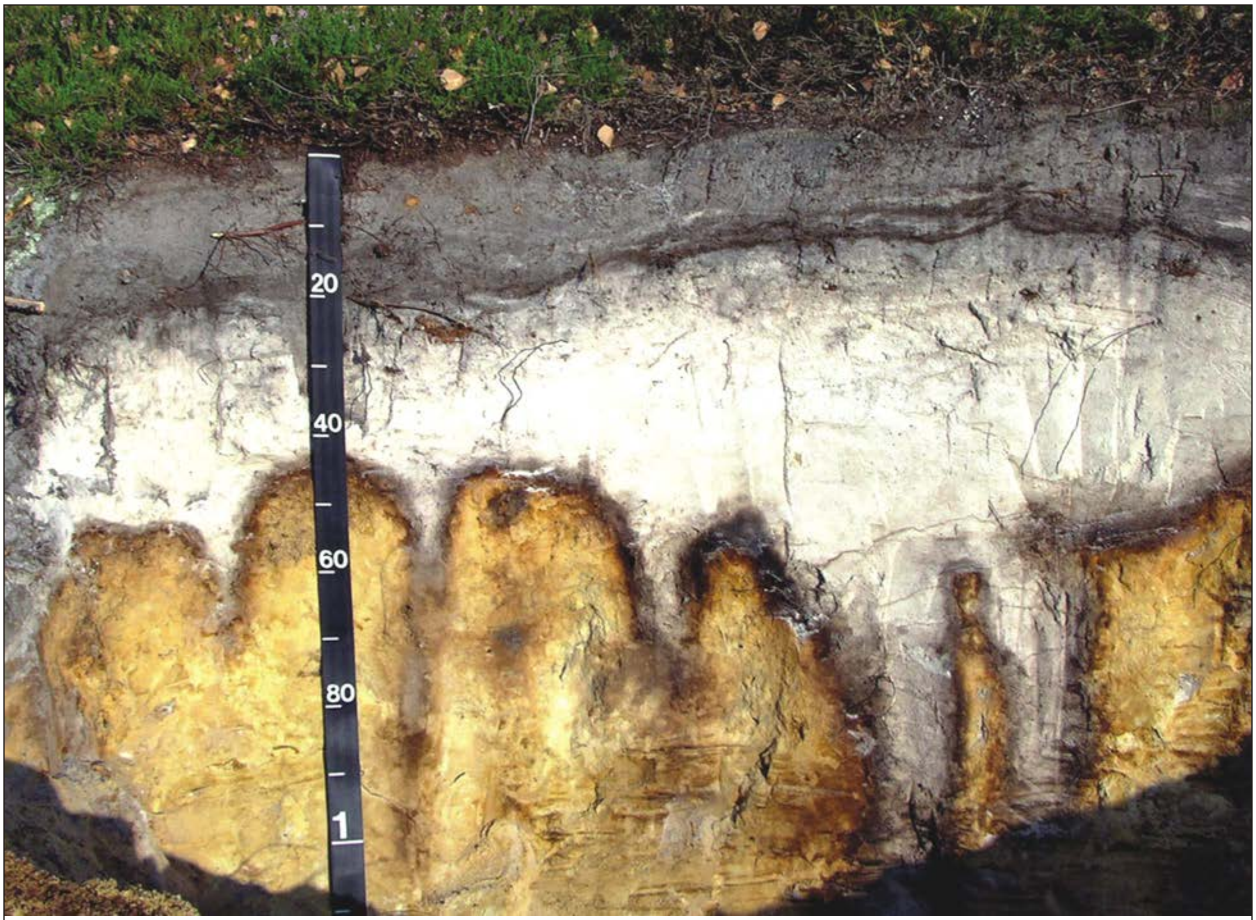

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Spatial Variability of Macronutrient for Soil Fertilization Management: A Case Study on Urmia Plain

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ABSTRACT

This research was conducted to study spatial distribution of soil nutrients including nitrogen, phosphorus and potassium and to compare the efficacy of various geo statistical approaches in the estimation of these nutrients and the preparation of spatial variability maps of these elements aimed to righteous management of fertilizers in Urmia plain, West Azerbaijan Province, Iran. To estimate the rates of soil nutrients including nitrogen, phosphorus and potassium of non-sampled areas, the Kriging, Co-kriging and Weighted Moving Average methods were used in a GIS system, instead. To compare these methods, cross-validation method with two statistical parameters Mean Absolute Error and Mean Bias Error were applied. Present studies implied that Kriging method has the least MAE of 0.450 and MBE of 0.025. This method with correlation coefficient of 0.99% and Gaussian semi variogram was of high preciseness in the estimation of nutrient rates in the points with no former information available. The estimation error in this method ranged between 0.18 and 0.75 and its deviation was between -0.002 to 0.12 meq/100 g of soil.

