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Mapping Agricultural Soil Nutrients Content Using Geostatistical Technique

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ABSTRACT

Soil nutrient are essential for crop growth. Spatial variability of nutrient can be occurred in various scales, between region, field or within field especially in variation in soil properties. This technology enables farm management is based on small-scale spatial variability of soil and crop parameters in the field. This study was carried out in Hamadan western Iran. The objectives of this study are to determine and map soil nutrient content especially potassium (K) and phosphorus (P) variability in studied area using geostatistical technique. The K and P was analyzed and mapped by GS+ to quantify the level of spatial nutrient available and predict nutrient values at unsampled location. Results indicated that K ranged from 45.8 to 66.3 mg kg^{-1} and P ranged from 2.55 to 6.05 mg kg^{-1}. Nutrient map showed that the area has less sufficient of P, while K was sufficient. Furthermore nutrient map can be used to apply fertilizer to an area, where less K and P content for efficient fertilizer management.

Key words: Soil nutrient mapping, Soil nutrient analysis, Geostatistical technique.

Introduction

Increasing population continues to put pressure on limited agricultural land resources. This problem will become increasingly serious in the 21st century [5]. The solution of this problem will depend on the application of advanced scientific technology to realize the rational allocation and efficient use of natural resources. How to manage soil nutrients and allocate efficiently organic and inorganic resources of nutrients is the key for sustainable development of crop production. Substantial progress has been made in soil testing and improvement of fertilizer application, but a uniform rate of application of fertilizer is usually recommended for a 15-20 ha of field regardless of soil nutrient variability within the field [5]. Therefore, some regions of the fields receive too much fertilizer, but others too little. As a result, land and nutrient resources are wasted with loss of opportunities and benefit. The precision agriculture approach has been successfully applied in some developed countries with advanced mechanization and large scale operation [4]. Precision farming has become increasingly significant in the agricultural operations for the site-specific management. The management and manipulation of farming operation are vital decision-making process in improving crop productivity where there is a need to ensure efficiency in the management of agriculture. Information on soil properties in crop field is very important and useful for fertilizer requirement and also to the specific management of the crop and soil. The availability of nitrogen (N), phosphorus (P) and potassium (K), whether in soils or plants is among of the most of the nutrient studied in precision farming concept [6].

Little work has been done in Hamadan, western Iran to understand the spatial variability of soil nutrients, which affect the sustainable development of agriculture. Therefore, the general objective of the study was to produce a spatial digital map of nutrient variability especially K and P in agricultural soils under wheat cultivation in Hamadan, western Iran.

Materials and Methods

1. Sampling Site:

The study was conducted in Hamadan province, western Iran. Hamadan province lies in a temperate mountainous region to the east of Zagros. The vast plains of the north and northeast of the province are influenced by strong prevailing winds, which persist throughout most of the year. Soil samples were collected from surface (0–30 cm). The selected areas included wheat cultivation. Total of 108 soil samples were collected from fields. Samples were then kept in labeled plastic bags and brought back to the laboratory for further treatment and analyses. The soil samples were air-dried and sieved to pass 2 mm mesh sieve.

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2. Chemical Analysis:

Soil samples were taken for exchangeable K and available P analysis and the location of specific soil samples were identified with specified intervals. The analysis carried out were exchangeable potassium determined by ammonium acetate [2] and available phosphorus determined by double acid and Mehlich [1].

3. Data Analysis:

Semivariograms and kriged map produced from geostatistical software GS+, version 5.1. From semivariogaram evaluation, the spatial variability of soil properties was generated. Descriptive statistic and variation of N and P nutrient status in soil was analyzed using SPSS 16.0 tool.

Results and Discussion

1. Potassium:

Descriptive statistics (Table 1) showed that great variation exists in the soil nutrient data of studied soils. The coefficients of variation (CV) for most soil nutrient properties had low CVs (2.7 and 13.7). CVs for soils nutrient properties lower than 20%, indicating there wasn't considerable variability of soil nutrient concentrations in the studied area. The value distributions of K are approximately normal, while the P distribution are positively skewed, which shows that higher P concentration values existed and suggests the spatial distribution of soil P in topsoil of the studied area is heterogeneous.

Table 1: Descriptive statistics for exchangeable potassium and available phosphorous content (mg kg^{-1}) in studied soils.

Variable	n	Mean	Maximum	Minimum	Standard deviation	Skewness	Kurtosis
K	108	55.5	90.7	20.0	13.2	-0.24	0.55
P	108	4.68	13.1	0.82	2.73	1.40	1.19
P (Log normal transform)	108	1.40	2.58	-0.20	0.52	0.25	0.06

Experimental semivariances of soil nutrients were calculated and modeled using GS+ software. No anisotropy was evident in the directional semivariograms of soil K properties; thus, isotropic semivariogram models were applied to the K data (Table 2).

