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The Relationship Between Nitrate Distribution in Groundwater and Agricultural Landuse (Case study: Ardabil Plain, Iran)

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Abstract: The use of chemical fertilizers in agricultural sector leads to increase of nitrate concentrations in surface and groundwater. The present study determined the vast impacts of agriculture in Ardabil Plain in the northwest of Iran. The study surveyed and measured the amount of nitrate concentration in groundwater sources of 46 wells in the region. Arc GIS software was used to zoning of the area by ordinary kriging function. To match the changes of nitrate concentrations with the land use patterns, images of Landsat Satellite ETM+ in June of 2012 was applied. To determine the relationship of agricultural land use with nitrate distribution in the area SPSS 16 software was used. According to the regression results, the use of agricultural land use and the amount of chemical fertilizer in the region are highly related with nitrate distribution with 95% accuracy. The results showed that the source of nitrate input to the region is the use of artificial nitrate fertilizer in agricultural activities.

Keywords: Groundwater pollution, Qualitative zoning, Nitrate distribution, Interpolation, Regression, Ardabil

1. Introduction

Increase of agricultural activities along with increasing the use of pesticides and chemical fertilizers has effects on the quality of groundwater. With the aim of achieving the maximum agricultural efficiency, high use of chemical fertilizers increases the nitrate concentration in groundwater, which can cause dangers to human health. Since more than 98% of drinking water is provided by groundwater, its protection has great importance (Rivett et al. 2008 and Fataei 2012).

Nitrate is a mobile anion in the soil and cannot be absorbed in it, because most soils have negative charge surface. Nitrate that is soluble in the water can persist decades in groundwater and tends to infiltrate in down layers of the soil and groundwater, because of its high-solubility in the water and stability in the soil. Mitra and Lohochoudhury (2019) showed that a negative and positive association with geo-environmental and nitrate content in groundwater. According to the research, the nitrate content influx was due to anthropogenic causes within the community.

Excessive nitrate concentrations[1] in drinking water cause gastric cancer, goitre, and children mental disorders[2]. High nitrate decreases the uptake of iodine in human and thyroid diseases spreads. In addition, it increases the rate of infant mortality and blood pressure problems (Bradley et al. 2011). One of the best ways for prevention of groundwater contamination is identification of the vulnerable areas of the aquifers and management of land use. Vulnerability can be defined as

1 - 50 mg/litre
2 - Methemoglobinemia

possibility of infiltration and diffusion of pollutants from surface to the groundwater (Nikjogh and Kaboli, 2010).

In order to control and reduce the pollution of groundwater and their effects, one needs to know the distribution and dispersion of pollutants. Such information can only be accessible by survey and monitoring of pollution in the region and interpolation of samples and different analyses (Al Sheikh et al. 2008).

At first, to survey the impacts of land use on nitrate distribution of groundwater, information of nitrate in Ardabil drinking water wells were extracted and GIS identified unknown points. Then land use maps were derived from satellite images in the same year and the main areas of agriculture use were identified. After that, the relationship between the amount of applied chemical fertilizers in agricultural lands and nitrate in the groundwater was studied. Since the estimation of exact amount of fertilizer is uncertain and impossible, the information of agricultural land use was used.

2. Materials and Methods

Study Area

The study area is in the central part of Ardabil Plain, northwest of Iran, in 38 to 38°, 31′ of north longitude, and 48°, 10′ to 48°, 39′ of east longitude (Fataei 2012) (Figure 1).

