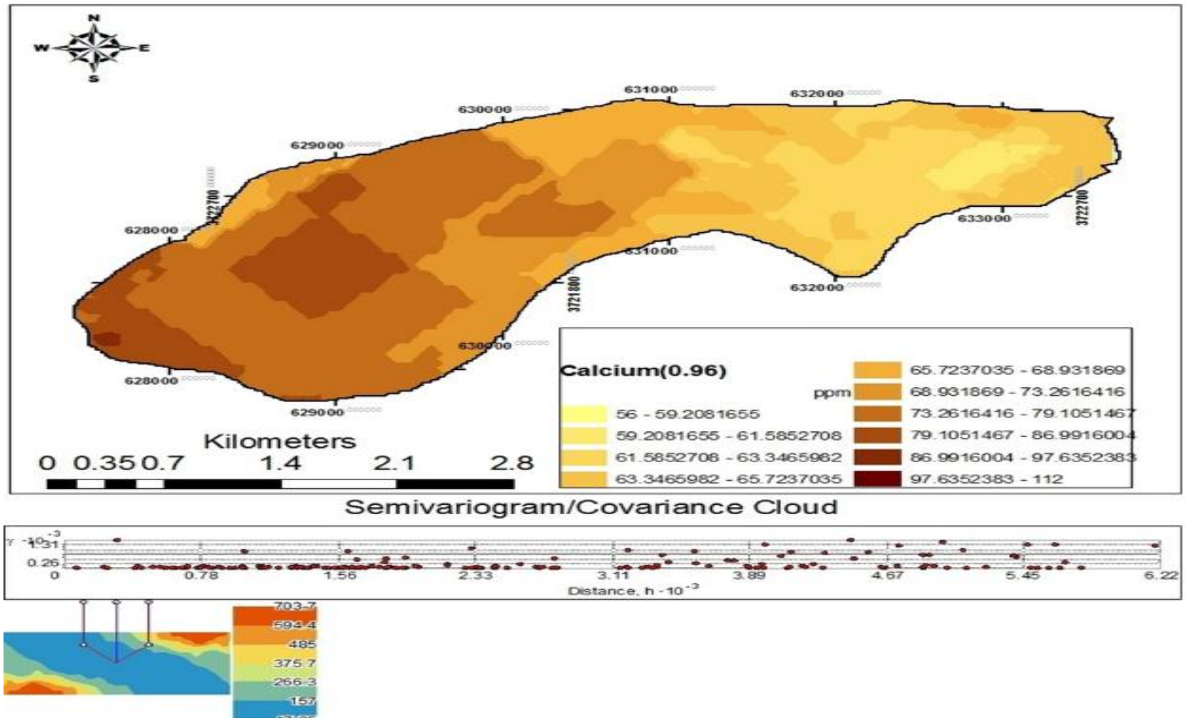

Fig 2 (d). Calcium spatial variations in Ilam water supplies in winter 2009

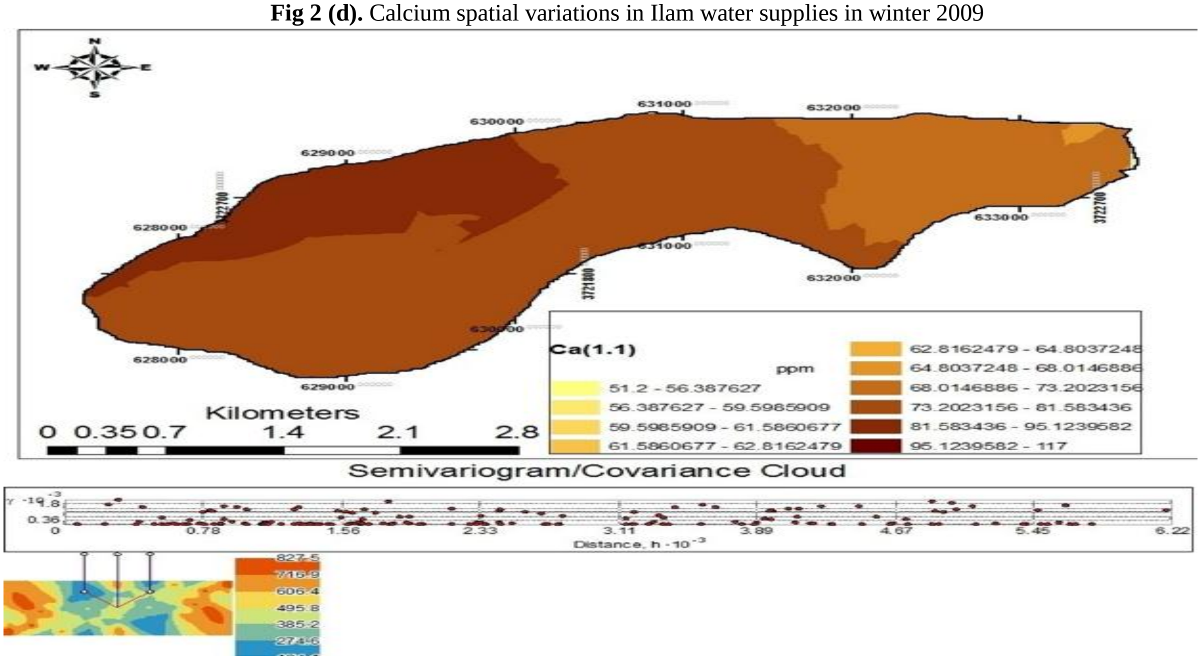

Fig. 3 (a). Calcium spatial variations in Ilam water supplies in spring 2013

Fig. 3 (c) shows that the calcium concentration in the area is sparse. The area mean calcium concentration is 84.06 mg/L as well as the highest amount of calcium in autumn. The Root Mean Square Error (RMSE) is 1 in autumn.