Table 2: Parameters of fitted semivariograms of soil K and P concentrations in studied soils (natural-logarithmic transformations were applied to the P values).

	Theoretic model	Nugget C_0	Partial sill C	Nugget to sill ratio (%)[a]	Spatial dependence[b]	Range (m)	R^2
K	Exponential	152.4	452.5	25.2	Weak	3110	0.22
P	Exponential	0.241	0.242	49.9	Weak		0.24

a Nugget to sill ratio (%) = (Nugget semivariance/total semivariance) × 100
b Spatial dependence was defined as strong, moderate, or weak for nugget to sill ratios < 25, 25–75, or >75, respectively, and weak if the best-fit semivariogram model $r^2 < 0.50$

Spatial dependencies differed among the soil K and P properties, as illustrated by the nugget and sill values, as well as the ranges (Table 2). The range establishes the outer limit at which points in space still interact spatially and the sill represents the total priori variance (Webster and Oliver, 2000). Nugget variance comprises measurement error plus variation that occurs over distances less than the shortest sampling interval (100 m in this study), the latter is usually dominant (Webster and Oliver, 2000).

The semivariogram of the exchangeable K in the soils were illustrated in Figure 1. The spatial variability map for exchangeable K (mg kg^{-1}) in the study area is shown in Figure 2. Potassium exhibited a more localized pattern of enrichment (Fig. 2).

The map showed that the content of exchangeable K for soils was varied from 45.8 to 66.3 mg kg^{-1}. According to Soil Survey Staff (1997), these ranges could be classified as high and very high (Table 3). Ismail and Junusi (2009) indicated that the exchangeable K content was very high in both top and sub soil layers.

Phosphorous:

Phosphorous losses from soils to water bodied occur mainly by erosion and surface runoff (particulate and dissolved P) and as leaching or surface runoff of P (dissolved P). All forms of soil P estimates have been shown to be susceptible to transport from land to water.

Agricultural P management has focused on identifying, through soil testing the amount of P for addition to enrich the deficit soil to reduce P loads reaching downstream for P rich soils. Phosphorous management is targeted towards reducing the soil P values via selection of appropriate agricultural practices that avoid excess P applications in the fields; regular testing of the soil to reduce potential P losses to water and attain economically optimal crop yields; implementation of soil conservation practices that prevent soil P losses; and addition of manure and organic P sources in timely manner for sustainable crop growth.

Table 3: Classification of exchangeable K and available P in soil.

Class	K (mg kg^{-1})	P (ppm)
Very high	>54	> 45
High	31-54	25-45
Moderate		10-24
Low		3-9
Very low		<3

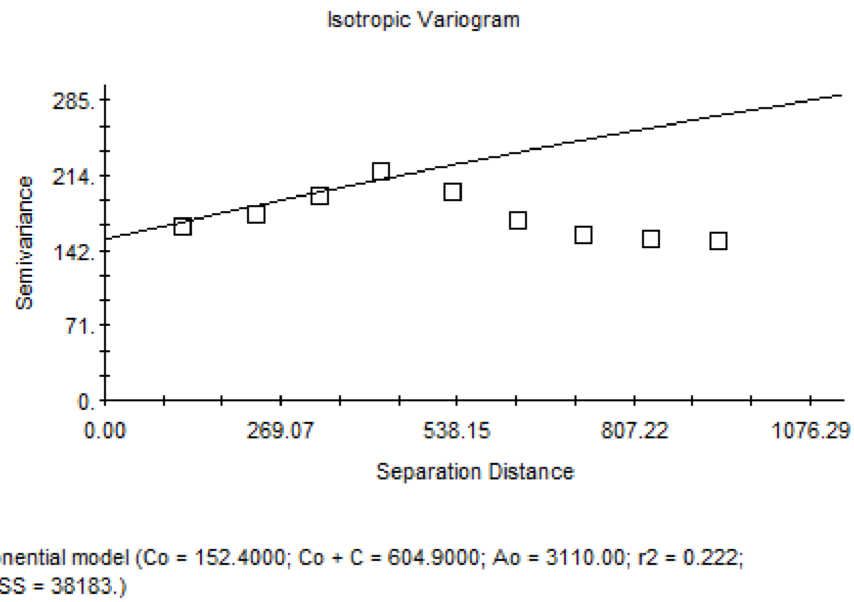


Fig. 1: Semivariogram of the exchangeable K in studied soils.