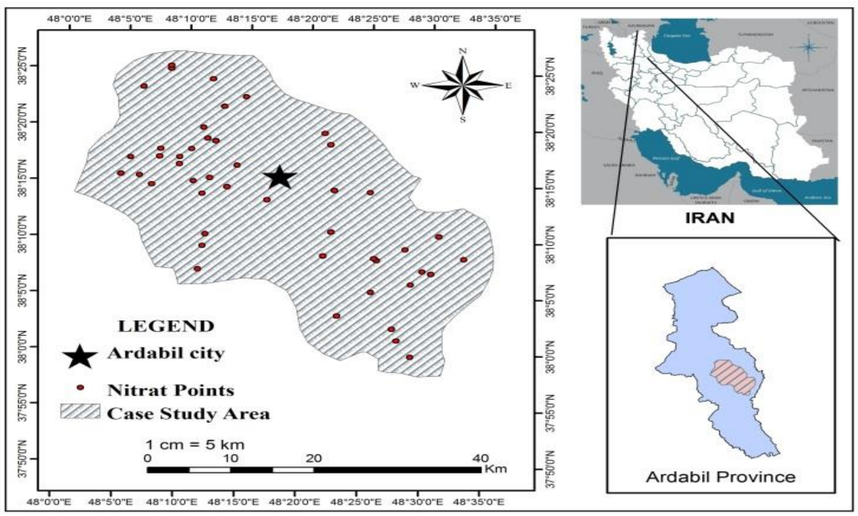

Figure 1: The location of the study area

2. Materials and methods

Analytical regression was used to determine the correlation between the change of nitrate levels in groundwater and agricultural land use. After determination of the amounts of nitrate in the groundwater, interpolation model in the region was applied as follows:

2.1. Interpolation models for nitrate

There are various methods for studying and zoning of the characteristics of groundwater change, each of which has different accuracy depending on the region conditions and data. Identification and mapping of quality changes and factors by traditional methods is a hard, time-consuming, and expensive work (Akbari et al. 2009). Some of interpolation methods for preparing the maps of groundwater contamination by nitrate include kriging geo-statistical and certain methods such as inverse distance, radial basis function, local and general estimator.

For analysis and zoning of the nitrate data, normality test, and entry to GS+ software was done. Cross validation, technique[3] was applied for the estimation of error using standardized root mean square of error model. The lower the amount, the more accuracy of the model (Shabani 2009). Therefore, the optimal method of interpolation was selected (Yao et al. 2013).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}[z^{*}(x_i)-z(x_j)]^2}{n}}$$

3 -Cross-validation

(1)

Nitrate data of the groundwater wells (including 48 wells with two repeat in dry and humid seasons) were entered into the GIS software and the distribution of nitrate concentration in the region was prepared by optimal interpolation method.

2.2. Analysis and provision of land use map

Land coverage and its change are important variables that has significant impacts on the environment and its processes. All decision-makers and researchers need reliable and updated data on land coverage and use. At present, satellite data have high capability in providing land use maps and especially in large geographical areas. For mapping of land use change Landsat ETM+ satellite images in June of 2012 was used (Foody 2000).

2.3. Regression analysis

One of the most common issues in environmental science is the question that if X variable changes, will there be any changes in Y variable? It is important to know the type and severity of changes in X, which causes change in Y. For example, if X changes as 10%, will Y change? If it is positive, is the change in Y increasing or decreasing, and how much? To answer such questions about variables relationship, researchers can use techniques of linear regression. In this method, the value of Y variable is plotted on the graph and the value of X will be achieved. This is the simplest and best method to describe the relationship of variables (Yuan et al. 2005).

In addition, the regression provides metrics that show how two variables are linearly correlated (or how distribution points are on a straight line). This is the standard Pearson correlation coefficient (known as R correlation coefficient), whose square is shown in R2.

The question here is that why both R and R2 are used. R can have both positive and negative values and shows that increase or decrease of independent variable can cause increase or decrease of other variable or not. On the other hand, R2 can only be positive (Yuan, 2005).

3. Results

3.1 Determination of optimal interpolation model

The location and amounts of nitrate in 46 sample wells are presented in Figures 2 and 3.