Fig. 3 (d) shows that the calcium concentration in the western regions is more than the other sites. The area mean calcium concentration is 82.3 mg/L. The Root Mean Square Error (RMSE) is 1.08 in winter.

Fig. 4 (a, b, c, d) shows magnesium changes in Ilam water supplies during different seasons in2009. In accordance to the normal data distribution, the best interpolation method for sulfate is ordinary kriging and Gaussian model.

Fig. 4 (a) shows that based on interpolation map magnesium values are sporadic in spring. The mean value Magnesium is 24.1 ppm as well as the highest amounts of magnesium in spring. The Root Mean Square Error (RMSE) is 0.99 in spring.

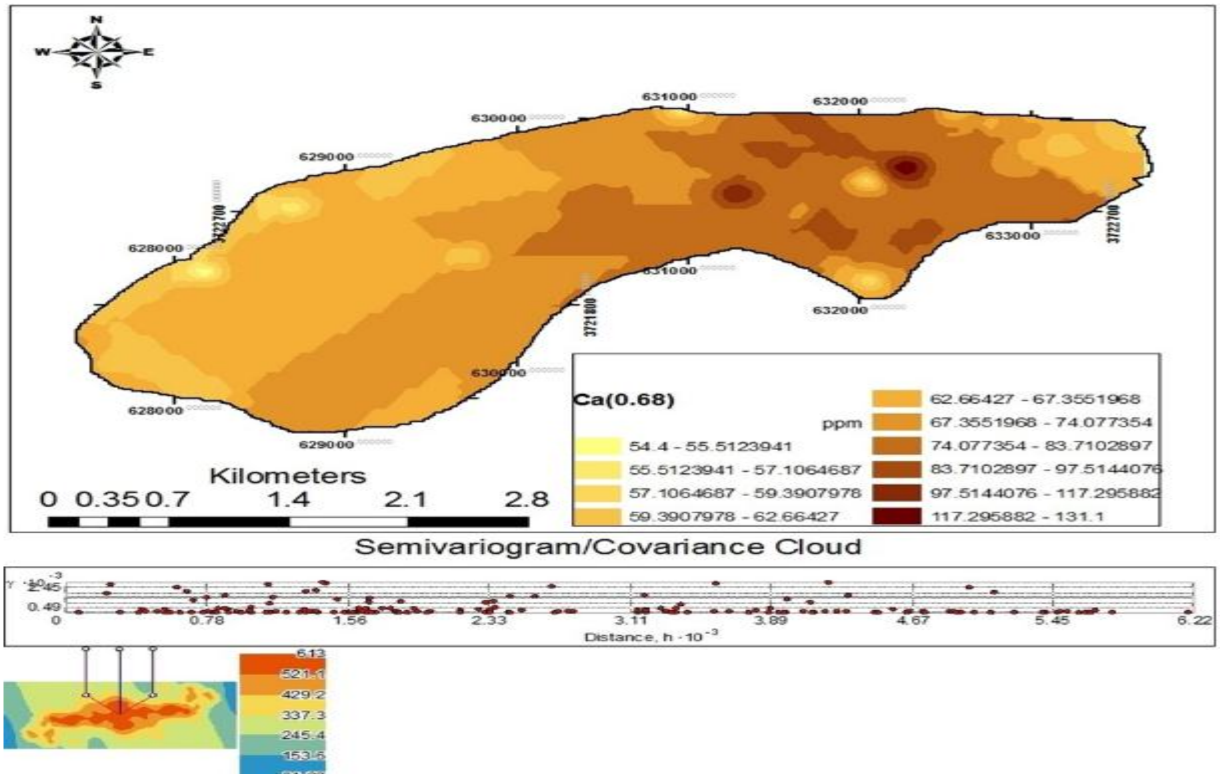

Fig 3 (b). Calcium spatial variations in Ilam water supplies in summer 2013

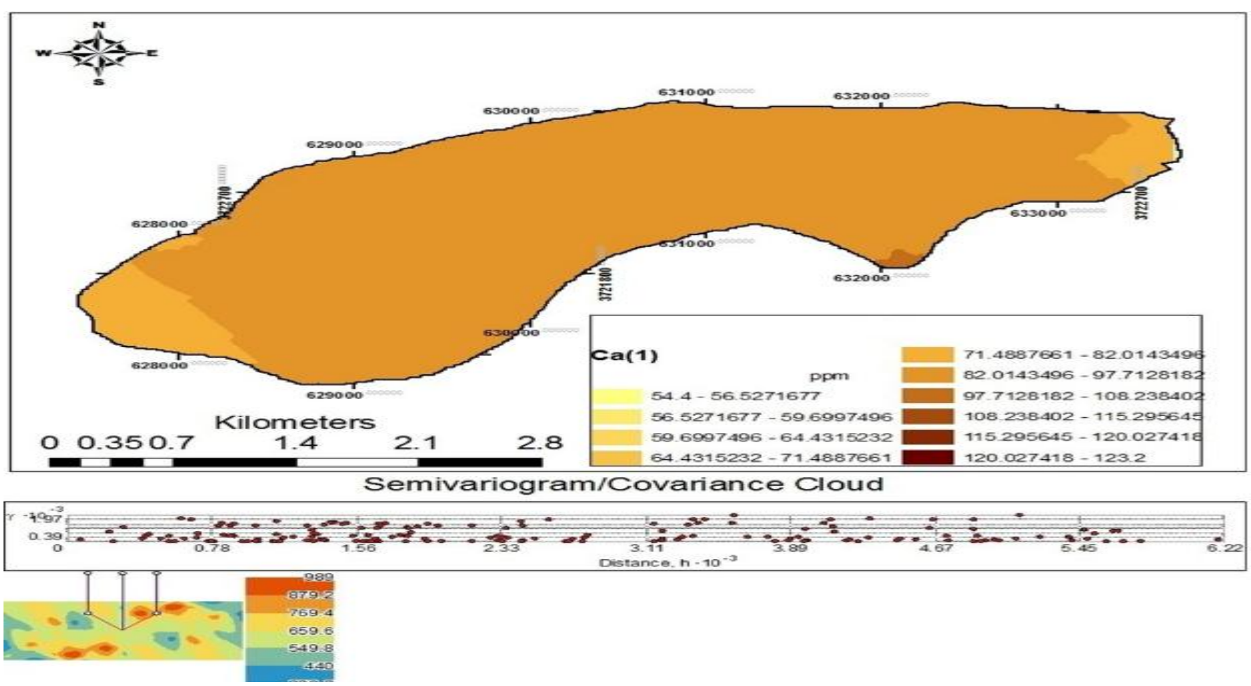

Fig 3 (c). Calcium spatial variations in Ilam water supplies in autumn 2013

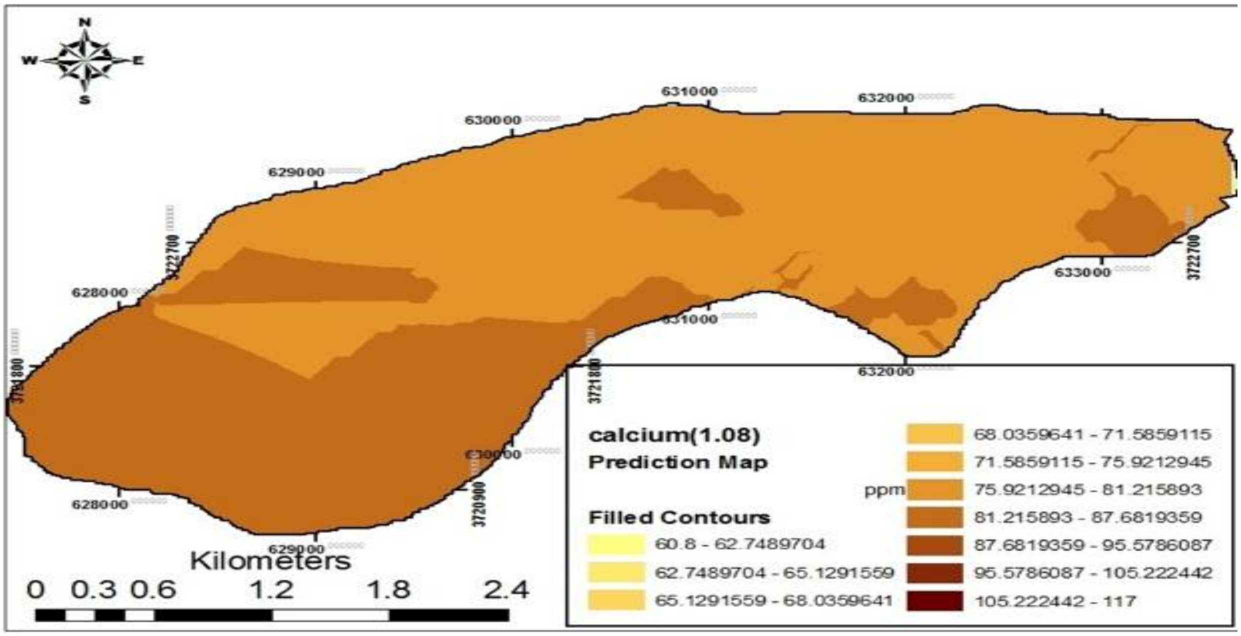

