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Spatial Variability of Soil Features Affected by Landuse Type using Geostatistics

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ABSTRACT Since the change of land use accrued in the Iran, especially in northern Iran, this research aims tocompare the spatial variability of soil properties in three adjacent land uses including cultivated by wheat lands, grazing lands and forest Lands covered by *juniperus sp, fagus orientalis, quercus castanifolia, and acer velotinum* species in kiasar region, Mazandaran Province, northern Iran. Some of soil features, i.e. pH, CaCO3, total nitrogen (TN), soil organic carbon (SOC), electric conductivity (EC), percentage of silt, clay and sand contents and saturation moisture content(SM) were measured at a grid with 20 m sampling distance on the top soil (0 – 30 cm depth). Accordingly, total of 147samples were taken from 49 soil sites. The normality of data was examined by the tests of normality. Then, data were analyzed by using of geostatistics approach. The results showed that spatial distribution of many soil properties could be well described by spherical model in the forest and exponential model in the cultivated and grazing lands. Spatial dependences were the highest for SOC, EC and the lowest for silt, (SOC and silt) in the forest method and grazing lands, respectively. Deforestation and conversion to cultivated and grazing lands decreased spatial dependence of soil properties.

Key words: *Cross validation, Kriging method, Soil properties, Spatial dependency*

1 INTRODUCTION

Soil as part of the nature has inherent variability that result of interactions between its constituent elements and also has non-intrinsic variability the impact on cultivation management, land use and erosion (Zolfaghari and Hajabassi, 2009). Study on soil quality is important and generally applicable in terrestrial ecosystems (Doran and Sarrantonio, 1996).In four the last century about 30%of forests and natural rangelands in the world was converted tograzing and agricultural lands that has followed the organic carbon loss, soil structure degradation, and soil Hydraulic conductivity reduce and bulk density increase (Canadell and Noble, 2001). Conversion of forests to pastures and agricultural lands was caused to reduce the soil organic carbon and total nitrogen (Venteris *et al.*, 2004). Land use changes affected physical and chemical soil features and then its quality (Hajabbasi *et al.*, 2008).

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In recent years, the geostatistical methods were used by many researchers in their studies (Brus and Heuvelink, 2007; Zheng *et al.,* 2008; Jafarian Jeloudar *et al.,* 2009). Some researchers studied spatial dependence of soil properties in different land use such as Mohammadi, 1999, Eihnax and Soldt, 1999, Wu *et al.,* 2003; He *et al.,* 2007; Wang *et al.,* 2009; Jin *et al.*, 2011. Literature review was shown that soil characteristics such as organic carbon and total nitrogen (Yimer *et al.,* 2007; Gol, 2009), soil moisture (Demir *et al.,* 2007), pH (Balesdent *et al.,* 2000; Bewket and Stroosnijder, 2003; Tejada and Gonzalez, 2008), EC (Bolan *et al.,* 1991), percentage of sand and silt (Gholami *et al.*, 2014) have effective with land use. Spatial and temporal analysis of environment, soil and plant characteristics requires to specific statistical methods (Mohammadi and Raeisi, 2004) that is not possible using classic statistics simply because in many of these such as analysis of variance is hypothesis random distribution of samples and were not considered them spatial and geographical position. Many methods can used to describe and model spatial patterns of soil more than 20 years with regard to their spatial variability, such as geostatistics (Turner *et al.,* 2001). Kriging is an interpolation method that provides the best linear and unbiased estimation that is used in the environmental sciences to analyze the spatial variability (Goovarerts, 1997).

The native forests in the North of Iran are undergoing a rapid conversion into agricultural land. Kelarestaghi and Jafarian Jeloudar, 2011; reported that decreasing forest area about 3.2% in transition 1967–2002 in parts of northern Iran. In this period, arable land increased about 36.9% in this region. Also, Raei, 2013; reported that decreasing forest area 79.77 km^2 in period 46 years (1966-2012) in parts of northern Iran. The forest of the study is having been transformed and deteriorated by human pressures such as deforestation and clearance for agricultural purpose, over harvesting for firewood and overgrazing. These rapid changes may have an impact on soil properties, which are not well understood in Iran (Kelarestaghi and Jafarian Jeloudar, 2011). Land use type is one of the most important effective factors onthe soil quality and fertility (Jin *et al.,* 2011). Then in this research has been tried to be studied the spatial variability of soil properties in three land use including the forest, grazing and cultivated lands in northern Iran. We want to know are land use type effect spatial variability of soil characteristics?