Key words: Geo statistic, GIS, soil nutrients, spatial distribution

INTRODUCTION

The deficiency of major nutrients in arid and semi-arid areas is apparent because of the encasement of nitrogen in the combination of organic materials, slow mineralization rate of these compounds, weak solubility of phosphorus and stabilization of potassium by some types of clays. Islam *et al.* (2009) studied N, P, K and organic carbon as main plant growth factors. Their results revealed that plant macro nutrients nitrogen, phosphorous and potassium were found in significant amount compared to some commonly used organic manures.

Chemical fertilizers are the most important source for the provision of plant nutrients and their proper and optimized application is of fundamental role in the obtainment of the purposed crop yield (Washburn *et al.*, 2002) and preserve of agro-ecosystem. If a plant suffers from the deficiency in one of the major nutrients, NPK; then the increased fertilization with other nutrients will not lead to the increased yield, unless the limiting factor is corrected. Soil fertilization management based on particular variations of each field soil is one of important principles of the reduction of the environmental pollutions caused by irrationally overuse of chemicals such as chemical fertilizers (Scharf *et al.*, 2002). With the correct fertilization management, comprehensive and sufficient information on the rates of soil nutrients can be applied for better yield of crop plants and to this end, the classification of the lands from the viewpoint of fertilization recommendations based on the soil nutrients analysis in laboratory is necessary and in the absence of such information on soil variation, some soils will receive more fertilizers and some will get less than the rates they require. Because of the complexity of local distribution and high variation in soil, the use of geo-statistical approaches for the estimation of soil properties in non-sampled points is necessary (Clark and Harper, 2000). In such cases, geo-statistical approaches including non-parametrical statistical estimators like weighted moving average and or parametrical land-statistical approaches such as Kriging and Co-kriging methods can be used (Wackernagel, 2003). The difference among these methods lies in the calculation of the weight factor which is considered for each of the points around a given point. Nazarizade *et al.* (2003) applied a geo-statistical approach to analyze local structure and the number of soil samples in order to study soil characteristics such as the rate of phosphorus and the number of arbuscular mycorrhizal fungus. They indicated that the variation of these two factors in irrigated cultivations were of local structures and introduced Kriging method as an appropriate method for the estimation of local distribution of phosphorus and arbuscular mycorrhizal fungus spores. Amini *et al.* (2003) evaluated the soil pollution of Isfahan region following Fuzzy login and geo statistics methods and concluded that this integrated approach made it possible to evaluate multiple element pollutions in the same time and that the calculated variograms also mainly followed exponential and spherical models. They prepared regional contaminated area allocation map. Calculating nutrient buffer index used in fertilizer recommendations. Myers *et al.* (2003) indicated that the mentioned index was positive with phosphorus and potash, reflective of the inadequacy of the fertilizer rate. Clay *et al.* (2003) studied and evaluated the efficiency of various field fertilization management strategies and concluded that the four hectare netting approach with the lowest error rate was the most appropriate method for the recommendation of phosphorus and potash. Balasundram *et al.* (2006) mentioned Spatial variations in soil fertility can obscure treatment effects and hence, lead to incorrect fertilizer recommendations. Their results showed that the effect of treatments on plant growth were not significant. Growth variables exhibited a significant spatial trend. A corresponding observation was found for growth residuals. Washburn *et al.* (2002) investigated the variability of one-ranged soil phosphorus distribution, but they did not apply geo-statistical approaches for fertilizer recommendations and fertilization management. Kamaruzaman and Tamaluddin (2001) suggested the preparation of soil variation maps for the agricultural production with the use of Gs+. Scharf *et al.* (2002) have recommended future studies on the determination of the spatial distribution of nitrogen to find out the variation of nitrogen in the ranches. Law *et al.* (2009) quantified the spatial variability of Soil Organic Carbon (SOC) and estimating SOC concentration in oil palm. Their Results showed all operational areas exhibited a definable spatial structure and were described by either spherical or exponential models.

