Evaluation of Spatial variability of soil quality in Wildlife Refugee of Karkhe in southwestern Iran

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ABSTRACT

Soil properties are continuous variables whose values at any location can be expected to vary according to direction and distance of separation from neighboring samples. The spatial variability and variation of soil properties should be quantified for a better understanding of the influence of such factors as management and pollution, and finally for leading to more efficient management. Geostatistics provide descriptive tools such as variogram to characterize the spatial pattern of continuous soil attributes. This study addressed the spatial variability of soil properties at the regional scale using geostatistical method. The study was carried out in Wildlife Refugee of Karkhe in riparian forests of Karkhe river southwestern Iran. The soil was sampled in 2009 using 200 sampling point along parallel transects (perpendicular to the river). The distance between transects were 0.5 km. The sampling procedure was hierarchically, we considered maximum distance between samples as 0.5 km, but the samples were taken at 250m, 100m, 50m, 10m and 5m at different locations of sampling. At each transect point, three 50 cm×50 cm×25 cm samples were taken for analyses at each sampling campaign. Soil bulk density, total nitrogen and C/N were analyzed using geostatistics (variogram) in order to describe and quantify the spatial continuity. Soil properties showed spatial variability with the highest coefficient of variation being observed for C/N and the lowest for soil bulk density. The variograms revealed the presence of spatial autocorrelation. Soil bulk density was moderately spatially dependent, while N_t and C/N showed the weak spatial dependence. The range of influence was 810, 1200 and 3300 m respectively for C/N, N_t and bulk density. The contour maps produced by kriging, showed a heterogeneous and patchy structure for the estimated values of N_t and C/N. The kriging map also showed the highest increase in the area next to river for soil bulk density.

Keywords: Spatial variability, Variogram, bulk density, C/N

1. Introduction

The production of forest ecosystems and their responses to other environmental factors are highly dependent on the sustainable function of the soils on which they grow, in particular the recycling of organic matter and nutrients (Zushi, 2006). Values of soil property anywhere on the landscape vary from location to location (Nielsen and Wendroth, 2003). Soil properties are continuous variables whose values at any location can be expected to vary according to direction and distance of separation from neighboring samples (Al-Kayssi, 2002). A key feature of soil information is that each observation relates to a particular location in space and time (Goovaerts, 1999). Recently, emphasis has been placed on the fact that the variations of a soil property are not completely disordered over the field and this spatial structure must be
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taken into account in the treatment of the data (Al-Kayssi, 2002). The heterogeneity and variation of soil properties should be monitored and quantified for a better understanding of the influence of such factors as management and pollution, and finally for leading to more efficient management (Sun et al., 2003).

Although values at locations close to each other tend to be similar, variations are generally highly irregular and not accurately described by deterministic equations. However important information may be lost if locations of observations are not considered: approaches which allow for spatial analyses of data (Nielson and Wendroth, 2003), provide a promising methodology and opportunity for evaluating soil properties distribution patterns at regional scales. An appropriate approach for the analysis of spatial patterns is a transect study in which samples are taken in a certain order and with a certain distance between samples. The analysis of transect data allows the detection of “spatial pattern” along environmental gradients. In addition, quantitative analyses of transect data are possible (Joschko et al., 2006).

Classical statistical procedures assume that variation is randomly distributed within sampling units (Mohmmadi, 2006). Geostatistics provides a set of statistical tools for incorporating spatial and temporal coordinates of observations in data processing (Goovaerts, 1999, Sun et al., 2003). This analysis considers the location of observations (Mohmmadi, 2006) and allows assessment of consistency of spatial patterns as well as the scale at which they are expressed (Jimenez et al., 2001).