Fig.3 (d). Calcium spatial variations in Ilam water supplies in winter 2013

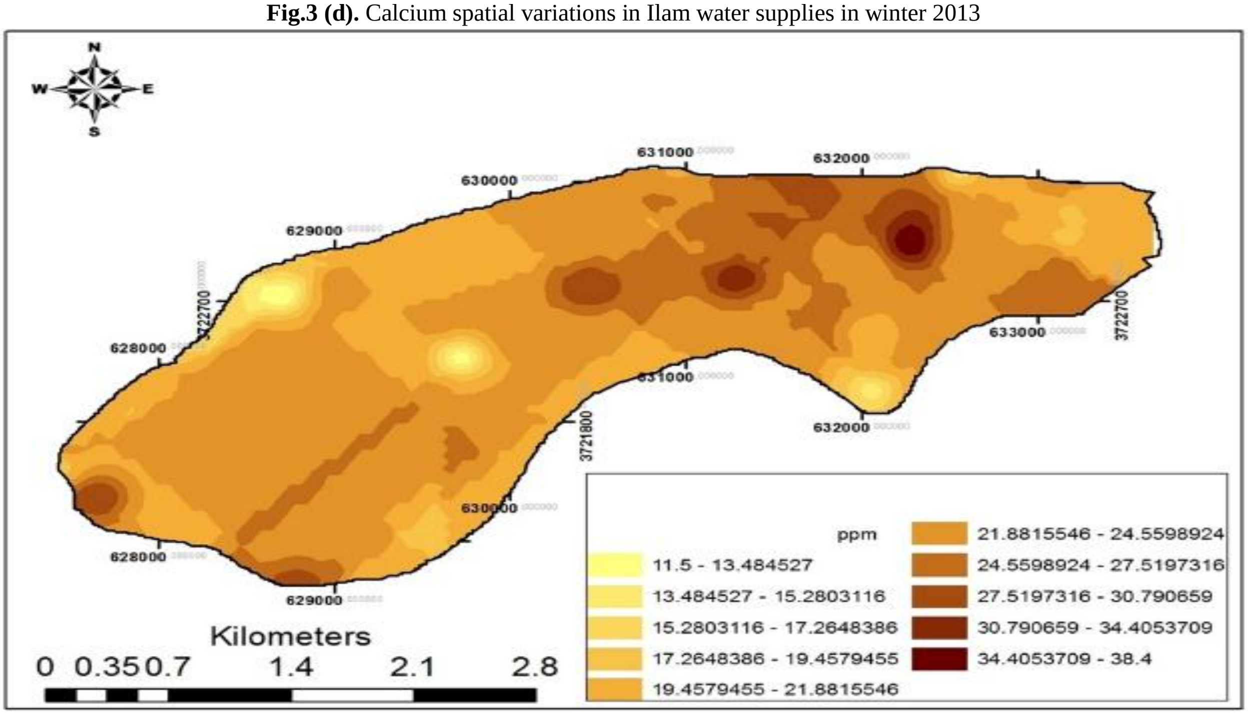

Fig.4 (a). Magnesium spatial variations in Ilam water supplies in spring 2009

Fig. 4 (b) shows that based on interpolation map, the highest amount of magnesium is in the eastern region in summer. The mean value of Magnesium is 21.4 ppm. The Root Mean Square Error (RMSE) is 0.84 in summer.

Fig. 4 (c) shows the highest amount of magnesium based on interpolation map in the eastern region in autumn. The average amount of magnesium is 18.9 mg/L. The Root Mean Square Error (RMSE) is 0.89 in autumn.

Fig. 4 (d) shows that the highest amounts of magnesium based on interpolation map is in the eastern and western regions in winter. The average amount of magnesium is 18.7 mg/L as well as the least levels of magnesium are related to winter. The Root Mean Square Error (RMSE) is 1.33 in winter.