2 MATERIALS AND METHODS

2.1 Research area

The study was carried out in the northern part of Iran, located in approximately 36°7'8" to 36°24'37" Northern latitude and 53°40' 22" to 53°58' 38" Eastern longitudes with height values of1350 meters to 3280 meter above mean sea level (Figure 1). Undercold semi-arid climate, theannual mean rainfall of 285 mm and annualmean air temperatures 12.5˚C. The dominant land uses are native forest, dry land farming of wheat and grazing land. The native forest is dominated by *juniperus sp, fagus orientalis, quercus castanifolia, and acer velotinum* species. Wheat production through forest clearance was started past 40-50 year. Grazing fields have created by transforming agricultural lands in steeper hill slopes when soil productivity decreased as intensively crop production. Dominant including *Artemisia aucheri, Stipa barbata, Agropyron elogatum, Festucaovina.*

2.2 Soil dataset and experiments

On the 20 × 20 grid sites, 147 soil samples were gathered from 0-30 cm depth (because of effective depth of root penetration) for all of land sues. Sampling method was systematic with equal distances between soil samples in this study. Random sampling can generate

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points that are very close together so decreases accuracy of these studies (Weindorf and Zhu, 2010). Wang, Qi 1998; McBratney and Webster, 1983, expressed that a systematic sampling pattern provides more accurate results than random sampling pattern, and precision increased with addition sample size. Soil particle size distribution was measured with Bouyoucos hydrometer method (Bouyoucos, 1962), total nitrogen (TN) and soil organic carbon content (SOC) were quantified with Kjeldahl method (McGill and Figueiredo, 1993) and the modified Walkley- Black wet oxidation procedure, respectively. pH was measured in a soil/water ratio 1:1, $CaCO_3$ was measured following the procedure outlined in Page *et al*., (1982), saturation moisture (SM) was determined as the difference between weight of saturated and the Oven-dried (at 105°C for 24 h) soil (Table 1).

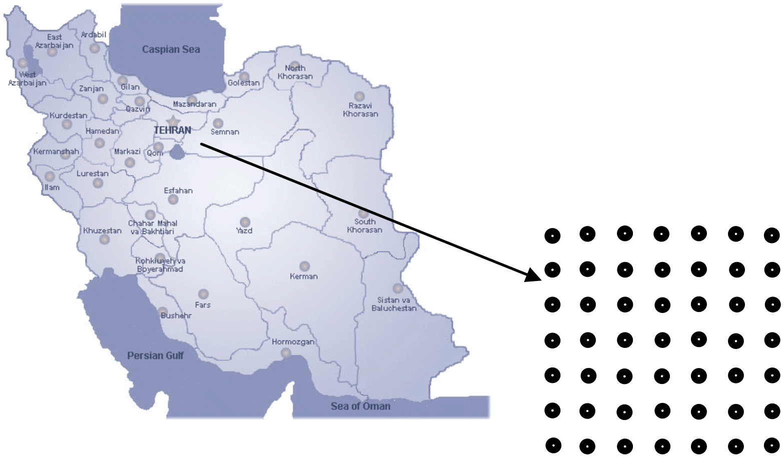

Figure 1 Position of study area in Iran (Left) and sampling plan in the each land use (Right)

Table 1 Mean, coefficient of variation and skewness of soil properties in the three land uses

Soil factor	Mean	CV [a)]	Skewness	Mean	CV	Skewness	Mean	CV	Skewness
	Forest			Grazing land			Cultivated land		
SM (g kg^{-1})	8.07	10.99	-0.10	7.55	13.81	0.52	3.85	8.20	0.37
SOC (g kg^{-1})	1.823	**22.76**	-0.14	1.12	**32.67**	0.24	1.16	**19.31**	0.21
pH	8.39	**1.54**	0.27	8.66	6.68	-0.58	8.67	**0.57**	-0.25
EC (µS sm^{-1})	138.96	19.84	0.67	192.69	16.19	0.15	121.76	12.20	0.22
Clay (%)	22.13	14.68	0.21	14.50	24.31	0.42	22.29	11.31	0.55
Sand (%)	49.71	9.85	-0.08	66.31	10	-0.08	42.90	13.31	0.76
Silt (%)	28.71	11.72	0.13	21.54	22.37	0.20	35.66	11.55	-0.72
$CaCO_3$ (%)	34.98	11.01	-0.39	41.11	**4.32**	-0.01	32.78	13.51	-0.19
TN (g kg^{-1})	0.17	21.76	0.22	0.14	23.57	0.24	0.09	17.77	0.21

a) Coefficient of variation

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2.3 Statistical and geostatistical analysis

Soil data set were first analyzed using descriptive statistical methods. Significant influences of land use change on analyzed soil properties were tested using One-way analysis of variance (ANOVA) and Duncantest (P<0.01). Variance homogeneity was tested using Liven test. Abnormal distribution of data has effects that may lead to high fluctuations of variograms and reduces the reliability of analytical results, thus normalization of data is necessary. Normal distribution of data was estimated based on their skewness, as the data with -1 to +1 skewness were normally distributed (Virgilio *et al*., 2007;Paz Gonzales *et al*., 2000). Since nitrogen showed skew coefficient greater than 1, a logarithmic transformation was performed to obtain a nearly distribution before proceeding with the geostatistical analysis (Webster and Oliver, 2001). Before the applying the geostatistical analysis, each soil variable were checked for isotropy and anisotropy. Plotted variogramson different directions including 0, 45, 135 degrees for all soil variables in this study showed that effective range and sill of variograms was uniform and then there was no clear anisotropy and soil properties were recognized isotropic. This point shows the variability of variables is equal in different directions and changes depend on distance between samples (Mohammad zamani *et al*., 2007). Semivariograms were obtained by the maximum likelihood cross-validation method. The semivariogram was defined as follows:

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

Where N(h) is number of pairs separated by the lag distance h, Z (x_i) and Z (x_i+ h) are the values of the measured variable at spatial locations i andi+ h, respectively.

