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Spatial variation of soil nutrients on sandy-loam soil

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ABSTRACT

The spatial variability of plant available phosphorus, plant available potassium, soil pH and soil organic matter content in central Croatia was investigated using geostatistical tools and geographical information system to create nutrient maps and provide useful information for the application of inputs that will also be used for the design of an adequate soil sampling scheme. In a regular grid (50 m × 50 m), 330 samples were collected on sandy loam Stagnic Luvisol. Soil available phosphorus and plant available potassium showed relatively high spatial heterogeneity, ranging from 105 mg kg^{-1} to 310 mg kg^{-1}, and from 115 mg kg^{-1} to 462 mg kg^{-1}, respectively. Content of soil organic matter and pH had lower variability ranging from 1.26% to 2.66% and from 3.75 to 7.13, respectively. Investigated soil properties did not follow normal distribution. Logarithm and Box–Cox transformation were applied to achieve normality. Directional exponential model for soil available phosphorus, potassium and pH and spherical model for soil organic matter was used to describe spatial autocorrelation. Fourteen different interpolation models for mapping soil properties were tested to compare the prediction accuracy. All models gave similar root mean square error values. Available phosphorus, potassium and pH evaluated by radial basis function models (CRS, IMTQ and CRS, respectively) provide a more realistic picture of the structures of analyzed spatial variables in contrast to kriging and inverse distance weighting models. For soil organic matter datasets the most favorable model was LP1. According to the best model soil nutrient maps were created to provide guidance for site-specific fertilization and liming. Soil fertility maps showed sufficient concentrations of soil available phosphorus and available potassium. Acidity map showed that the largest part of the investigated area is very acid and acid. For future management it is necessary to provide more liming materials while fertilization rate should be lower.

1. Introduction

Nowadays, the vast majority of farmers in Croatia use fertilizers without analyzing the soil fertility. Just a minority of farmers use fertilizers according to soil analysis but without considering in-field spatial variability. In recent decades better investigation methods resulted in higher awareness of crop and soil science and soil properties variability within fields. Most of the yield variability studies have focused on soil nutrient availability and less on soil physical property variability (Castrignano et al., 2002). In contrast to texture and soil organic matter content, nutrients (e.g., potassium, phosphorus) have higher temporal change in soils depending on soil or crop property (Heege, 2013). Therefore, it is necessary to monitor the condition of the soil in a shorter period of time which raises the operating costs. Present technology allows us to improve the application of fertilizers and other inputs by varying rates and blends as needed within fields (Robert, 2002). Geostatistical concept with properly applied sampling trough interpolation technique allows us to assess the value of a soil property at unsampled locations within the area covered by observation points. Respecting the principles of regionalized variable theory (Clark, 1979; Journel and Huijbregts, 1978; Matheron, 1963) it is possible to find the necessary dependence between two sampling points in space. But mapping the spatial distribution of nutrients needs better spatial interpolation methods and their comparisons. Papers that compare different interpolations methods have already been published (Pereira et al., 2013a,b; Robinson and Metternicht, 2006; Xie et al., 2011; Yang et al., 2004; Yasrebi et al., 2009) but the results are not clear. Studies reported different distances between dependent sampling points. Fu et al. (2010) found ranges of 264 m, 300 m and 290 m for phosphorus, potassium and pH on grassland. Robinson and Metternicht (2006) in topsoil of dryland paddock reported ranges of 2110 m

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and 273 m for pH and organic matter, while Kravchenko and Bullock (1999) recorded spatially dependent sampling points from 82 m to 608 m for phosphorus and 85 m to 532 m for potassium in 30 different agricultural fields. Montanari et al. (2012) reported different spatially dependent ranges for phosphorus depending of soil type. Two ranges were 1419 m on Alfisols and 689 m on Alfisols and Oxisols. On colluvial and alluvial soils in regular grid 500 m × 500 m Sağlam et al. (2011) recorded spatial dependent ranges for soil organic matter between 809 and 1680 m depending on soil type. Some researchers prefer ordinary kriging (Kravchenko and Bullock, 1999; Laslett et al., 1987), others (Gotway et al., 1996; Weber and Englund, 1992) inverse distance weighting (IDW) and splines (Robinson and Metternicht, 2006) depending on the investigated parameters, distance between sampling points, dealing with data transformation and the number of neighborhood data points used. Furthermore, interpolation is always associated with some degree of uncertainty, because estimation of an unsampled point produces some error, independent of the method used (Ahmed et al., 2011). The purpose of this study was to investigate statistical methods to describe the observed spatial patterns of soil available potassium (AK), available phosphorus (AP), soil acidity (pH) and soil organic matter (SOM). By comparing the interpolation accuracy for each method and analyzing the errors, the objective of this study was to try to determine the optimum method for analyzing spatial variations of investigated properties.