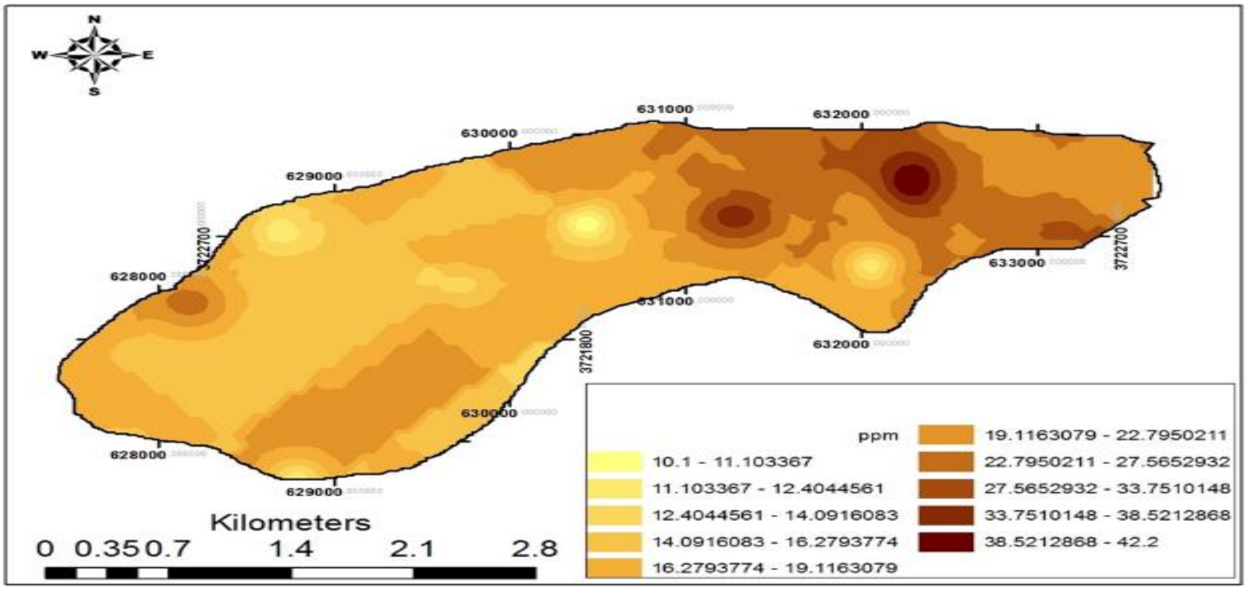

Fig. 4 (b). Magnesium spatial variations in Ilam water supplies in summer 2009

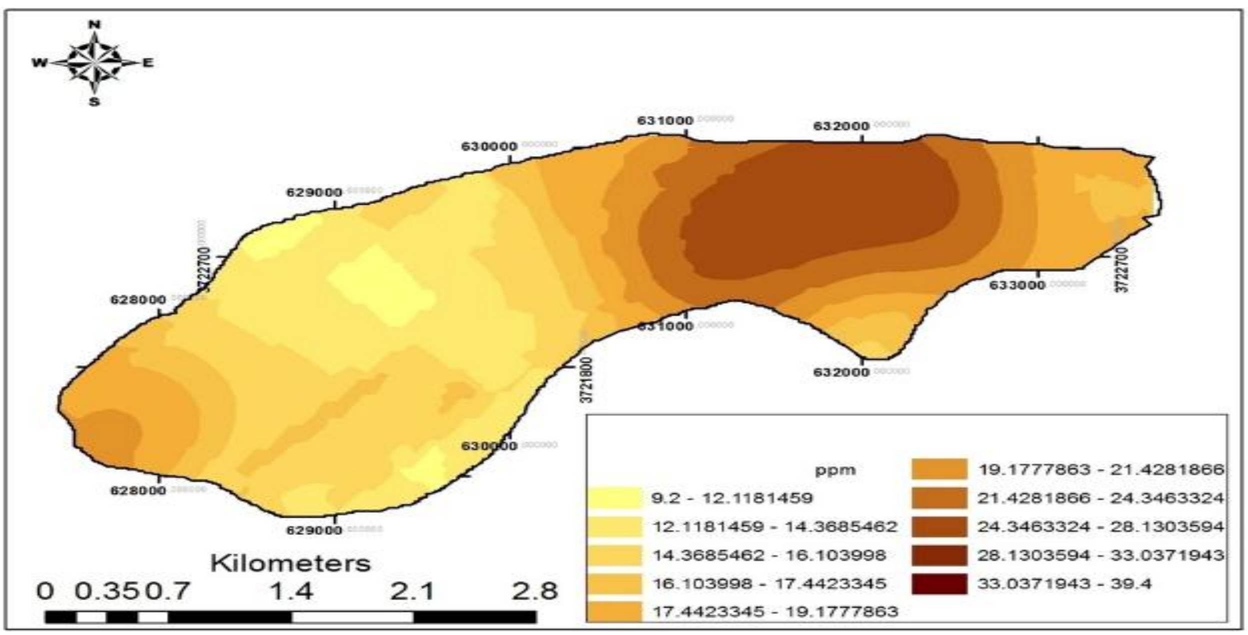

Fig. 4 (c): Magnesium spatial variations in Ilam water supplies in autumn 2009

Fig. 5 (a, b, c, d) show magnesium changes in Ilam water supplies during different seasons in 2013. In accordance to the normal data distribution, the best interpolation method for Magnesium is ordinary Kriging and Gaussian model. The highest amount of magnesium based on interpolation map is more related to central locations in different seasons.

Fig. 5 (a) shows the highest amount of magnesium in the central regions is based on interpolation map. The average amount of magnesium is 21.8 mg/L as well as least magnesium levels are in the spring. The Root Mean Square Error (RMSE) is 1.09 in spring.