Appropriate model functions were fitted to the semivariograms. The semivariograms were used to determine the degree of spatial variability on basis of distinguished classes of spatial dependence by Cambardella *et al*., 1994: strongly spatial dependence (C_s/ (C_0+C) >75%), moderately spatial dependence (C_s/ (C_0+C) >25% and <75%), weakly spatial dependence (C_s/ (C_0+C) <25%). The statistical and geostatistical analysis were carried out using SPSS 16. (SPSS Inc., Chicago, USA) and GS+ 5.1 (Gamma Design Software, MI, USA), respectively.

3 RESULTS

The summary of descriptive statistics for soil features are presented in table 1.Coefficient of variation was used to show total changes. The coefficient of variation pH and organic carbon was lowest and highest in the forest and cultivated land, respectively. Organic carbon and CaCO3 was shown highest and lowest coefficient of variation in the grazing land(Table 1).

F test results show mean of soil properties in the three land uses were different significantly (p<0.01). Saturated moisture (8.07), organic carbon (1.823) and total nitrogen(0.17) under the native forest were significantly higher than the contents in cultivated and grazing land (Table 2). Soil pH and organic carbons were not significant different between soils under the cultivated and grazing lands (Table 2). Percent of clay was not different between the soils under the forest and cultivated lands (Table 2). Saturated moisture, electric conductivity (EC), TN and CaCO3 under cultivated land were significantly lowers than the contents in the forest and grazing lands. EC and pH under the forest were significantly higher and lower than the contents grazing and cultivated land respectively (p<0.01).

High coefficients of determination (R^2) indicated that fitted semivariogram models are well. According to our findings in the forest, CaCO3, EC and total nitrogen had shown the highest and lowest effective range with 932.7 and 60.1 meter, respectively. The proportion of spatial structure indicates moderate spatial

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dependence for all of soil characteristics except organic carbon and percent of silt that had shown strong and weak spatial dependence, respectively (Table 3).

Semivariograms of soil characteristics in the three land uses are presented in Figure 2 to 4. Table 4 shows, in the grazing land, moisture and present of silt and clay had shown the lowest and highest effective range with 57.6 and 932.7 meter, respectively. The spatial dependence of soil characteristics was moderate and weak except EC.

Table 2 Results of ANOVA and comparison mean of soil properties in the three land uses

Soil Factor	Mean[a)]	Mean	Mean	*F test*
	Forest	**Grazing land**	**Cultivated land**	
SM	8.07^{a}±0.297	7.55^{b}±0.376	3.85^{c}±0.057	393.69^{**}
SOC	1.823^{a}±0.099	1.12^{b}±0.072	1.16^{b}±0.063	62.83^{**}
pH	8.39^{a}±0.245	8.66^{b}±0.023	8.67^{b}±0.015	153.98^{**}
EC	138.96^{a}±4.84	192.69^{b}±5.07	121.76^{c}±3.29	102.97^{**}
Clay	22.13^{a}±0.913	14.50^{b}±0.679	22.29^{a}±0.391	99.30^{**}
Sand	49.71^{a}±1.203	66.31^{b}±1.26	42.90^{c}±0.972	211.84^{**}
Silt	28.71^{a}±0.961	21.54^{b}±0.766	35.66^{c}±0.928	142.23^{**}
CaCO3	34.98^{a}±0.916	41.11^{b}±0.367	32.78^{c}±0.817	72.70^{**}
TN	0.17^{a}±0.010	0.14^{b}±0.006	0.09^{c}±0.0035	78.51^{**}

*, and ** Significant at P = 0.05 and P = 0.01 respectively.

a) Similar letters show means have not significant different and dissimilar letters show means have significant different

Table 3 Semivariogram models and model parameters for soil properties without transformation in the forest

Soil Properties	Model	R^2	Nugget (Co)	Sill (Co+C)	Nugget /Sill Ratios[a)]	Spatial Dependency[b)]	Effective Range[c)]	Cross Validation
SM	Gaussian	0.990	4.27	8.54	50	Moderate	538.944	1.75^{ns}
SOC	Spherical	0.999	0.115	0.543	21.2	**Strong**	74	12.52^{**}
pH	Linear to sill	0.998	0.015	0.0294	49.8	Moderate	310.9	0.94^{ns}
EC	Exponential	0.918	1008	2017	50	Moderate	**932.7**	0.05^{ns}
Clay	Spherical	0.996	16.6	54.2	31	Moderate	276.7	5.82^{*}
Sand	Spherical	0.996	43.1	127.2	33.9	Moderate	255.3	7.32^{*}
Silt	Gaussian	0.150	33.3	66.61	50	**Weak**	538.495	12.05^{**}
CaCO3	Exponential	0.523	23.43	46.87	50	Moderate	**932.7**	0.66^{ns}
TN	Spherical	0.999	0.0016	0.0055	31	Moderate	**60.1**	6.45^{*}

*, and **Significant at P = 0.05 and 0.01, respectively

a) Nugget/sill (%) = (nugget/sill) × 100; b) Spatial dependency was defined as strong, moderate, weak or pure nugget based on nugget to sill ratios < 25, 25 to 75, > 75, or = 100, respectively, and weak if the fitting R^2< 0.50;c) The effective range is the model range multiplied by 1.0, 3.0, or 1.73 for spherical, exponential, and Gaussian models, respectively.

