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Spatial Variability of Some Soil Properties in Mountain Rangelands of Northern Iran

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Abstract**—**In this paper spatial variability of some chemical and physical soil properties were investigated in mountain rangelands of Nesho, Mazandaran province, Iran. 110 soil samples from 0-30 cm depth were taken with systematic method on grid 30×30 m2 in regions with different vegetation cover and transported to laboratory. Then soil chemical and physical parameters including Acidity (pH), Electrical conductivity, Caco3, Bulk density, Particle density, total phosphorus, total Nitrogen, available potassium, Organic matter, Saturation moisture, Soil texture (percentage of sand, silt and clay), Sodium, Calcium, magnesium were measured in laboratory. Data normalization was performed then was done statistical analysis for description of soil properties and geostatistical analysis for indication spatial correlation between these properties and were perpetrated maps of spatial distribution of soil properties using Kriging method. Results indicated that in the study area Saturation moisture and percentage of Sand had highest and lowest spatial correlation respectively.

Keywords—Chemical and physical soil properties, Iran, Spatial variability, Nesho Rangeland

I. Introduction

DESPITE the temporal and spatial changes of soil characteristics in small and large scale, information about these changes for increase profitability and sustainable agriculture management are necessary [3].

Spatial changes and heterogeneous geographical distribution of chemical and physical properties of soils in rangeland ecosystem is influenced by a set of biological and physical factors including topography, vegetation, soil microclimate, different grazing systems and various rangeland management [5]. Soil compaction following heavy grazing cause homogenous spatial distribution of soil properties that is followed vulnerability of soil, water and soil loss, and consequently reduce available water for plants and production of rangeland [34]. There is clear special spatial relation between plant and soil [10], [6] and [34].

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Determining soil variability is important for ecological modeling, environmental predictions, precision agriculture and management of natural resources [13] and [30]. Temporal and spatial investigation of data is essential for understanding of soil spatial variability. Reference [19] knew geostatistics technique as confidence able, strongest and widest method for interpolation and has acknowledged that in geostatistics is considered spatially variance, location and distribution of samples. Geostatistics is a powerful tool for determining the spatial variability [25]. Many studies use geostatistics for determination of spatial variability and map creation of soil characteristics spatially organic matter [17], [35], [11] and [2]. Knowledge of soil variability is necessary for applied management as well as for model development [26]. Then this research was done to investigate spatial variability of some chemical and physical soil properties in mountain rangelands.

II. Material And Methods

This study is located at central Alborz zone, Mazandaran province in North of Iran and 40 km south of Ruyan city (50 ° 08 '00" E to 50 ° 08 '17" and 36 ° 21 '49" N to 36 ° 22 '04"). It has 1700 m altitude above sea surface. The climate is cold-mountain based on Amberjhe method with mean annual precipitation of 253 mm. The mean temperature annual is 12.17 ◦C.

Soil samples were gathered according regulars sampling pattern with grid 30×30 m2 from 0-30 cm depth. 96 points were selected and also were added 14 margin points to increase the accuracy of research (total 110 soil samples). The UTM coordinates of soil samples were recorded for use in spatial analysis of soil characteristics. The samples were air-dried and passed through a 2 mm sieve to prepare them for experiments. Normal distribution of data was estimated based on their skewness, as the data with -1 to +1 skewness were normally distributed [28] and [24].

Since nitrogen and phosphorus had skewness coefficient greater than 1, were used Logarithmic conversion after deletion of imperfect data [31]. Geostatistics is based on spatial correlation between observations or samples and this correlation can be expressed with mathematical model which called "variogram". In fact, variogram is defined as functions which described spatial variations of one variable [14] and is defined by formula (1):