The present research was performed in order to study the spatial variation of soil nutrients including nitrogen, phosphorus and potassium, to compare various geo-statistical approaches from the stand point of their efficacy in the estimation of the rates of the nutrients as the major soil fertility determinants and to map their spatial distribution.

MATERIALS AND METHODS

Area identification: This research was conducted in the Southern part of Uromieh plain of 36690 ha area, in West Azerbaijan Province, Iran, during years 2008 to 2009. Geographically,

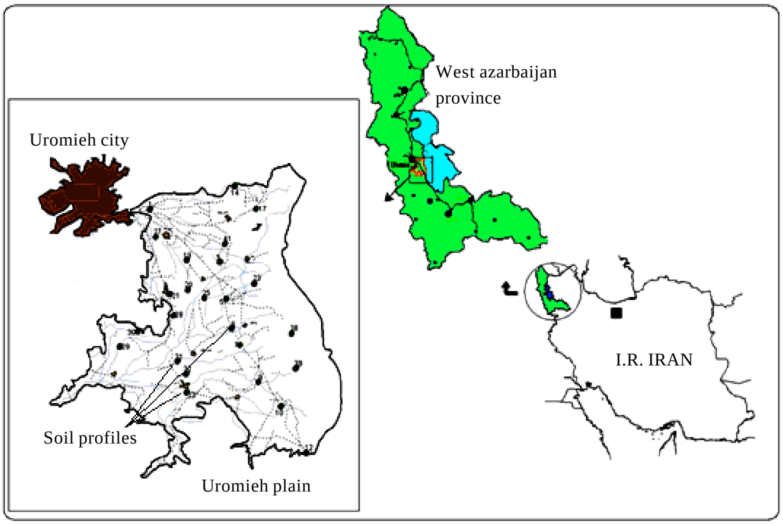

Fig. 1: Location of study area and soil profiles

located in an area between longitudes 45° 05' 00" E and 45° 20' 00" E and between 37° 15' 00" N and 37° 35" 00" N. Figure 1 indicates the location of the region in the country and province and shows the position of the profiles used in the plain. Based on the semi detailed pedological studies, the regional soils are classified as Inceptisols and belong to one of two main subgroups, typical Calcixerepts and typical Haploxerepts. The distance between the profiles in the studied region varied between 1300 and 4700 m.

Research framework: Normality of data was tested with Shapiro-Wilk test (Shapiro and Wilk, 1965) by SPSS software (Levesque, 2007). To evaluate the spatial distribution of the major soil nutrients including nitrogen, phosphorus and potassium, the data from 28 profiles were studied and geo statistical methods including Kriging, Weighed Moving Average and Co-Kriging methods (Metternicht and Zinck, 2003) were used in GIS medium and GS^+ and $ARCVIEW_8$ software (Goovaerts, 1999) were applied to investigate the spatial changes and the estimation of soil nutrients. The general equation for these methods is as Eq. 1.

$$Z^*(xi) = \sum_{i=1}^{n} \lambda i \; z(xi) \tag{1}$$

Where:

Z* (xi) = The estimated amount
Z (xi) = The observed amount around the assumed point
(xi) = The position of the observed points
λi = The amount of weights of the observed points
N = No. of the measurement points

To evaluate interpolation methods, the cross validation technique (Moore, 2007) and two MAE (Mean Absolute Error) and MBE (Mean Bias Error) statistical parameters were used. The MAE is an indicator of errors in the results and MBE indicates the bias of the results obtained through the applied method. When MAE and MBE are 0.00 or near to naught, the applied method simulates the fact well. However, as far as its amount is farer than 0.00, it implies to less precise and more bias. How the parameters MAE and MBE are calculated, has been indicated as Eq. 2 and 3.

$$MBE = \frac{\sum_{i=1}^{n}(R_s - R_o)}{n} \quad (2)$$

$$MAE = \frac{\sum_{i=1}^{n}|R_s - R_o|}{n} \quad (3)$$

Where:
R_s = The estimated amount
R_o = The measured amount
n = No. of the data

RESULTS AND DISCUSSION

To generalize the results obtained from point rates in profile sites to the regional one, the normal distribution of the data was checked with Shapiro-Wilk test. If test coefficient and skew ness are, respectively less than 0.5 and 1.0, the data will be of normal distribution. The results indicated that the data related to soil nitrogen and phosphorus were of such a characteristic, however, those related to the rates of soil potash were not normally distributed and therefore, these data were logarithmically converted and normalized (Table 1).