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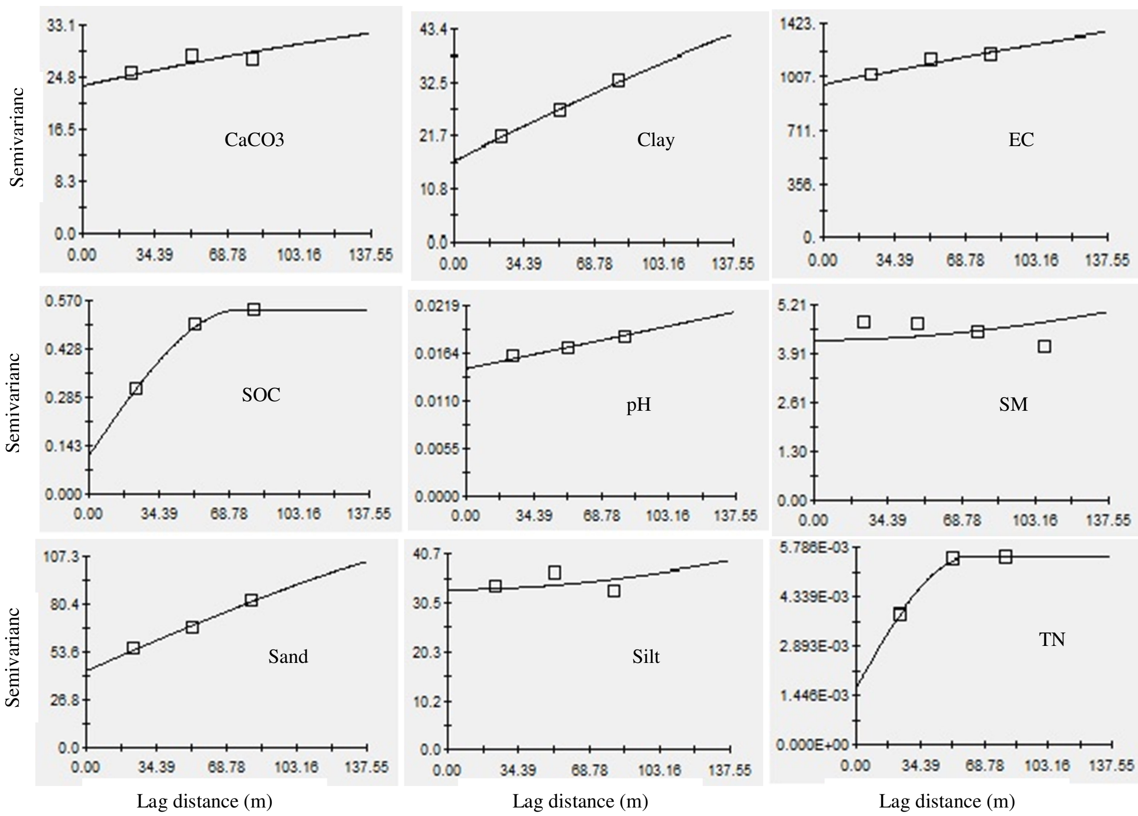

Figure 2 Semivariograms of soil properties in the forest

Table 4 Semivariogram models and model parameters for soil properties in the grazing land

Soil Properties	Transformation	Model	R^2	Nugget (Co)	Sill (Co+C)	Nugget /Sill ratios	Spatial dependency	Effective Range	Cross Validation
SM	No	Spherical	0.999	0.0094	0.0359	26.2	Moderate	**57.6**	13.49^{**}
SOC	No	Gaussian	0.044	0.74	0.48	50	Weak	538.495	2.98^{ns}
pH	No	Exponential	0.916	2.44	6.7	36.4	Moderate	740.1	0.23^{ns}
EC	No	Exponential	0.952	0.015	0.0798	18.8	**Strong**	584.1	16.21^{**}
Clay	No	Exponential	0.891	0.023	0.047	49.9	Moderate	**932.7**	0.51^{ns}
Sand	No	Linear to sill	0.741	0.018	0.036	49.9	Moderate	310.9	1.51^{ns}
Silt	No	Exponential	0.356	0.0095	0.192	49.7	Weak	**932.7**	0.27^{ns}
CaCO3	No	Exponential	0.905	0.025	0.0719	35.5	Moderate	86.7	4.38^{*}
TN	No	Exponential	0.863	0.033	0.066	49.9	Moderate	930.9	0.78^{ns}