Fig. 5 (b) shows that magnesium levels are sporadic based on interpolation map. The average amount of magnesium is 21.9 mg/L. The Root Mean Square Error (RMSE) is 0.85 in summer.

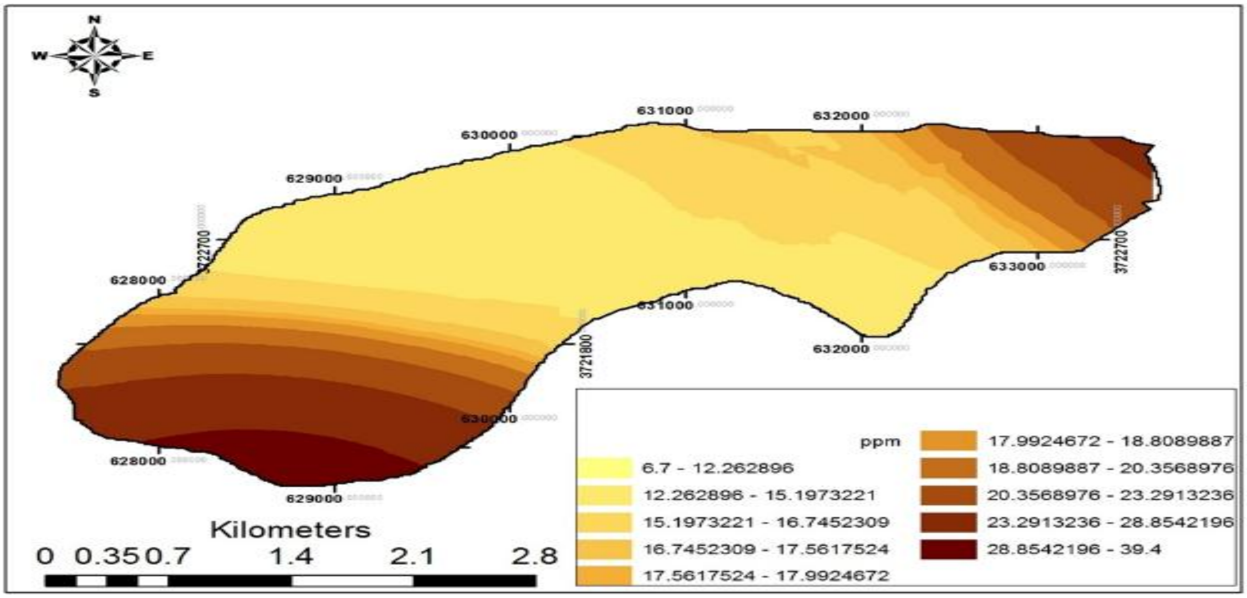

Fig. 4 (d). Magnesium spatial variations in Ilam water supplies in winter 2009

Fig. 5 (c) shows that in the central regions the highest amount of magnesium is based on interpolation map. The average amount of magnesium is 24.3 mg/L as well as the highest amounts of magnesium in autumn. The Root Mean Square Error (RMSE) is 1.16 in autumn.

Fig. 5 (d) shows that based on interpolation map magnesium levels are sporadic. The average amount of magnesium is 23.2 mg/L. The Root Mean Square Error (RMSE) is 0.93 in winter.