The distribution of the studied profiles, together with the measured rates of nitrogen has been shown for example in Fig. 2.

Table 1: Results of the Shapiro-Wilk test of normality

Fertility factor	Freedom degree (d_f)	Test coefficient	Skewness
Nitrogen	27	0.015	0.154
Phosphorus	27	0.023	0.652
Potassium	27	0.512	3.248
Potassium logarithm	27	0.044	0.432

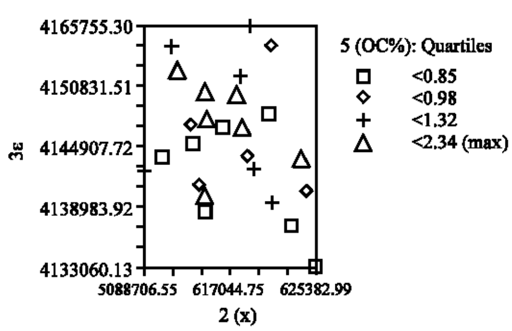

Fig. 2: The rates of nitrogen measured in each of the profile sites

Table 2: Rates of geo-statistical interpolation parameters

Interpolation method	Fertility parameters	Semi variogram	Nugget effect (Meq/100 g)	sill (Meq/100 g)	Distance (m)	Correlation coefficient
Kriging	Nitrogen	Gaussian	0.008	0.65	1323	0.999
	Phosphorus	Exponential	0.100	97.70	1228	0.998
	Potassium logarithm	Spherical	0.033	0.21	6220	0.998
Co-kriging	Nitrogen with potassium	Gaussian	0.010	21.60	2510	0.999
	Phosphorus with potassium	Gaussian	93.000	878.20	1870	0.999

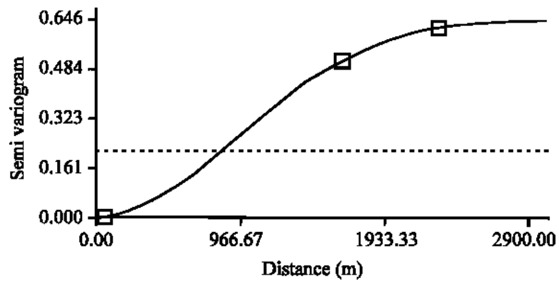

Fig. 3: Empirical semi variogram of nitrogen obtained based on Kriging method

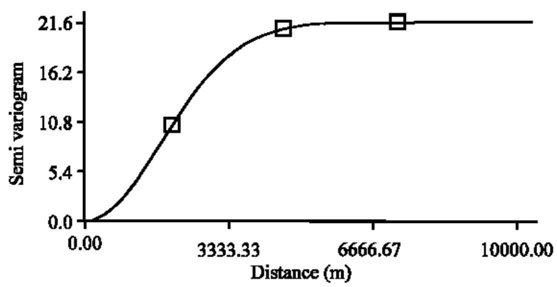

Fig. 4: Nitrogen empirical semi variogram with potassium based on Co-kriging method

Then, the spatial variations of soil fertility parameters in the non-sampled points were studied. In Kriging method, the effect radiance of this semi variogram was determined as equal as 1323 m; the nugget effect was calculated as 0.008 and sill was equal to 0.65 milli-equivalent per 100 grams of soil. The summary of the results related to other nutrients has been presented in Table 2.

To use Co-kriging method, the empirical semi variogram curve of nitrogen was drawn taking advantage of potassium as an auxiliary factor with the most rate of mutual correlation. An example of Kriging and Co-kriging method based on Gaussian model to semi variogram in relation to nitrogen cross taking advantage of auxiliary variable of potassium has been presented in Fig. 3 and 4.

The radius of the effect of this method was calculated as equal to 2510 m, the nugget effect was determined as equal as 0.01 and sill was calculated as 21.6 milli-equivalent per 100 g of soil. The correlation coefficient for the presented model was calculated as 1. The results related to other nutrients have been indicated in Table 2.

The weighted moving average approach was taken in use with three of soil properties, that an example of the calculation of the rates of organic carbon and its comparison with the measured rates with this method has been indicated in Fig. 5.