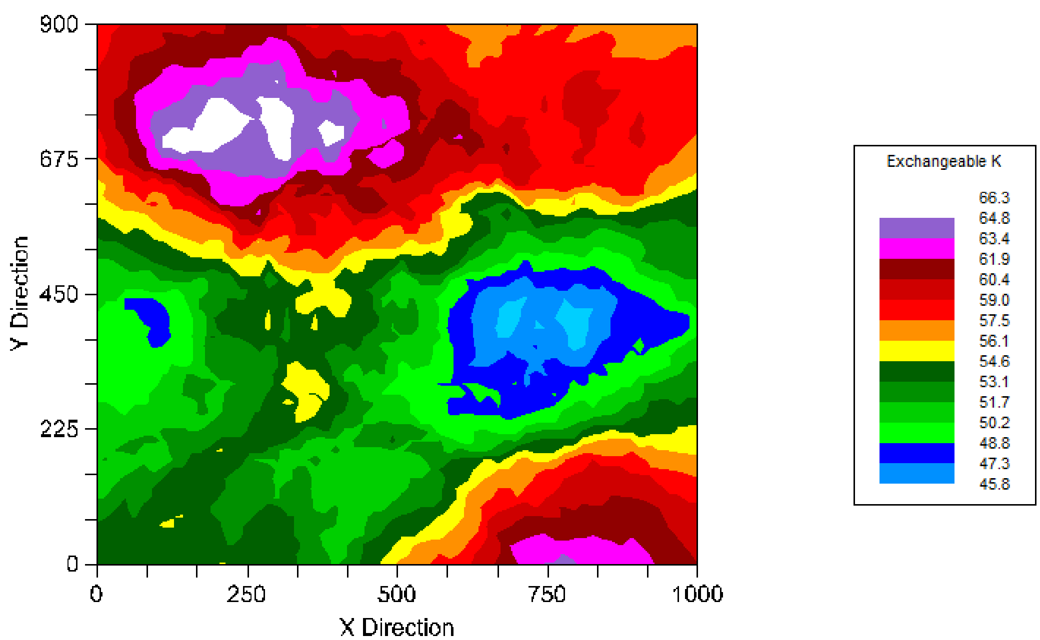
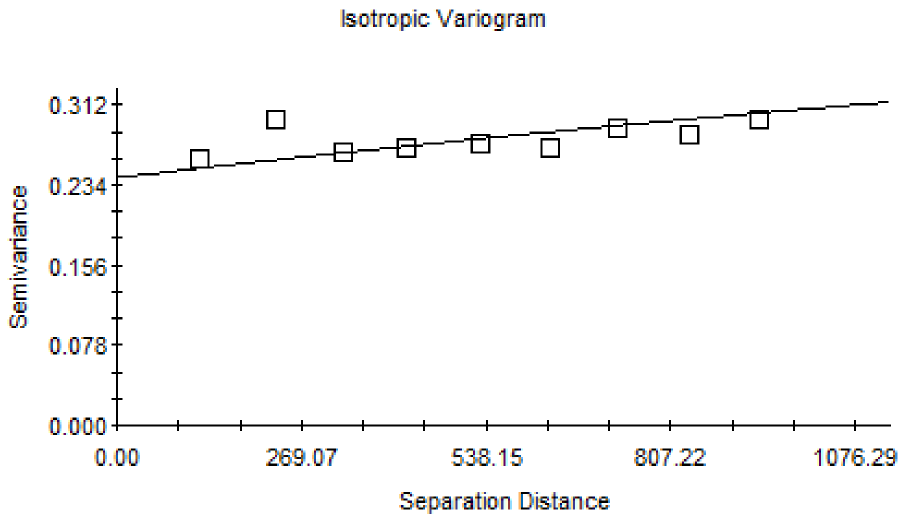


Fig. 2: Spatial distribution of exchangeable K (mg kg^{-1}) in studied soils.

The maps developed in Figure 4 allow for individual producers to identify if they are in a priority zone for soil P richness, to address the question of elevated P losses. Beyond the safe P levels, risks of excessive P losses to the environment from agricultural fields are elevated.