*, and **Significant at $P = 0.^{05}$ and 0.01, respectively

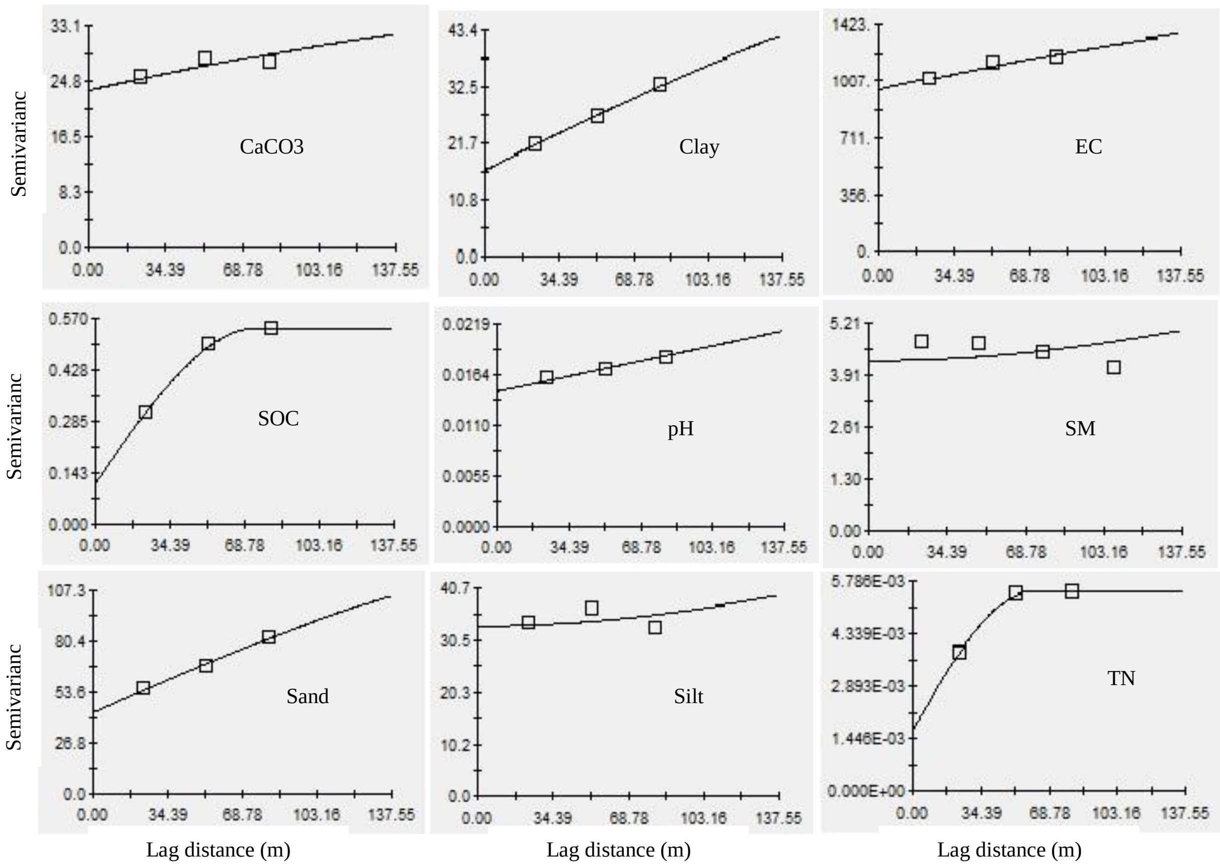

Figure 2 Semivariograms of soil properties in the forest

Table 4 Semivariogram models and model parameters for soil properties in the grazing land

Soil Properties	Transformation	Model	R^2	Nugget (Co)	Sill (Co+C)	Nugget /Sill ratios	Spatial dependency	Effective Range	Cross Validation
SM	No	Spherical	0.999	0.0094	0.0359	26.2	Moderate	**57.6**	13.49**
SOC	No	Gaussian	0.044	0.74	0.48	50	Weak	538.495	2.98 ns
pH	No	Exponential	0.916	2.44	6.7	36.4	Moderate	740.1	0.23 ns
EC	No	Exponential	0.952	0.015	0.0798	18.8	**Strong**	584.1	16.21**
Clay	No	Exponential	0.891	0.023	0.047	49.9	Moderate	**932.7**	0.51 ns
Sand	No	Linear to sill	0.741	0.018	0.036	49.9	Moderate	310.9	1.51 ns
Silt	No	Exponential	0.356	0.0095	0.192	49.7	Weak	**932.7**	0.27 ns
CaCO3	No	Exponential	0.905	0.025	0.0719	35.5	Moderate	86.7	4.38*
TN	No	Exponential	0.863	0.033	0.066	49.9	Moderate	930.9	0.78 ns

*, and **Significant at P = $0.^{05}$ and 0.01, respectively

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In the cultivated land, results showed that percent of sand had the lowest effective range with 120.9 meter and pH, EC, percent of clay and silt had highest with 932.7 meter. The spatial dependence of soil characteristics was moderate and weak (Table 5).