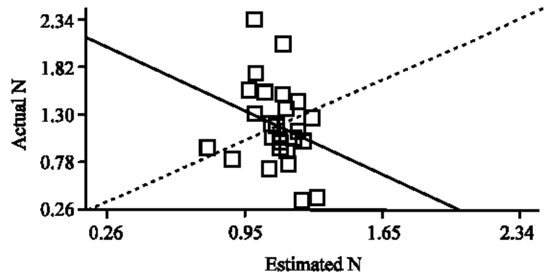

Fig. 5: Weighted moving average based evaluation of soil nitrogen

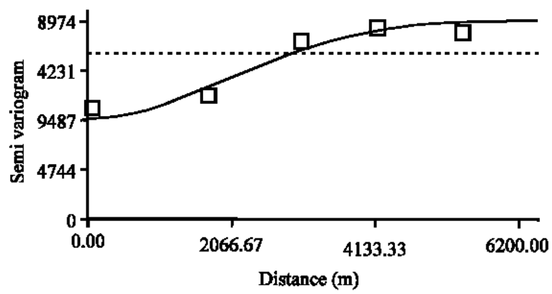

Fig. 6: Empirical semivariogram model of real soil potassium rates based on Kriging method

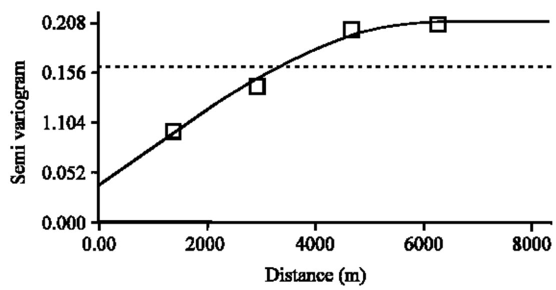

Fig. 7: Empirical semivariogram model of soil logarithmic rates of potassium based on Kriging method

The results of geo-statistical analyses of studied fertility factors have been presented in Table 2. Based on this table, the empirical semi variogram models of most of the factors have been obtained as of Gaussian type. There are also exponential and spherical models obtained to Phosphorus and Potassium by Kriging method. Considering to the nugget effect, it is revealed that the lowest rate of it calculated based on Kriging method, is related to nitrogen with the rate of 0.008 Meq/100 g of soil and its highest rate calculated based on the same method, is related to potassium with the rate of 93 Meq/100 g. The distance of efficiency of models ranges between 1228 for Phosphorus and 6220 m for Potassium.

As shown in Table 2, the logarithmic amounts of potassium were used in Kriging model. Differences of the fitted semi-variogram to the actual potassium rates and its logarithmic amounts are shown in Fig. 6 and 7. The change of origin has been conducted to normalize data of potassium and to decrease nugget effects as Fig. 7. Accordingly the correlation coefficient increased from 0.23 to 0.998.

Table 3: The preciseness and deviation rates of the methods applied for the estimation of some soil nutrients

Method	Fertility determinant nutrients	MBE	MAE
Kriging	Nitrogen	0.025	0.450
	Phosphorus	0.120	0.750
	Potassium logarithm	- 0.002	0.180
Co-kriging	Nitrogen with potassium	0.670	0.800
	Phosphorus with potassium	6.240	123.080
Weighted moving average	Organic carbon	0.030	0.510
	Phosphorus	0.120	8.060
	Potassium logarithm	- 0.790	130.300

To evaluate and select the most proper geo-statistical method for the estimation of soil major nutrients, the rates of preciseness and deviation for each of the methods were investigated with each of the individual fertility nutrients, the results from which have been indicated in Table 3.

Based on the Table 3, it was revealed that with all cases, Kriging method was of less error and deviation rates compared with Co-kriging approach. Also, it was notable that weighted moving average method was of more error and deviation rates compared with Kriging approach but still of deviation rate less than that of Co-kriging method.

Thus, Kriging method with high preciseness and less deviation was selected as the suitable model for the regional estimation of soil fertility nutrients and their rates in the different points of the region were estimated and their maps of regional distribution were prepared in GIS medium. The results showed that the rate of organic carbon is generally low in the region so that most of the regional areas are of very low to low organic carbon rates and only some spots around Orumia city are of high organic carbon contents (Fig. 8). With phosphorus, the region is totally classified as in the range of high to very high (Fig. 9). From the standpoint of potassium content, the region is evaluated as one of low to mediate contents of potassium (Fig. 10). In some limited points around the city, the regional content of potassium rises to high to very high amounts.