The variogram is a critical input to geostatistical studies. It is a tool to investigate and quantify the spatial variability of the properties under study, and most geostatistical estimation or simulation algorithms require an analytical variogram model (Gringarten, 2001). The main application of geostatistics to soil science has been the estimation and mapping of soil attributes in unsampled areas. Kriging is a generic name adopted by the geostatisticians for a family of generalized least-squares regression algorithms (Goovaerts, 1999). This procedure interpolates values at unsampled locations with measured values (Nielson and Wendroth, 2003). The objective of this study was to define the spatial variability of soil total nitrogen ($N_t$), C/N and bulk density in Wildlife Refugee of Karkhe in the riparian forest of the southwestern Iran. Since soil C and N contents are closely related to soil physical, chemical, and biological properties and so are widely regarded as indicators of soil quality (Zushi, 2006). The practical consequences of these findings are useful for sustainable management of soils and in monitoring soil quality. Many scientists believe promoting sustainability is the overarching goal of landscape (and regional) planning (Leitao, and Ahern, 2002).

2 Materials and Methods

2.1 Study Site

The study area was located in Wildlife Refugee of Karkhe in the riparian forests of the Karkhe river southwestern Iran ($31^{\circ} 57^{\prime}$ - $32^{\circ} 05^{\prime}$ N and $48^{\circ} 13^{\prime}$ - $48^{\circ} 16^{\prime}$ E). The climate of this area is semi-arid. Average yearly rainfall is about 325.8 mm with a mean temperature of 24°C. Plant cover, mainly comprises Populus euphratica and Tamarix sp.
2.2 Soil Sampling

The both sides of river are similar, so we sampled on one of the two sides. The soil were sampled in 2009 using 200 sampling point along parallel transects (perpendicular to the river). The distance between transects were 0.5 km. The sampling procedure was hierarchically, we considered maximum distance between samples as 0.5 km, but the samples was taken at 250m, 100m, 50m, 10m and 5m at different locations of sampling.

At each transect point, three 50 cm×50 cm×25 cm samples were taken for analyses at each sampling campaign. Soil samples for measuring bulk density consisted of soil core of 250 cm$^3$ volume, dried for 48 h at 105°C. Soil organic carbon (C$_{org}$) measured by means of wet oxidation (Walkley, Black method). Total soil nitrogen content (N$_t$) was determined by Kjeldahl method. C/N was calculated from C$_{org}$ and N$_t$ (Burt, 2004).

2.3 Statistical Analysis

Classical statistical parameters, i.e. mean, standard deviation and coefficient of variation were calculated using SPSS 15 software. Soil properties data were analyzed using geostatistics (variogram) in order to describe and quantify the spatial continuity. Geostatistical analysis was performed using the software Variowin 2.2 (variograms). Spatial distribution maps were made by block kriging using the software Geoease and Surfer 8.0.

3. Results and Discussion

Table 1 shows the Mean, standard deviation, coefficient of variation, minimum and maximum values for each of the soil properties determined. Among the three soil properties, soil bulk density shows the lowest CV, while C/N the highest. It could be linked to the heterogeneity and differences of vegetation cover. Mean of C/N was 34.9 with a standard deviation of 18.7. Coefficient of variation was 53.5% (Table 1).

<table>
<thead>
<tr>
<th>soil property</th>
<th>mean</th>
<th>S. D</th>
<th>C.V (%)</th>
<th>minimum</th>
<th>maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil bulk density (gr/cm$^3$)</td>
<td>1.25</td>
<td>0.1</td>
<td>8</td>
<td>1.12</td>
<td>1.9</td>
</tr>
<tr>
<td>Total soil nitrogen (%)</td>
<td>0.048</td>
<td>0.024</td>
<td>50</td>
<td>0</td>
<td>0.13</td>
</tr>
<tr>
<td>C/N</td>
<td>34.9</td>
<td>18.7</td>
<td>53.5</td>
<td>13.9</td>
<td>93.6</td>
</tr>
</tbody>
</table>