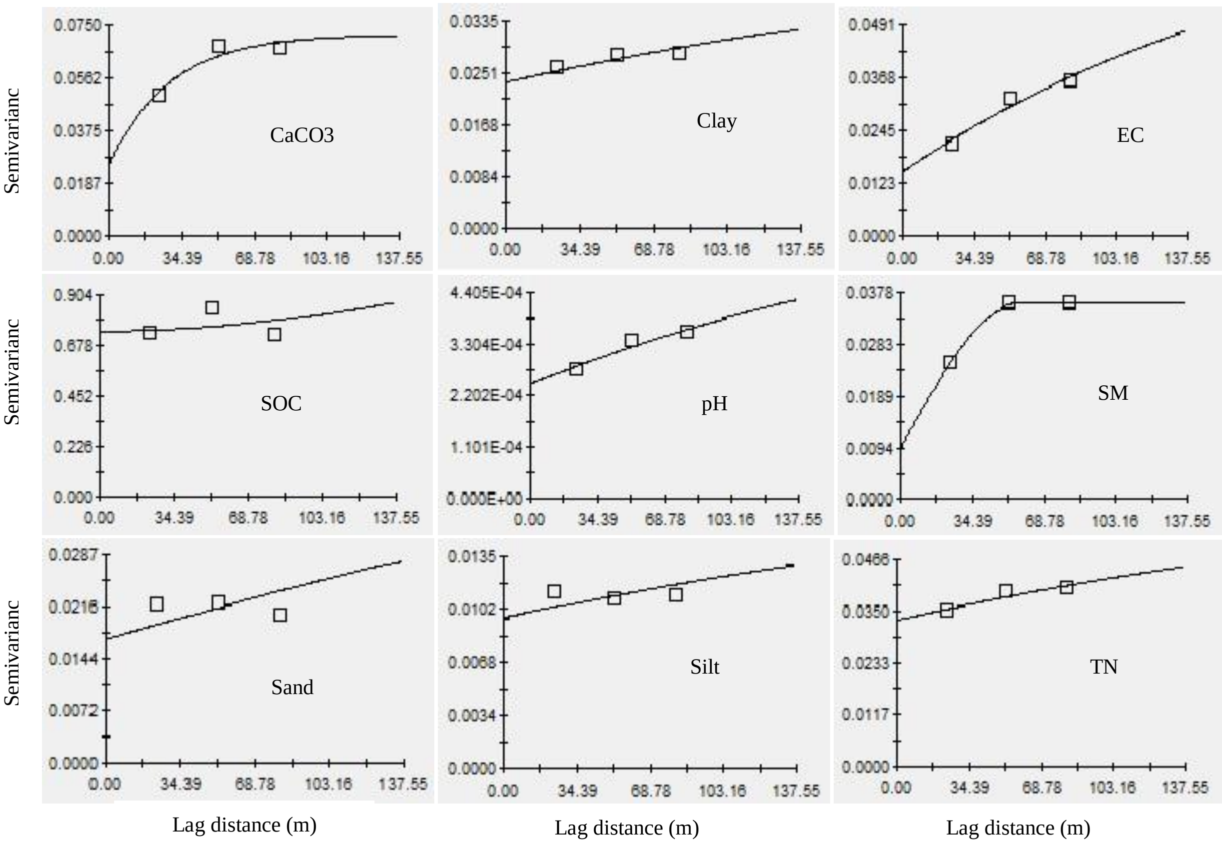

Figure 3 Semivariograms of soil properties in the grazing land

Table 5 Semivariogram models and model parameters for soil properties in the cultivated land

Soil Properties	Transformation	Model	R^2 Model	Nugget (Co)	Sill (Co+C)	Nugget /Sill Ratios	Spatial Dependency	Effective Range	Cross Validation
SM	No	Gaussian	0.469	0.0405	0.110	36.4	Weak	464.882	0.69 ^{ns}
SOC	No	Gaussian	0.799	0.063	0.127	50	Moderate	538.495	0.27 ^{ns}
pH	No	Exponential	0.259	0.031	0.062	49.4	Weak	932.7	0.05 ^{ns}
EC	No	Exponential	0.774	0.544	1.089	50	Moderate	932.7	11.28**
Clay	No	Exponential	0.410	0.0689	0.138	50	Weak	932.7	0.05 ^{ns}
Sand	No	Exponential	0.895	0.131	0.310	42.3	Moderate	**120.9**	8.41**
Silt	No	Exponential	0.498	0.114	0.229	49.8	Weak	932.7	1.55 ^{ns}
$CaCO^3$	No	Gaussian	0.403	0.265	0.533	49.8	Weak	538.32	2.22 ^{ns}
TN	No	Linear to sill	0.007	1.384	2.778	49.8	Weak	310.9	7.62**