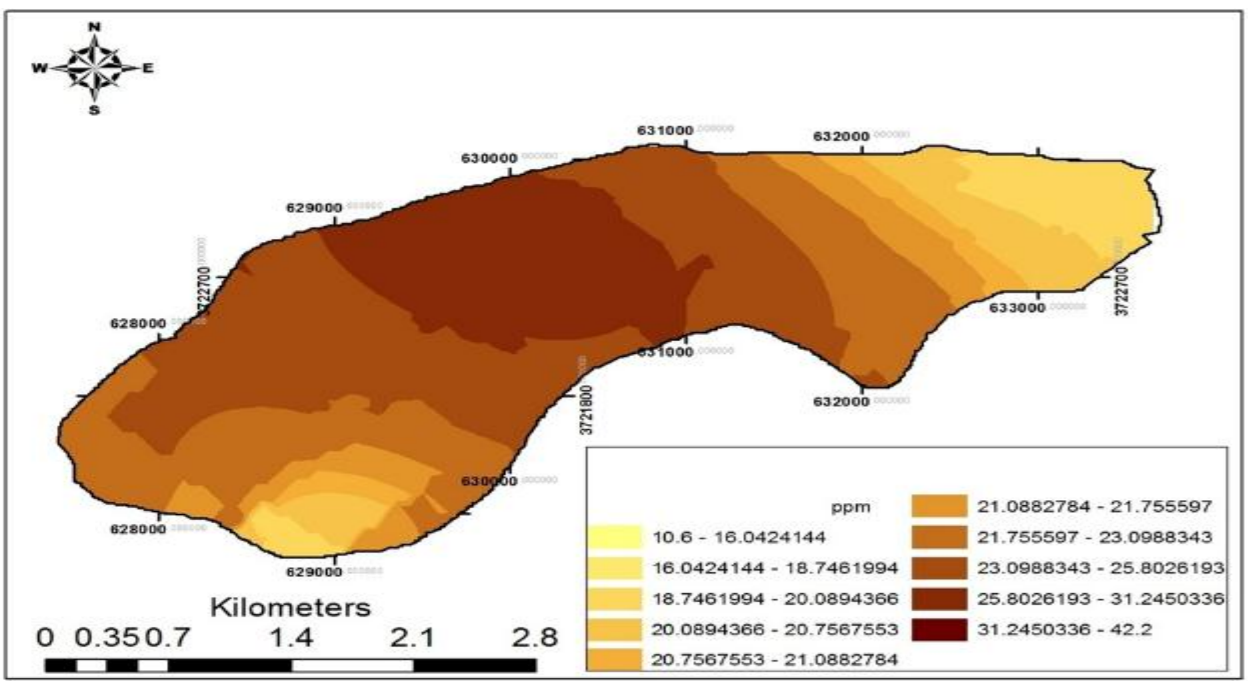

Fig.5 (a). Magnesium spatial variations in Ilam water supplies in spring 2013

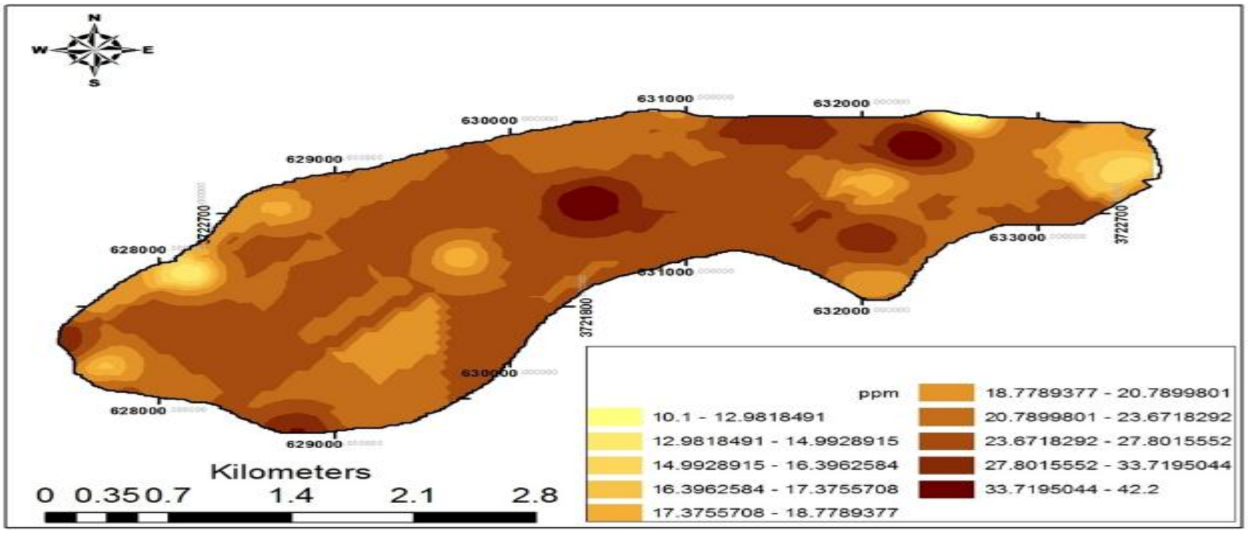

Fig. 5 (b). Magnesium spatial variations in Ilam water supplies in summer 2013

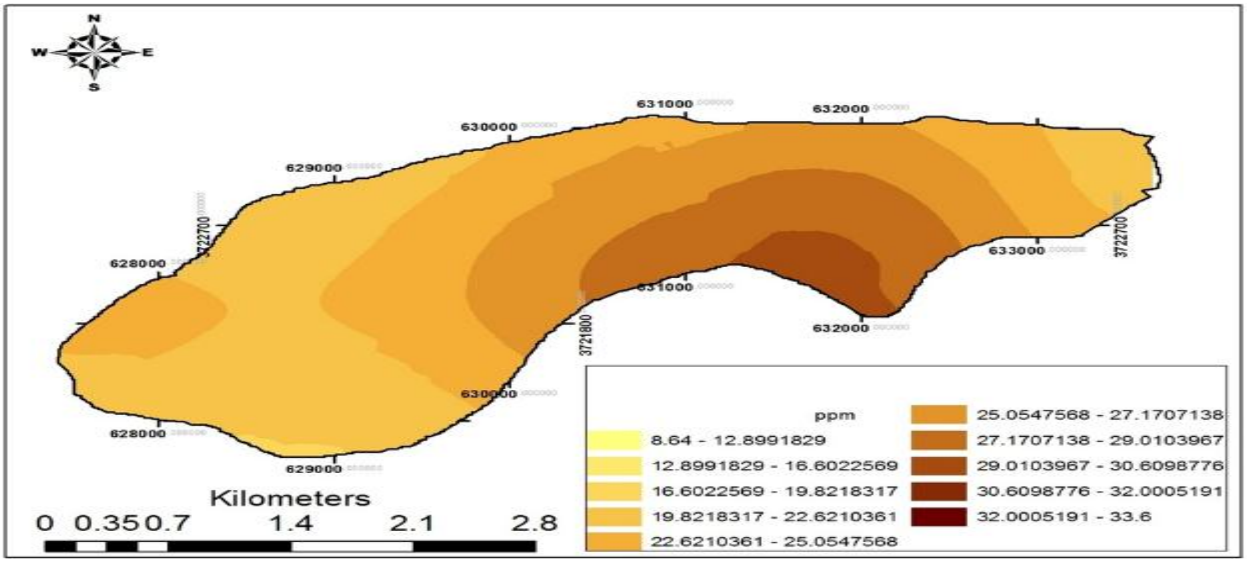

Fig. 5 (c). Magnesium spatial variations in Ilam water supplies in autumn 2013

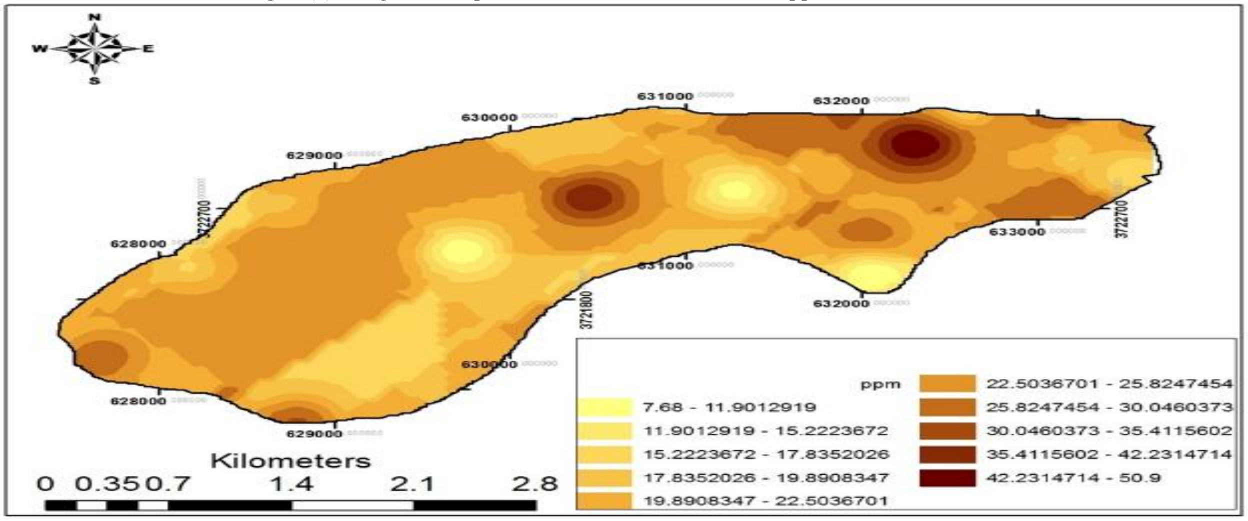

Fig. 5 (d). Magnesium spatial variations in Ilam water supplies in winter 2013

Calcium and Magnesium temporal variations in Ilam water supplies during 2009-2013

Fig. 6 and Fig. 7 present Calcium and magnesium temporal variations in Ilam water supplies during 2009-2013 respectively.