3.1 Spatial dependence of soil properties

Analysis of spatial dependence of soil properties showed an isotropic behavior, which might be caused by a low variability of soil formation factors (Sun et al., 2003). The variogram revealed the presence of spatial autocorrelation (Fig. 1). The parameters of the theoretical model fitted to experimental variograms are given in Table 2. All soil properties showed positive nugget, which can be explained by sampling error, short range variability, random and inherent variability (Rossi, 2003, Gongalski et al., 2008,). Typically these structures constitute one source of the nugget variance of the variograms (Rossi, 2003). The nugget-to-sill ratio can be used to classify the spatial dependence of soil properties. In this study we used similar criteria to those reported by Sun et al. (2003). The variable is considered to have a strong spatial dependence if the ratio is less than 25%, and has a moderate spatial
dependence if the ratio is between 25% and 75%, otherwise the variable has a weak spatial dependence. This ratio showed a weak spatial dependence for \( N_t \) and C/N (Table 2), which might be attributed to the small-scale variability of them and important proportion of unexplained variance. This is consistent with the results reported by Afshar et al., (2009) who showed the weak spatial dependence for \( N_t \) and C/N. Soil bulk density was moderately spatially dependent, imprinted by intrinsic factors such as soil forming processes. The range of influence is considered as the distance beyond which observations are not spatially dependent (Mohmmadi, 2006, Sun et al., 2003). This distance was 810 for C/N, 1200 for \( N_t \) and 3300 for soil bulk density (Table 2). The large range of soil bulk density could be explanatory of monotonous condition and the extensive spatial structure (Hassani Pak, 1998).

![Table 2: Variogram model parameters for soil property](image)

<table>
<thead>
<tr>
<th>Soil property</th>
<th>Model</th>
<th>Sill</th>
<th>Nugget</th>
<th>Nugget/Sill (%)</th>
<th>Range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil pro (gr/cm(^3))</td>
<td>spherical</td>
<td>1.15</td>
<td>0.59</td>
<td>51</td>
<td>3300</td>
</tr>
<tr>
<td>Total soil nitrogen (%)</td>
<td>spherical</td>
<td>1.02</td>
<td>0.86</td>
<td>84</td>
<td>1200</td>
</tr>
<tr>
<td>C/N</td>
<td>spherical</td>
<td>1.02</td>
<td>0.83</td>
<td>81</td>
<td>810</td>
</tr>
</tbody>
</table>

![Figure 1: Variograms of (A) Log transformed data for C/N, (B) total soil nitrogen and (C) soil bulk density](image)

**Figure 1**: Variograms of (A) Log transformed data for C/N, (B) total soil nitrogen and (C) soil bulk density

### 3.2 Kriging of spatial pattern of soil property

The spatial changes of soil properties for unsampled locations can be directly interpolate with classical kriging based on semivariogram of their changes over time (Sun et al., 2003). Kriging results showed relatively similar spatial structure for the estimated values of \( N_t \) and C/N. These maps have demonstrated the existence of a highly heterogeneous and patchy structure in distribution of these two properties. It could be influenced by spatial distribution...
of vegetation cover. Soil properties like organic matter content, may be quite patchy in some soils (Rossi, 2003b). These results show that the spatial variability is not high. Spatial variation in soil C and N storage is thought to be associated with variation in plant productivity through the effect of organic matter input to the soil (Zushi, 2006).

The area with lower bulk density was far from the river, while it increases near the river and in the places with more vegetation density (Fig. 2). Probably the variations of vegetation cover and soil moisture might be the main factors of the variability of soil bulk density. These results illustrate the reliability of kriging estimate directly to the spatial changes of soil properties. The maps obtained by kriging for soil properties are shown in Fig. 2.

![Figure 2: Distribution of (A) C/N, (B) total soil nitrogen and (C) soil bulk density](image)

4. Conclusion / Suggestions/ Findings

The following conclusions can be drawn from the experimental results:

1. The higher variation was observed for C/N, while the lowest for Soil bulk density.
2. All the soil properties had a spatial structure. The nugget-to- sill ratio revealed a moderate spatial dependence for soil bulk density and a weak spatial dependence for N_t and C/N.
3. The contour map produced by kriging showed a spatial similarity among the estimated values for N_t and C/N.
4. The distribution maps showed a heterogeneous and patchy structure for both.
5. The kriging map also showed the highest increase in the area next to river for soil bulk density. Kriging gives a spatial structure analysis and a view of soil quality changes by contour plots.
6. This geostatistical method can be used as an analysis tool for monitoring soil quality changes.

5. References

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