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Original article

Geostatistical analysis for predicting soil biological maps under different scenarios of land use

F. Shahbazi*, N. Aliasgharzad, S.A. Ebrahimzad, N. Najafi

Soil Science Department, Faculty of Agriculture, University of Tabriz, Tabriz, East Azarbaijan 5166616471, Iran

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A B S T R A C T

The ArcGIS Geostatistical Analyst aims to effectively bridge the gap between geostatistics and geographical information system analysis by enabling to model spatial phenomena and accurately predicting values within the study area. This approach was conducted to forecast the distribution patterns of some soil biological indices in Mirabad area, North West of Iran. Three different land uses (apple orchard, crop production, and rich pasture) were selected to conduct the experiments in a randomized completely blocks design with five blocks. Soil samples (0–30 cm) were collected on mid July 2010. Soil biological indices i.e. (i) substrate induced respiration, (ii) microbial biomass carbon, (iii) the activity of urease; (iv) alkaline phosphomonoesterase, and also (v) dehydrogenase were determined. *Kriging* and inverse distance weighting methods were applied to assess the spatial variability of five stated indices. Ordinary *kriging* was applied because it is the most general and widely used method. Digital soil biological indices maps will be the last output of integrating geostatistics and geographical information system. The study, while addressing spatial variability of soil biological properties, also discusses the accuracy of modeling as well as spherical model is now distinguished as the best fitted model. Assessing spatial variability of alkaline phosphomonoesterase activity has the lowest accuracy than urease and dehydrogenase activities. The geostatistical results showed that management practices might not have relevant effect on microbial biomass carbon and enzyme activities. But, the statistical analysis revealed significant differences between pasture and two other land uses.

1. Introduction

Understanding about soil healthy and quality can be achieved by information on soil enzyme activities used to determine soil microbiological characteristics [1]. In spite of that soil respiration is a parameter to present the decomposition intensity [2], populations of organisms and respiration rate are two mentioned indicators. Physical and chemical parameters such as soil texture and electrical conductivity compared with biological and ecophysical parameters are not oriented in a short-term [3].

Advanced information technologies in modern software tools such as spatial geostatistics and geographical information system (GIS) enable the integration of large and complex databases, models, tools and techniques, and are proposed to improve the process of soil quality and sustainability. Digital soil mapping and pedometrics are well understood by (i) sampling using statistical methods, (ii) statistical analysis, (iii) predicting soil properties using pedotransfer functions and environmental correlation, (iv) geostatistics, and (v) analyzing uncertainty [4]. Stochastic simulations have been popular for spatial prediction and uncertainty assessment of soil properties in soil science in recent decade [5]. Late in the 1970s, pedologists realized that geostatistics could be employed in soil survey. Pedologists realized that they could also make maps of individual soil properties without having to classify the soil and getting embroiled in all the doubts and controversy [6]. It has been widely used for spatial variability characterization and prediction of some physical properties such as soil water content [7] which has a vital role in hydrological processes such as infiltration and runoff [8]. Spatial variability of nitrogen, phosphorous and potassium for soil fertilization management in Urmia Plain, Iran, has also revealed the better accuracy of *kriging* model [9] as well as its efficiency was reported to predict the spatial topsoil salinity in the Chelif Valley, Algeria [10].

Literature review in relation to soil biological properties confirmed the presence of some investigations such as the effects of distance, land use type and soil properties on structure of soil bacterial and fungal communities e.g. in northern Japan [11]. Reportedly, soil microbes are not randomly distributed, but instead

* Corresponding author. Tel.: +98 411 339 20 56; fax: +98 411 335 60 06.
E-mail address: shahbazi@tabrizu.ac.ir (F. Shahbazi).

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exhibit spatial aggregation [12]. Therefore, geographic assemblages of soil microbial communities should reflect spatial pattern of decomposition activity of organic matter and nutrient mineralization rate at regional scale [13]. Some researchers already include extracellular enzyme activity as a biological indicator when discussing soil quality indicators [14]. Soil enzymes are potential indicators of soil quality because of their relationship to soil biology, ease of measurement, and rapid response to changes in soil management [15]. Almost all soils have enzymatic activity and the amount of activity depends on many factors, including texture [16], organic matter content and nutrient composition of soils [17], soil depth profiles [18], and season [19]. The state of the art of this research work is that this type of soil analysis in this part of the world is rarely used. The main objectives of this research are: (i) design an experiment according to RCBD with five blocks to assess the land uses (apple orchard, crop production, and rich pasture) effects on soil biological properties in the whole study area, (ii) applying geostatistics to find the best modeling approach such as spherical and linear bounded models to predict the spatial variation of some biological indices such as substrate induced respiration (SIR), microbial biomass carbon (MBC), enzymes involved in nitrogen, phosphorus, and intracellular metabolism example given the activity of urease (UA), alkaline phosphomonoesterase (ALPA), and dehydrogenase (DHA), respectively, (iii) fitting models to experimental variograms, (iv) interpolation of selected indices in the study area using popular methods (e.g. *kriging* and inverse distance weighting (*IDW*)) and to compare the applied procedures, (v) integrate the geostatistical results with *GIS* using ArcGIS Geostatistical Analyst to create digital maps of variables and then zoning of the study area to elucidate land uses with respect to biological variables.