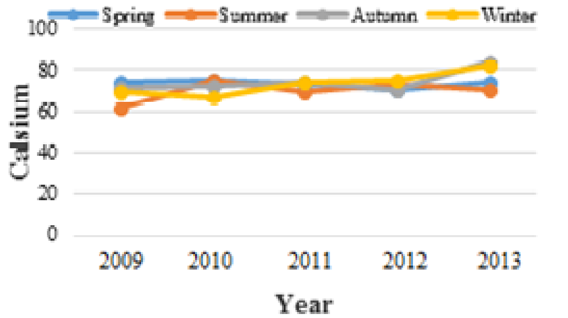

Fig. 6. Calcium temporal variations in Ilam water supplies during 2009-2013

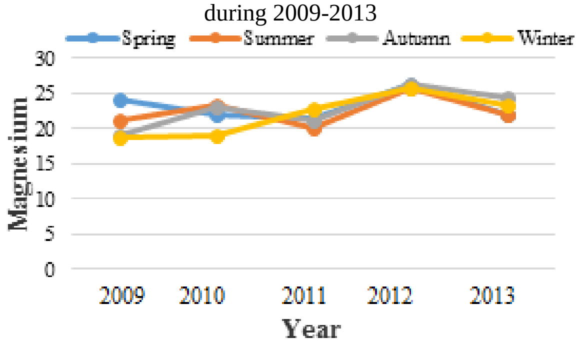

Fig. 7. Magnesium temporal variations in Ilam water supplies during 2009-2013

Water and wastewater analysis results

For Mean differences in the variables, we used one-way variance analysis. The default analysis of variance homogeneity in the groups we want to compare their averages. LEVEN test is the homogeneity of variances statistics if ANOVA test will be significant, determining which tests the chase with equal variances (such as LSD) or heterogeneous (i.e. Dunnett T3) we use mean differences.