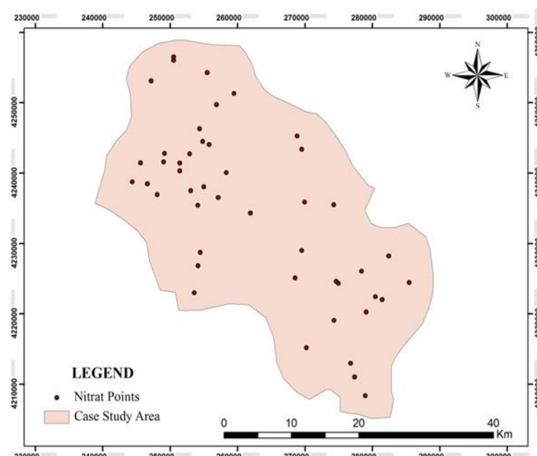

Figure 2: Location of sample wells in the study area

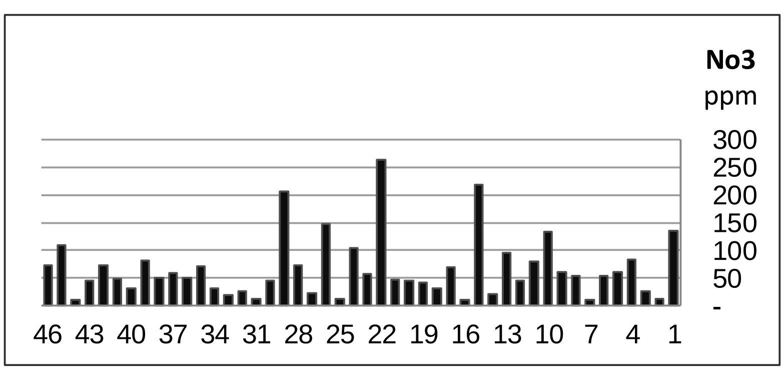

Figure 3: The change of nitrate concentration in in the study area

The evaluation of validation results for determination of optimized interpolation model showed that common kriging method with the lowest RMSE (Table 1) was selected as final and most suitable method for provision of the map of change in nitrate concentration. Some researchers such as Barky and Pasarla (Barca et al. 2008; Shabani 2009) used the method to represent the quality map of groundwater change in the study area.

Table 1: RMSE value for each of interpolation methods

Method	RMSE
(Inverse Distance Weighted)	56.79
(Global Polynomial Interpolation)	55.28
(Local Polynomial Interpolation)	53
(Radial Basis Function)	52.74
(Ordinal Kriging)	51.35

Based on statistical analysis during two sampling periods, the best interpolation method is ordinal kriging.

3.2. Providing of nitrate zoning maps

Based on Ordinal Kriging method, nitrate zoning maps was done by Arc GIS software. The results show that maximum amount of nitrate is in the north and south of the region where extensive agricultural activities are carried (Figure 4).

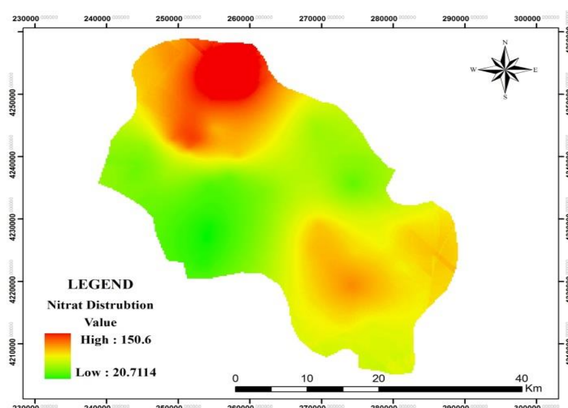

Figure 4: Distribution map of nitrate values in the region

3.3. Map of land use

For mapping of land use change, Landsat satellite images ETM+ in June of 2012 were used. Based on field data, maps of land use patterns of 2012 were provided using unsupervised and supervised classification. Land use patterns includes agriculture, range, arid areas, groundwater, and residential areas (Figure 5).

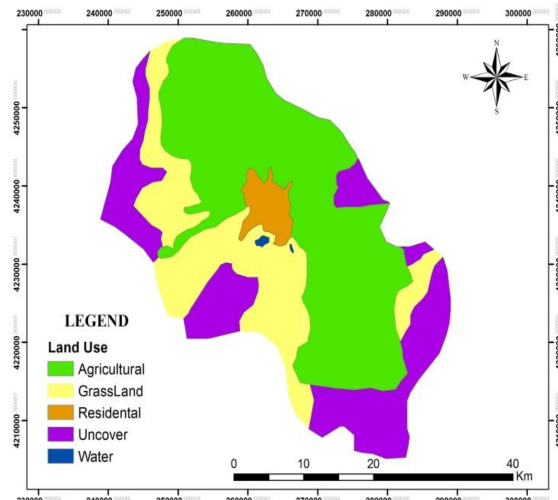

Figure 5: Classified map of 2012

3.4. Evaluation of accuracy of land use map

Many studies of land use mapping (Sepehry and Mottaghi 2002; Alavipanah 2018) have used the maximum likelihood method due to its high accuracy. The model used in this study is valid because of high value of Kappa statistic of 0.8. Table 2 shows the Error matrix of land use in 2012.