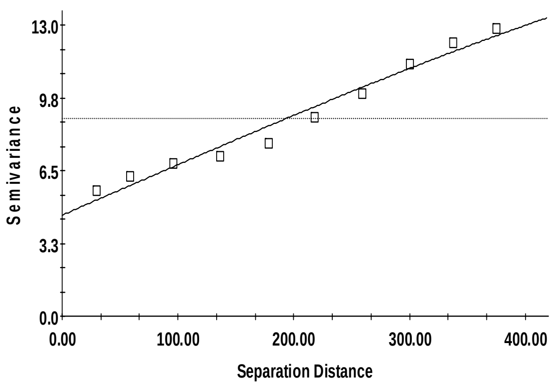
$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(x_i + h) - Z(x_i)]^2 \qquad (1)$$

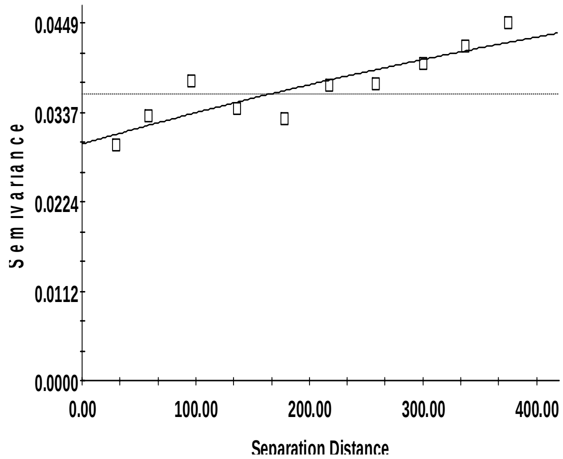
N (h) is number of sample pairs that separated by a particular lag vector of h. Z (xi) and Z (xi+ h) are the values of regionalized variable at location of xi+ h.

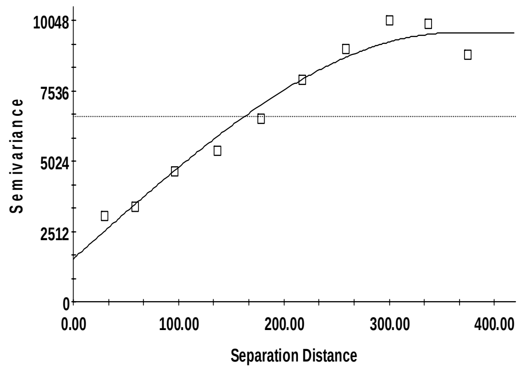
After calculating the experimented variogram, fitting a theoretical model is necessary to generalization of deduction and estimation of variables in points where not have been sampled. In the next spatial interpolation and spatial mapping of soil characteristics were performed Kriging method. Accuracy assessment of interpolation was used with Cross-validation methods [12]. The software package GS+ version 5.1 was used for geostatistical analysis (Gamma Design Software, MI, USA).

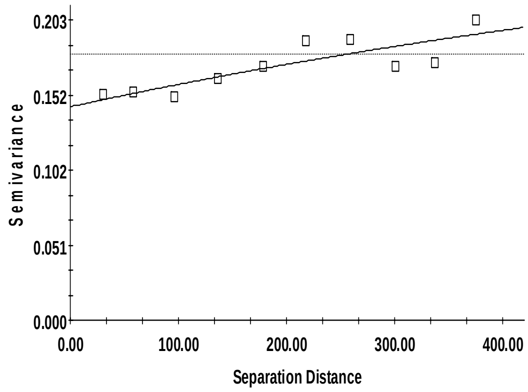
III. Results

Presented models were selected from fitted models to soil characteristics because had less residual sum of squares and better structure. Suitable model for soil characteristics was isotropic. Results showed that caco3, organic matter, nitrogen, phosphorus, particle density, magnesium and sand had highest effective range with 910.900 meter and clay, with 157 meter had minimum effective range between the studied characteristics of soils. The spatial dependence of soil characteristics was different. Nitrogen, phosphorus, sodium, magnesium, and sand had weak, organic matter, bulk density, particle density, electrical conductivity and clay had moderate, and Caco3, available potassium, pH, calcium, silt and saturated moistures had strong spatial dependence in the study area. Assessment of fitted models showed that models of phosphorus, clay and sand content had a higher regression coefficient and thus more accuracy (TABLE I). Semivariograms of some studied soil properties were showed in Fig. 1.