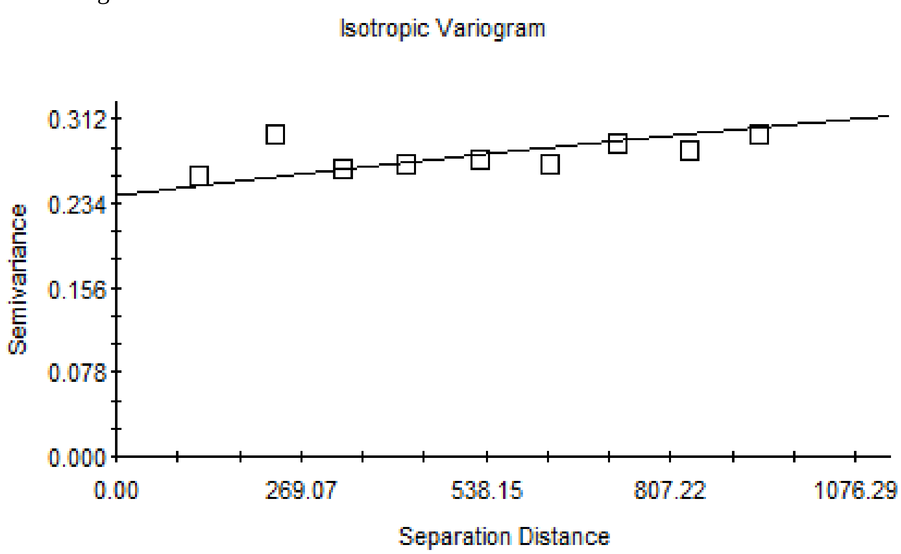
The summary of the statistics for available P are shown in Table 1. The semivariogram of the available P in the soils were illustrated in Figure 3. Since the value distributions of available nutrient concentrations are positively skewed, logarithmic transformations (natural logarithm) were applied to the measured values in order to eliminate the positive skewness of distribution and improve estimation. Although the distribution of log-transformed data was improved, but still not rigorously normal, the distribution is closer to normal.

The available P content was varied from 2.55 to 6.05 mg kg^{-1} (= 1.25 to 3 ppm) (Figure 4).



Exponential model (Co = 0.2414; Co + C = 0.4838; Ao = 3110.00; r2 = 0.239; RSS = 2.230E-03)

Fig. 3: Semivariogram of the available P in studied soils.



Exponential model (Co = 0.2414; Co + C = 0.4838; Ao = 3110.00; r2 = 0.239; RSS = 2.230E-03)

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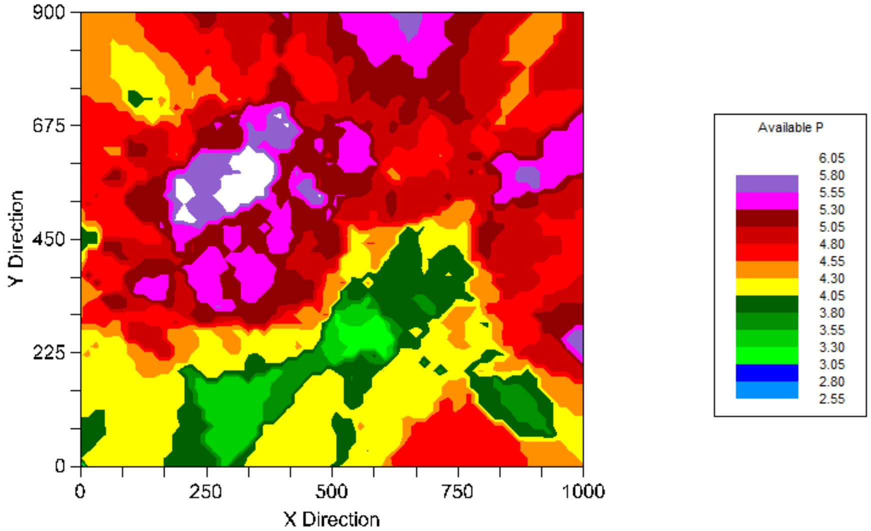

Fig. 4: Spatial distribution of available P (mg kg^{-1}) in studied soils.

According to Table 2, the availability of P for the studied soils can be classified as very low. In contrast Ismail and Junusi (2009) showed that the available P content of soils in 99.9% of Phosphorous fertilizer is usually recommended when available P soil test levels are below15 mg kg^{-1}, and large, economical yield increases are expected from applied P when soil tests are below10 mg kg^{-1} (Havlin *et al.*, 1999).

The average annual application rate of P fertilizer in Iran is currently over 40 kg P ha^{-1} (200 kg ha^{-1} as superphosphate). In high-yielding crop regions of Iran, P fertilizer application is usually over 63 kg P ha^{-1} y^{-1} (Malakouti and Gheibi, 2000), with accompanying decreases in utilization efficiency.

Conclusion:

From the study it can be concluded that by using Geostatistical –variogram analysis and spatial interpolation (kriging), there is possible to determine and mapped of K and P distribution in Hamadan western Iran. In fact, result showed that the K and P variability in soil were spatially ranging from 45.8 to 66.3 mg kg^{-1} and 2.55 to 6.05 mg kg^{-1} respectively.

Thus the K and P content in soil analyzed in this study revealed that the studied soil is poor in P. Therefore it requires more P fertilizer inputs if productivity is to be increased. Meanwhile, K is sufficient for this site, and the management does not need to add more K fertilizers to the soil.

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