Table 2: Results of accuracy evaluation in classification of land use

Average accuracy	81.28	Overall accuracy	70.87
KAPPA COEFFICIENT	0.834	Standard Deviation	0.00323

3.5. Regression analysis of nitrate zoning map with land use changes

Linear regression was used in measurement of the relation of mentioned standards with zoning of nitrate change (Table 3).

Table 3: Regression data of nitrate distribution with land use.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.497[a]	.247	.247	22.207

a. Predictors: (Constant), land use

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5316467.699	1	5316467.699	1.078E4	.000[a]
	Residual	1.620E7	32845	493.171		
	Total	2.151E7	32846			

a. Predictors: (Constant), Land use
b. Dependent Variable: Nitrate

4. Discussion

Statistical analysis on nitrate data showed that in the dry season 43.47% and in the wet season 54.34% of the total samples measured in terms of nitrate content were higher than Iranian drinking water standard (50 mg / l). Overall, there was a significant difference at the 99% probability level between the nitrate data in the two dry and wet seasons. There was a significant relationship between nitrate concentration and other physical and chemical parameters during the two sampling periods at 99% and 95% probability level. Suthar (2010) in Rajesthan , India Shown that about 95% of sites of this region contain a higher fluoride level in groundwater than the maximum permissible limit as decided by the Bureau of Indian Standards. Nitrate (as NO3-) contamination has appeared as another anthropogenic threat to some intensively cultivable rural habitations of this region.

The main reason for the high nitrate concentration in the wet season in 60.87% of the samples compared to the dry season, was more rainfall due to leaching of the previous year's fertilizers and their infiltration into water resources. The highest amount of nitrate in the dry season was related to drinking water of Taleb Gheshlaghi Village (212 mg / l) and the lowest amount of Jamadi Village (11.5 mg / l). In the wet season, the highest values were in the village of Dujjin (264 mg / l) and the lowest in the village of Agbalagh Rostam Khan (9.55 mg / l).

GS + software analysis results showed that the best model for normalized nitrate data is the exponential model. Validation results also showed that conventional kriging method with the lowest RMSE is the most accurate method for interpolation and zoning of nitrate values. Results of interpretation of the maps showed that areas with high nitrate were located in the lowland areas where the dominant irrigation was potato and wheat, and areas with low nitrate were observed in areas with dry farming and pasture - dry farming.

Examination of the elevation map showed that the slope in the region was from northwest to east and center of the plain, which was in line with the map of changes in nitrate levels, which had also decreased from west to east. The concentration of nitrate in these areas was also critical due to the landfill site of Ardebil city near Talib Gheshlagh and Samian villages. The main cause of groundwater pollution in this area is due to leachate infiltration from Ardebil landfill to the aquifer.

5. Conclusions

Nitrate is considered as one of the polluting factors of groundwater resources that has been increased in recent years because of extensive agricultural and human activities. Groundwater is important in meeting human needs for urban and rural applications. Since most of drinking water resources of villages in Ardabil Plain are provided by underground wells, knowing the possible contamination of the resources is critical in health issues.

The major factor of Nitrate in soil and water is overuse of nitrate chemical fertilizers in agricultural lands. Therefore, this study aimed to investigate the relationship between land use and nitrate distribution in the region. Regression results indicated that the correlation of land use map with nitrate distribution are 95% accuracy. Hence, it can be said that agricultural land and chemical fertilizers use in farmland are significantly correlated. In addition, the zoning results show that high nitrate areas are in those parts where wheat and potatoes are dominant. Low nitrate zones are located in dry farming and dry farming-range parts.

We can say that the main reason of increasing the nitrate concentration in groundwater is increase of extensive land use in the region. The result of field study show that use of interpolation and regression analysis can be used in modelling of environmental quality and quantity parameters and its relation with pollutant sources.

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7. Additional information and declarations

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Competing Interests

The authors declare there is no competing interests, regarding the publication of this manuscript

Author Contributions

Ebrahim Fataei: Prposed the plan, conceived the experiments, analyzed the data, authored or revised drafts of the paper, approved the final draft.

Habib Farhadi: Conceived and designed the experiments,contributed reagents /materials/analysis tools, prepared figures, and tables.

Marjaneh kharrat Sadeghi: Analyzed the data

Data Availability

All the data are shown in the tables of this article.

Ethics Statement

The study was conducted by Azar Ab Andish Engineering Consulting Co.

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