For the variables means in four seasons (i.e. spring, summer, autumn and winter), we used one-way analysis of variance during 2009-2013, that presented in Table 1. To check which one of the means are different because a significant amount LEVENE test is 0.012 and the low terminal value is 0.05, we conclude that the variances between groups are not homogeneous. And we use Dunnett T3 test to evaluate the differences among the groups.

According to the test Dunnett T3 at a significance level of 95% there was a significant difference between in winter during2009-2012 ($P=0.011<0.05$), 2010-2012 ($P=0.013<0.05$), as well as 2011-2012 ($P=0.027<0.05$). There is no significant difference between the mean calcium variable and the verification test in the summer during 2009-2013 at 95% level ($P=0.760>0.05$) (table 2).

There is a significant difference between the mean magnesium variable and the verification test in the summer during ($P=0.019<0.05$). To check which one of the means are different because a significant amount LEVENE test is less than 0.037 and 0.05 is a significant level ,we conclude that the variances between groups are not homogeneous. And we use Dunnett T3 testto evaluate the differences among the groups. According to Dunnett T3 test, there is a significant difference at0.05 significant level in July 2010-2015 (P-value=0.007<0.05), 2011-2015 ($P=0.004<0.05$) as well as2013-2015 ($P=0.009<0.05$). Table 3 shows comparsion of water and wastewater engineering company Ilam verification test results.

Table 1. Mean of Calcium and Magnesium in different years and P_{value} in different seasons based on ANOVA test

Parameters	2009	2010	2011	2012	2013	description
Average calcium	68.9	72.00	72.60	71.80	77.60	
P_{value} in spring	0.955					no significant
P_{value} in summer	0.246					no significant
P_{value} in autumn	0.052					no significant
P_{value} in winter	0.054					no significant
Average magnesium	20.7	21.7	21.3	26.00	22.8	
P_{value} in spring	0.257					no significant
P_{value} in summer	0.305					no significant
P_{value} in autumn	0.201					no significant
P_{value} in winter	0.035					significant

Table 2. Primary data Analysis Results with the Experimental Data Verification

		sum of squares	df	F	Sig.
Ca	Between Groups*	1289.351	5	.518	.760
	Within Groups	11957.024	24		
	Total	13246.375	29		
Mg	Between Groups	1291.299	5	3.386	.019
	Within Groups	1830.616	24		
	Total	3121.915	29		

*Each year define as a Group in this table.

Table 3. Compare the results of water and wastewater engineering company Ilam verification test results

Chemical Parameters	Average of primary data results for 20 Wells during 2009-2013	Average Verification test Results for 20 Wells in 2015	Allowed Maximum	The Desirable Maximum
calcium (ppm)	72.03	85.6555	-	300
magnesium (ppm)	22.47865	35.235	-	30

DISCUSSION

Based on all the maps obtained in this study, the best interpolation method was the ordinary Kriging. The study conducted by Taghizadeh Mehrjardi *et a.l* on spatial salinity variability in groundwater using geostatistical study (Case study: Rafsanjan) showed that the salinity zoning IDW (Inverse Distance Weighted) is preferred for the kriging method [11].

To better understanding the spatial samples structures as well as to choose the best interpolation method, spatial autocorrelation is studied between samples. It can be traced distance between the sample and the sample variance values or in other words, semi-variogram is achievable. Based on the idea that semi-variogram properties are more similar phenomena in places closer to farther distances, the degree of association or is correlated between the measurement points [7].

For the statistical parameter assessment, the interpolation methods were used as well as the Root Mean Square Error (RMSE) and this value less than the desired method will be better. In this study, in the majority of cases, the lowest average of Root Mean Square Error showed that in addition to kriging method, Gaussian models, spherical and exponential chemical quality variables are most commonly used for interpolation.

According to the WHO standard, the maximum desirable calcium and magnesium are; respectively 300 and 30 mg/L. The region Calcium mean is 72.03 ppm, in 2009-2013, which is lower than the standard. The results of 2015 verification tests, compared to international standards WHO showed that magnesium concentrations in the resources majority is higher than the desirable maximum.

In a study conducted by Esfandiar Taghavi on calcium and magnesium ion concentration, and water hardness of Kelardasht springs drinking water, the measurement results show that only a spring of water samples are placed in the category of medium hardness. Two water samples were also in hard water and other samples are among the waters with very high hardness [12].

In a research reported in 1997, the result of the study revealed that magnesium intake from drinking water has a significant protective effect on the risk of cardiovascular disease. The level of magnesium in this study was between 7.4 and 13.4 mg/L [13, 14]. In the present study, the level of magnesium was between 22.5 and 35 mg/L, that is in around desirable maximum of WHO standard. The mean calcium concentration in Taiwan's drinking water was obtained 34.7 mg/L, the same as present study. A study suggested drinking water wells need to have clearly defined sanitary boundaries to ensure proper water quality [15]. A study recommended to we need to prevent the flow of agricultural, urban and industrial wastewater and other decentralized wastewater into the ources in order to have an optimal management to protect water quality.

CONCLUSION

Chemical parameters examined in this study do not cause any health problems. However, it is recommended that regular monitoring of water quality should be done in order to protect water quality.

ETHICAL ISSUES

Mazandaran University of medical sciences ethics committee approved this research project. Also researchers considered all contents of ethical issues in the study.

CONFLICT OF INTEREST

We affirm that this article is the original work of the authors and have no conflict of interest to declare.

AUTHORS' CONTRIBUTIONS

All authors were involved in all stages of the research and participated to write this manuscript.

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