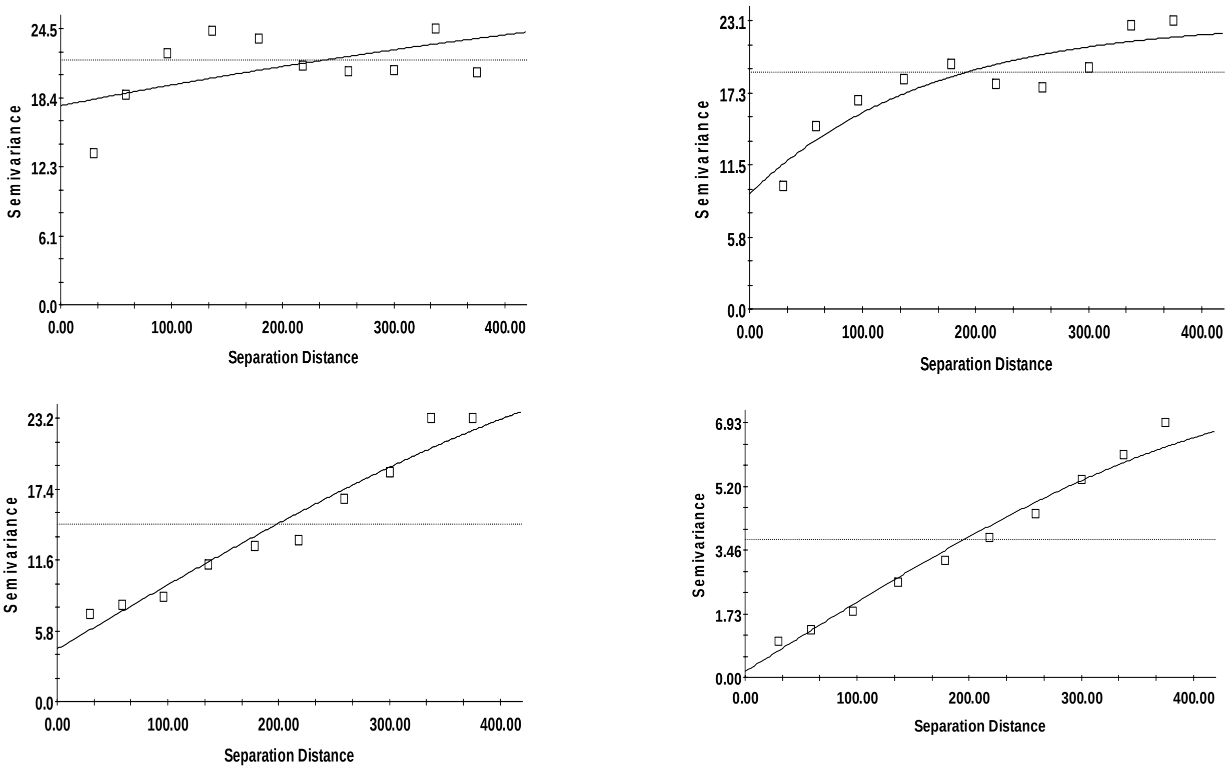


Fig. 1 Semivariograms of soil properties

TABLE I
CALCULATED SEMIVARIOGRAMS PROPERTIES OF SOIL FACTORS AND REGRESSION COEFFICIENT OF CROSS VALIDATION

Soil Properties	Model	Range A0 (m)	Nugget (C0)	Sill (C0+C)	Nugget /Sill Ratios C0/(C0+C), %	R2	RSS	Spatial Dependence Level	Regression Coefficient
Caco3	spherical	910.90	4.52	18.310	24.68596	0.970	1.82	strong	0.900
OM	exponential	910.90	0.144	0.29000	49.65517	0.688	8.702E-04	moderate	0.852
N	Gaussian	910.90	0.4810	0.9630	49.948	0.087	7.883E-03	weak	0.017
P	spherical	11320	0.1390	0.37427	37.1389	0.238	0.021601	weak	2.579
K	spherical	360.40	1530.000	9610.000	15.92092	0.965	2.222E+06	strong	0.905
Bd	exponential	874.20	0.02912	0.05834	49.9143	0.686	3.937E-05	moderate	0.841
Pd	exponential	910.90	0.03420	0.06850	49.92701	0.689	4.951E-05	moderate	0.547
pH	exponential	889.10	0.01400	1.58300	0.884397	0.996	9.859E-04	strong	0.977
EC	spherical	273.80	8270.000	26740.000	30.92745	0.909	3.018E+07	moderate	0.995
Na	spherical	910.90	4260	8521	49.994	0.232	8.654E+06	weak	0.503
Ca	spherical	562.00	0.16000	7.32900	2.183108	0.979	0.868	strong	0.951
Mg	Gaussian	910.90	2.8800	5.7610	49.991	0.211	1.10	weak	0.669
Sand	exponential	910.90	17.690	35.390	49.98587	0.239	73.2	weak	1.098
Silt	spherical	688.30	4.300	28.590	15.04022	0.951	15.9	strong	0.896
Clay	exponential	157.00	9.210	23.0100	40.02608	0.821	23.4	moderate	1.212
SM	spherical	710.90	1.5000	154.400	0.97150	0.929	409	strong	0.919

IV. DISCUSSION AND CONCLUSION

Sampling method was systematic with equal distances between soil samples in this study. Random sampling can generate points that are very close together so decreases accuracy of these studies [32]. Reference [7] reported whatever variables have been more random distribution and samples have been less continuous, nugget effect of variogram increase and precision of interpolation decreases. Also, References [29] and [21] expressed that a systematic sampling pattern provide more accurate results than random sampling pattern, and precision increased with addition sample size.

Soil properties were recognized isotropic. This shows the variability of variables is equal in different directions and changes depend on distance between samples [23]. Nitrogen, phosphorus, sodium, magnesium and sand had a weak spatial dependence because the fitted $r2<0.50$ [9]. % Silt, available potassium and acidity (pH) had strong spatial dependence according to results of References [4], [20] and [32]. Bulk density had moderate spatial dependence as had been showed in research [4] and [15] also organic matter had moderate spatial dependence according to results of [33].