*, and **Significant at $P = 0.^{05}$ and 0.01, respectively

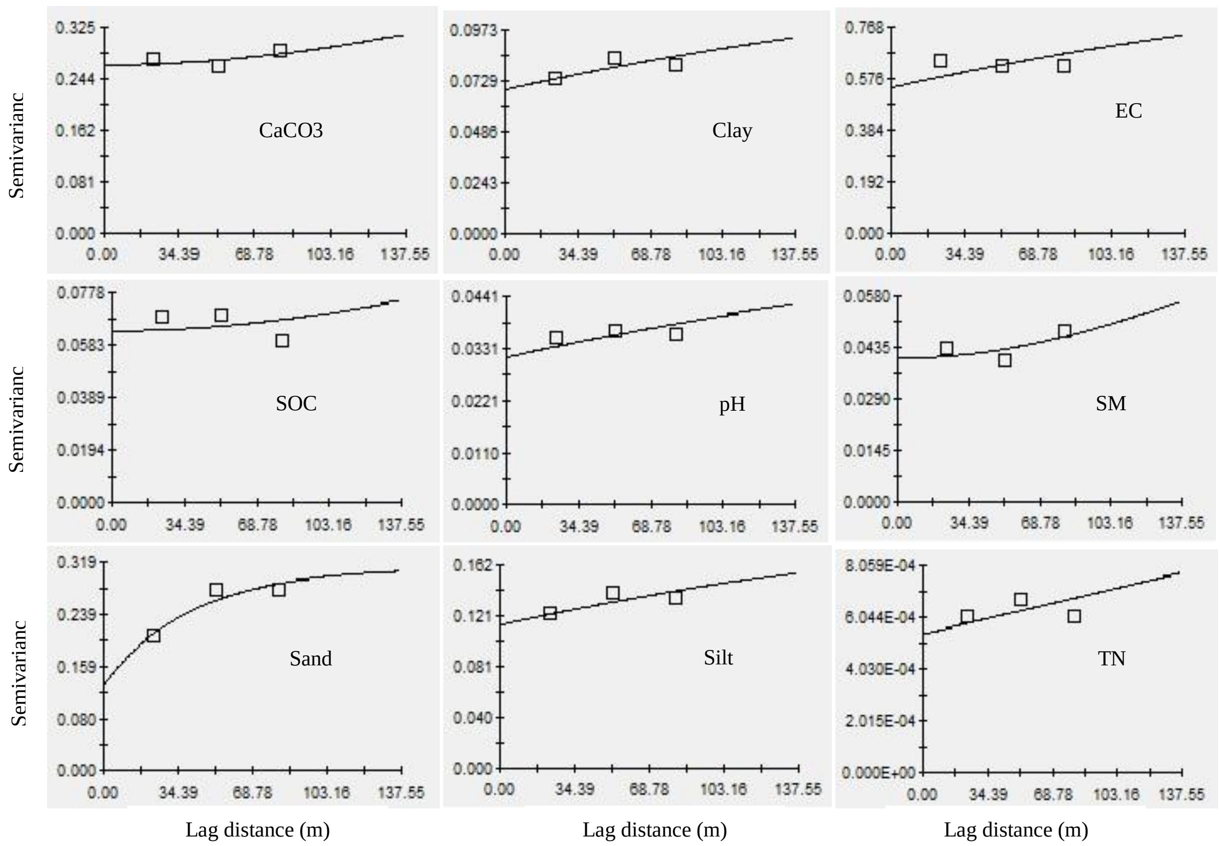

Figure 4 Semivariograms of soil properties in the cultivated land

4 DISCUSSION

Different systems of land uses refer to different levels of human activities that arecaused different effects of land uses on soil properties. In northern Iran, The most of land use change occurs from forest to agriculture and since potential of converted lands is not appropriate for agriculture usually after few years is released and used for grazing (Raei, 2013).Often, in the forest, soil organic carbon content and available nutrition are more than grazing and agricultural land that has been creation from convention of forest such as study area (Lal, 2002;Gol, 2009) because natural plant cover were cute or burned and were cultivated plants that are less protected from soil organic carbon content and above ground plant biomass. One of the reason high organic carbons in the forest is high litter. Cause of low organic carbon in the agricultural land is loss of it following harvest (Celik, 2005; Dominy and Haynes, 2002). Results showed that organic carbon and total nitrogen in the cultivated land was lower than the forest and grazing land significantly, because of land use change (Yimer *et al.*, 2007; Gol, 2009). Land use change is caused change of infiltration, run off and evaporation then soil moisture between land uses had significant different (Demir *et al.*, 2007). Increasing of soil pH following land use change from forest to cultivated land has been approved in other studies too (Bewket and Stroosnijder, 2003; Tejada and Gonzalez, 2008) that reason is management activities such as fertilization (Geissen *et al*., 2009). In addition, cultivation will bring increase of soil pH with effects on micro organisms' activities and soil organic carbon (Balesdent *et al*., 2000). EC increasing affected deforests destruction of rangelands and cultivation on these lands (Bolan *et al.*, 1991) that we were faced with this problem in the study area. In the study area, convention of forest to grazing land decreases and increase percent of silt and sand respectively. Increased soil bulk density indicates an increasing loss of soil binder materials, reduced soil biological activity, especially earthworms and plant roots, and is due to the land use change and significant reduction of clay and silt and instead of increasing the amount of sand in the soil texture (Gholami *et al*., 2014).