2. Materials and methods

2.1. Study site, soil sampling and analysis

The study area is located near Zagreb (Croatia) at 45° 31′ N and 16° 59′ E and 112 m.a.s.l. in a rural/forest interface area. Soil sampling was performed in a period from 23 to 26 July 2012, after harvest of winter wheat at the field of 84 ha. Soil samples (0–30 cm) were taken (330) with the newly designed soil sampling probe (for more information see Mesic et al., 2013) in a 50 m × 50 m grid. The location of the sampled field is shown in Fig. 1. Precise location of sampling at grid intersections was set up using Trimble GeoExplorer GeoXH 6000 with ± 10 cm accuracy. Sampling, transport and preservation of samples were conducted in compliance with the protocol ISO 10381 from 1 to 8 (1993–2006) (HRN ISO 10381-6, 1993; HRN ISO 10381-3, 2001; HRN ISO 10381-1, 2002; HRN ISO 10381-2, 2002; HRN ISO 10381-4, 2003; HRN ISO 10381-5, 2005; HRN ISO 10381-7, 2005; HRN ISO 10381-8, 2006) and Mesić et al. (2008). Preparation of samples for

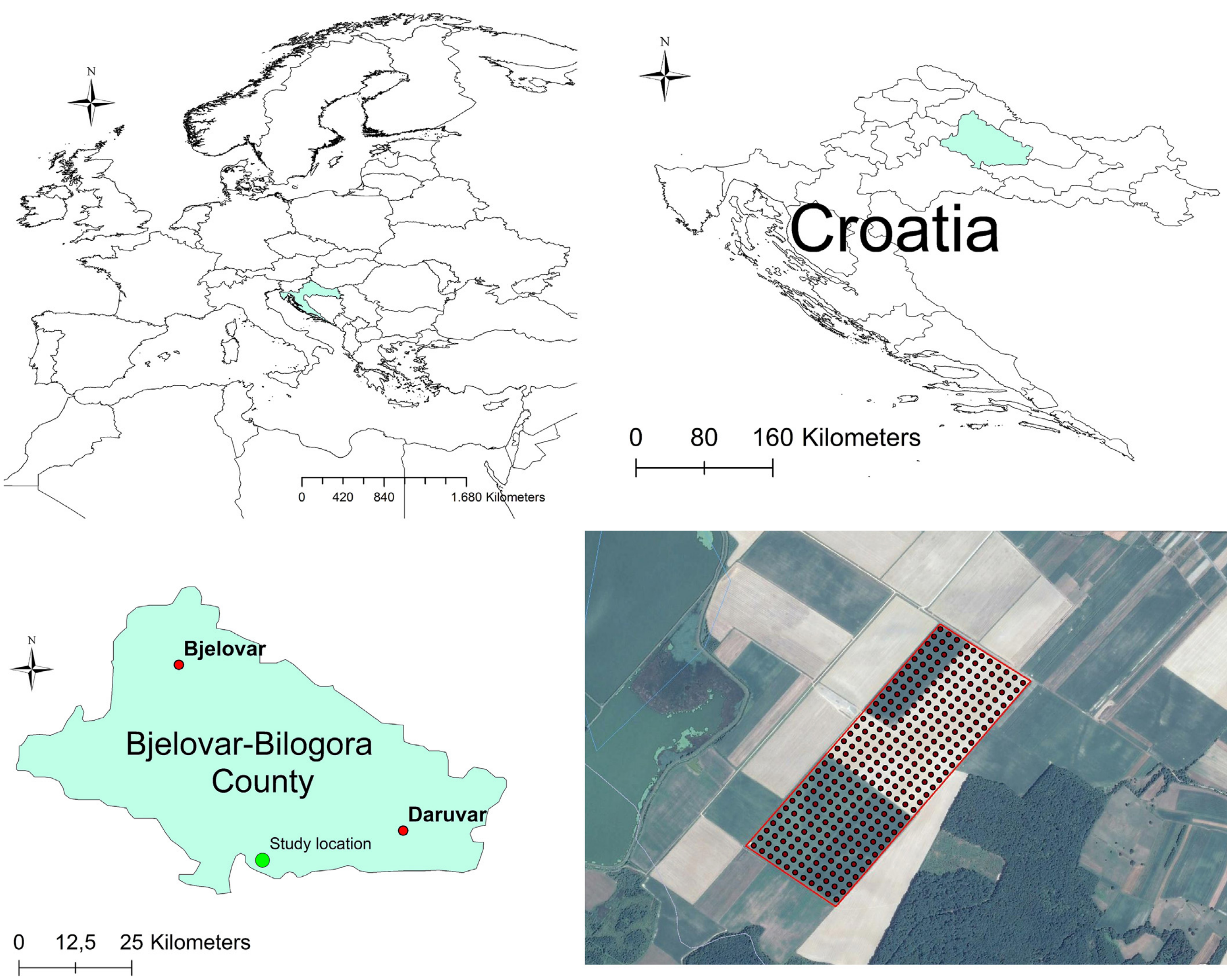

Fig. 1. Study area in Moslavina region, Central Croatia.