Variables with strong spatial structure and very low nugget effect have high continuous distribution in this area. Strong spatial dependence can be controlled through the inherent variability of soil properties such as soil texture, mineralogy and less dependence by non-intrinsic factors such as grazing [4]. Semivariograms have difference forms depending on the quality of data and the distance between samples [7]. The results showed spatial distribution of clay content can be described with spherical model according to results of [27], [32], [16] and [15].

Organic matter can be described with exponential model according to results of [16]. Available potassium can be expressed with spherical method as had been showed in research [33] and [22]. The value of nugget effect for pH, bulk density and saturated moisture is small which suggest the random variance of variables is low in the study area. This means that near and away samples have similar and different values respectively. In other words, a small nugget effect and close to zero indicates a spatial continuity between the neighboring points. Results of [24] and [23] showed that variogram of nitrogen had very small nugget effect equal to 0.006. References [18], [1] and [16] reported that nugget effect of clay content; electrical conductivity and bulk density were 0.01, 0.0008 and 0.00308 respectively.

The larger effective range has more widespread spatial structure and this expansion will increase the virtual range that its data can use to estimate the amount of regional variable at unknown points [14]. Effective range of some soil properties including caco3, organic matter, nitrogen, phosphorus, bulk density, magnesium and sand content were higher than others which probably is due to same impact of intrinsic processes on these soil characteristics and spatial structure of these parameters have more widespread rather than others also can increase sampling interval as effective range in sampling design. The effective ranges were 157- 911 meters in this study which represents an increase in soil heterogeneity or potential of retrospection processes. The results of this study can be used to present management recommendations and modeling of soil and plant relationships in future studies.

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