Among the investigated variables in this study, organic carbon in the grazing land had highest coefficient ofvariationwith32.76% and pH in the forest and cultivated land had lowest coefficient of variation with 1.54 %, 0.57, respectively, which could be because of the uniform conditions in the region such as small changes in slope and its direction that led to uniformity of soil in this region. Cambardella *et al*. (1994), Kavianpoor *et al*. (2012), found similar results.

In the forest, percent of silt had weaker spatial structure than other variables that it may be have spatial structure in the smaller scale than study scale as had shown Mohammadi and Raeisi, 2004 about of phosphorous Emadi, 2008, Kavianpoor *et al*., 2012 about of nitrogen. Spatial dependence of organic carbon had been different between three land uses according to results of Wang *et al*., 2009. Variables with strong spatial structure and very low nugget effect have high continuous distribution in this area. Strong spatial structure can be controlled by inherent changes of soil properties such as soil texture and mineralogy and weak spatial structure by non-intrinsic variable such as grazing (Cambardella *et al*., 1994). The results showed spatial distribution of most properties in three land use can be described with spherical and exponential model according to results of Zhao*et al*. (2007); Jafarian Jeloudar *et al.* (2009), Kavianpoor *et al*. (2012).

The value of nugget effect for total nitrogen in the forest and grazing land uses was small which suggest the random variance of variables was 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 Vieira and Paz Gonzalez, (2003); and Mohammadzamani *et al*. (2007) showed that variogram of nitrogen had very small nugget effect equal to 0.006. Afshar *et al*., 2009 reported that nugget effect of electrical conductivity was 0.0008. The larger effective rangehas 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 (Hasani Pak, 2007). Effective range of soil properties were increased from forest to cultivated land then they have higher widespread than forest. The effective ranges were 100- 932 meters in this study which represents an increase in soil heterogeneity or potential of retrospection processes. Effective range of some soil properties including CaCO3, nitrogen, EC, pH, silt and clay content were higher than others which probably is due to same impact of intrinsic processes on these soil characteristics (Kavianpoor *et al*., 2012).

5 CONCLUSION

Deforestation and conversion to cultivated and grazing lands has been decreased spatial dependence of soil properties including soil moisture, organic carbon, pH, clay, CaCo3, total nitrogen. Land use change was caused destruction of physical and chemical soil properties specially organic carbon, total nitrogen, soil moisture and soil texture then it should be prevented and management activities

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be applied for improvement of soil quality and prevention of more destruction.

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تغییرپذیری مکانی خصوصیات خاک تحت تاثیر نوع کاربری با استفاده از زمین آمار

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چکیده از آن‌جا که در کشور خصوصا شمال ایران با پدیده تبدیل اراضی مواجه است، در این تحقیق، تغییرپذیری مکانی خصوصیات خاک در سه کاربری متفاوت کشاورزی گندم، مرتعی و جنگلی (با گونه‌های *juniperussp, fagusorientalis, quercuscastanifolia, and acervelotinum*) در منطقه کیاسر استان مازندران در شمال ایران بررسی شد. نمونه‌برداری در سه منطقه جنگل، مرتع و کشاورزی با پیاده کردن یک شبکه نمونه‌برداری ۱۲۰×۱۲۰ متر مربعی انجام و از هر منطقه تعداد ۴۹ نمونه خاک از عمق ۰-۳۰ سانتی‌متر و در مجموع ۱۴۷ نمونه جمع‌آوری و به آزمایشگاه انتقال یافت. در آزمایشگاه ویژگی‌های خاک شامل pH، آهک، نیتروژن کل، کربن آلی، بافت خاک (درصد سیلت، رس و شن) و درصد رطوبت اندازه‌گیری شدند. سپس داده‌ها نرمال گردیده و آنالیزهای زمین آماری برای نشادن دادن وابستگی مکانی این ویژگی‌ها صورت گرفت. آنالیز مکانی ویژگی‌های مورد مطالعه نشان داد که در کاربری جنگل توزیع مکانی بیش‌تر ویژگی‌های خاک با مدل کروی و در کاربری‌های کشاورزی و مرتع با مدل نمایی قابل توصیف بوده است. وابستگی مکانی کربن آلی در جنگل بالاترین و درصد سیلت پایین‌ترین بود. وابستگی مکانی هدایت الکتریکی در مرتع بالاترین و درصد سیلت و کربن آلی پایین‌ترین بود. درکل تبدیل جنگل به اراضی زراعی و چرایی سبب کاهش وابستگی مکانی ویژگی‌های خاک شده است.

کلمات کلیدی: اعتبارسنجی متقاطع، روش کریجینگ، وابستگی مکانی، ویژگی‌های خاک