The present investigation was carried out in order to have a better understanding of the local variation in the rates of soil major nutrients as the pre-requirement for programming and management of fertilization and fertilizer provision in vast regions. Scharf *et al.* (2002) have suggested next studies on the determination of the local distribution of nitrogen in order to understand its variation in vast ranches and this investigation has been necessarily performed to respond to this necessity and the question of this type but with other major nutrients. The results related to phosphorus got through this research are in accordance with those obtained by Nazarizade *et al.* (2003). Also present results agree well with the results of Amini and his collaborators studies on the subject of soil pollution and the selection of Kriging method as the proper approach, however, in our studies, the semivariogram was Gaussian model. In contrast in the study conducted by Amini *et al.* (2003), the calculated variograms were mostly exponential and spherical. Washburn *et al.* (2002) investigated the one-ranged variability of phosphorus distribution but they did not use land-statistical approaches to make fertilizer recommendations and to manage fertilization. Kamaruzaman and Tamaluddin (2001) have recommended the mapping of soil variation with the

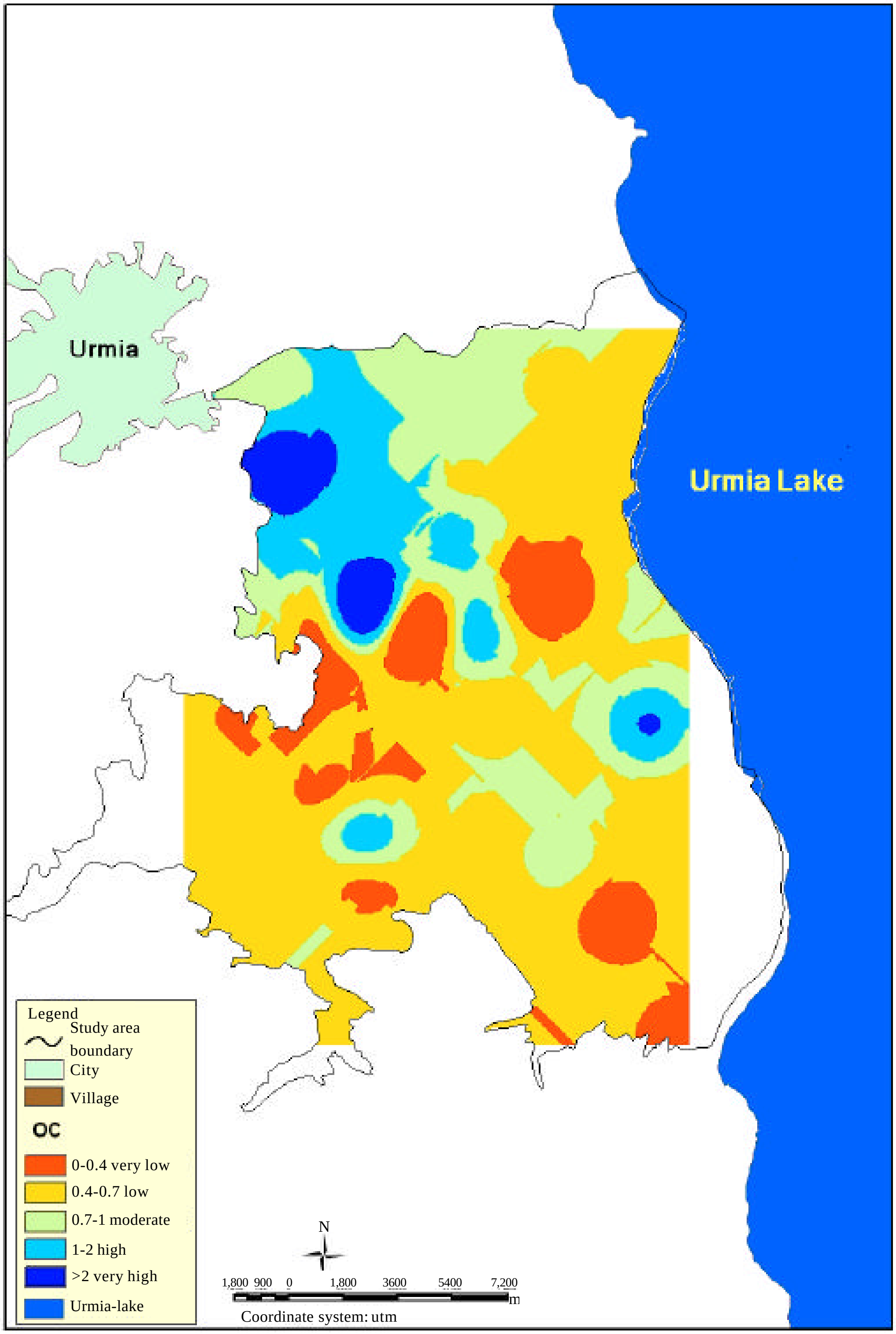

Fig. 8: Spatial variability map of Nitrogen by Kriging

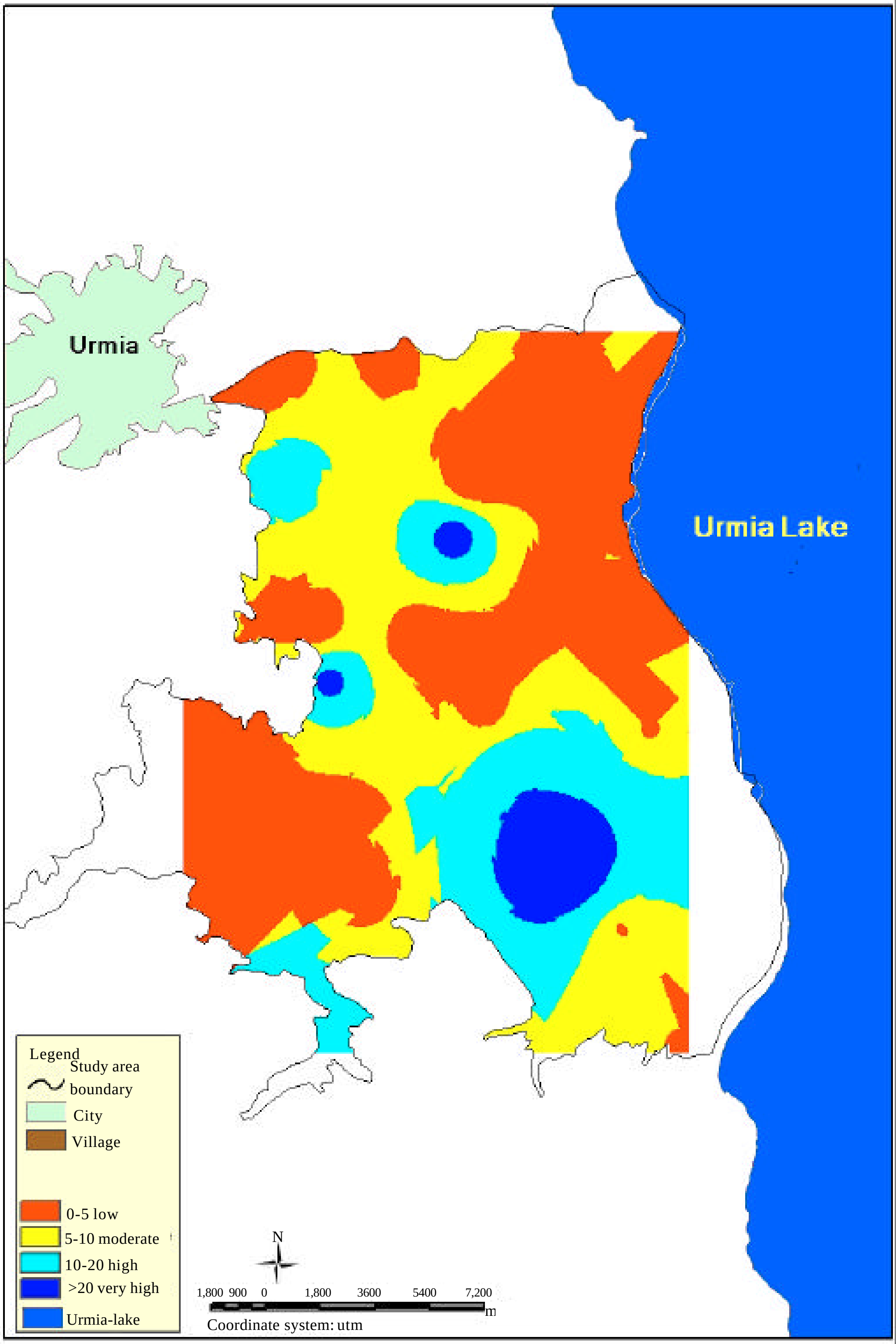

Fig. 9: Spatial variability map of exchangeable phosphor by Kriging

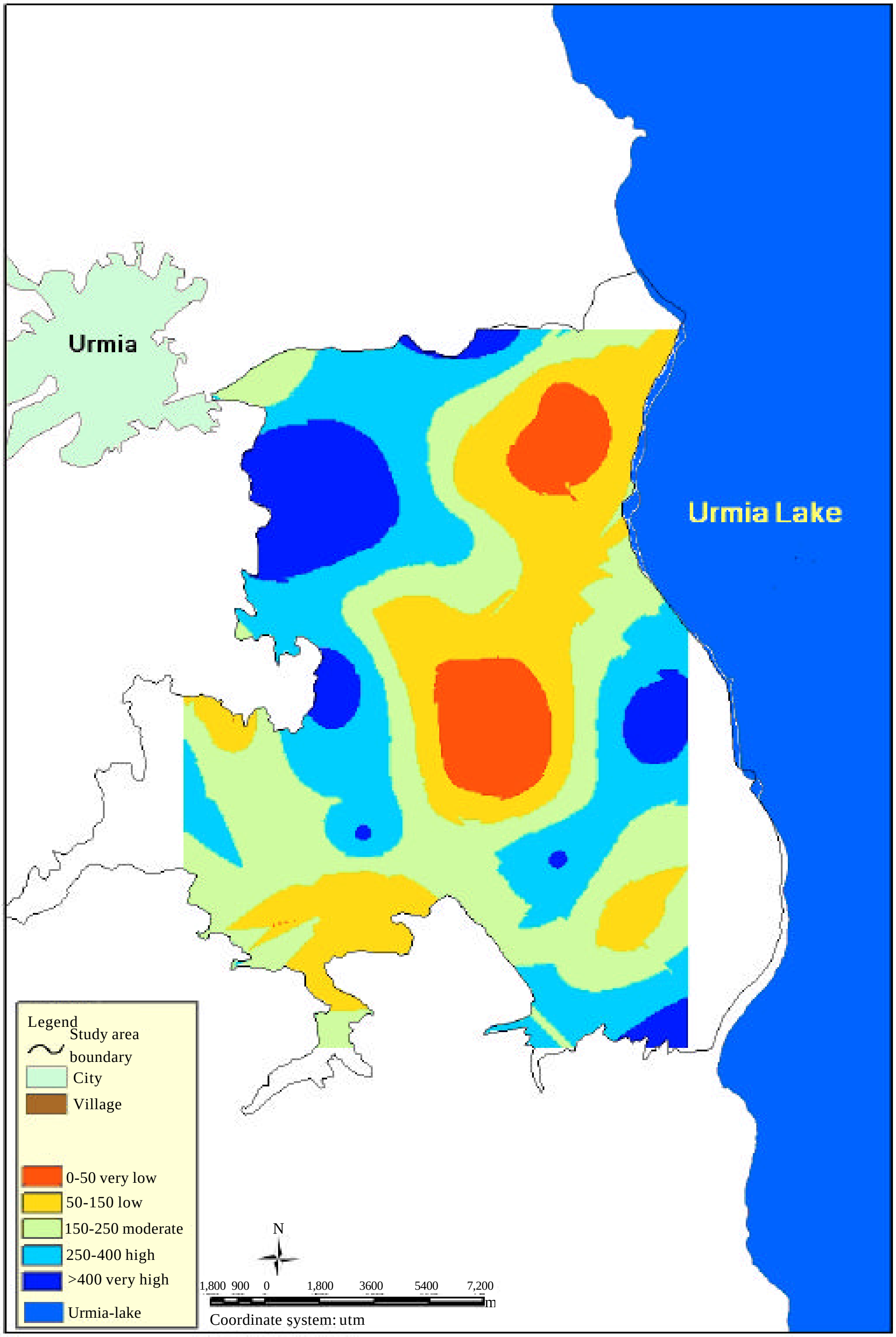

Fig. 10: Spatial variability map of exchangeable potassium by Kriging

use of Gs+ for agricultural production purposes, however, they have not applied geographical information system to compensate the existent limitations of the software they used.

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