2. Materials and methods

2.1. Site description

The study area is located in the western part of Souldoz plain surrounded by Urmieh, Miandoab, Piranshahr and Naghadeh cities in the west Azerbaijan province of Iran, 36°59′N, 45°18′E, within the Universal Transverse Mercator projection (UTM) zone 38S (Fig. 1). Mirabad pasture is a virgin site which has been selected as control. The altitude varies from 1310 to 1345 with average 1325 m above sea level. The monthly average temperature ranges from −1.4 °C in January to 24.6 °C in July and precipitation ranges from 0.9 mm in July to 106.6 mm in March based on recent 25-year period during 1980 till 2006 [20]. The sampling sites were designated as having all three lands use types: apple orchard, crop production, and rich pasture.

2.2. Sampling and characterization of soils

Although triangular sampling for mapping by *kriging* will give the most precise estimates for a given sample density, a rectangular grid is more practicable and is only slightly less efficient [4]. Soil samples were systematically collected from the upper 30 cm of soil at 65 sampling points in the 270 ha (300 × 300 m) on mid July 2010 (Fig. 1). The impact of climatic, geology and geomorphology factors to sampling points is equal. It is widely agreed that only 30–50 paired comparisons are needed which seriously lead to poor estimates. 65 samples were then taken within the nested in the study area. It has been reported that many combination of statistical designs are possible and they can be tailored to ensure efficient sampling of a landscape [21]. Therefore, selected sample size is now

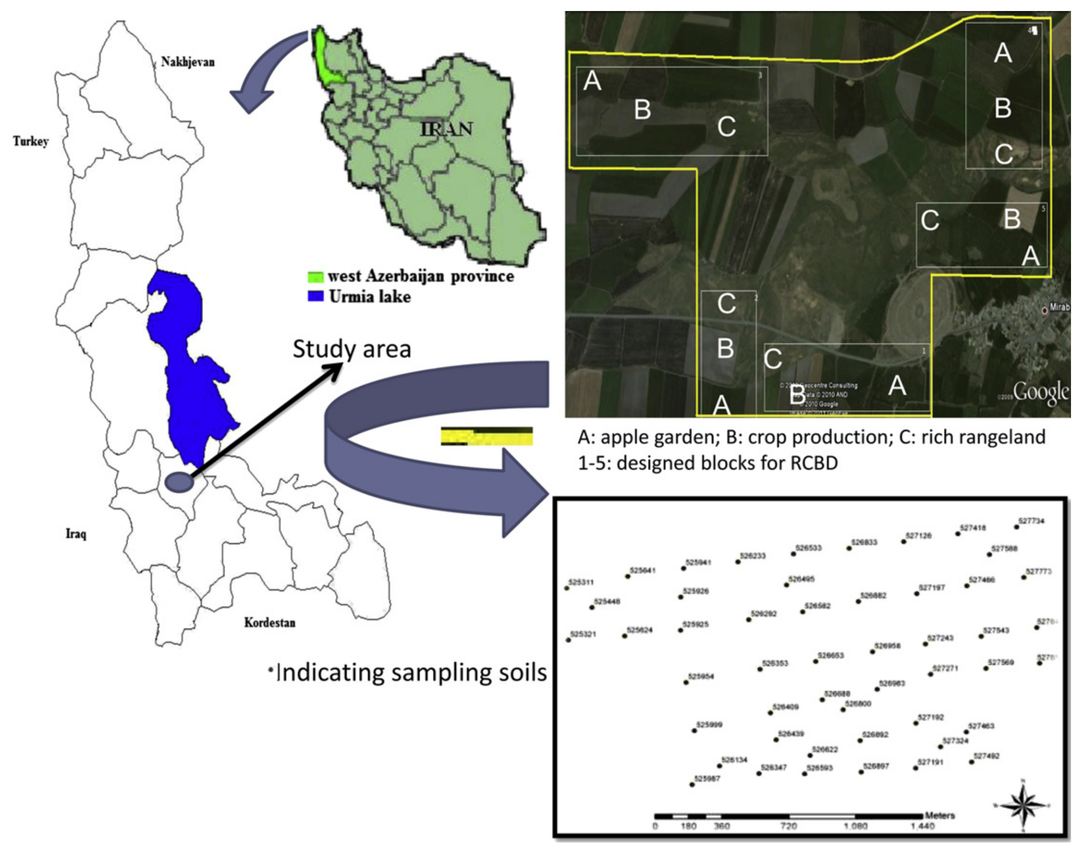

Fig. 1. Map of the study area showing the sampling design.