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Comparison of GIS-based interpolation methods for spatial distribution of soil organic carbon (SOC)

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Abstract The ecological, economical, and agricultural benefits of accurate interpolation of spatial distribution patterns of soil organic carbon (SOC) are well recognized. In the present study, different interpolation techniques in a geographical information system (GIS) environment are analyzed and compared for estimating the spatial variation of SOC at three different soil depths (0–20 cm, 20–40 cm and 40–100 cm) in Medinipur Block, West Bengal, India. Stratified random samples of total 98 soils were collected from different landuse sites including agriculture, scrubland, forest, grassland, and fallow land of the study area. A portable global positioning system (GPS) was used to collect coordinates of each sample site. Five interpolation methods such as inverse distance weighting (IDW), local polynomial interpolation (LPI), radial basis function (RBF), ordinary kriging (OK) and Empirical Bayes kriging (EBK) are used to generate spatial distribution of SOC. SOC is concentrated in forest land and less SOC is observed in bare land. The cross validation is applied to evaluate the accuracy of interpolation methods through coefficient of determination (R^2) and root mean square error (RMSE). The results indicate that OK is superior method with the least RMSE and highest R^2 value for interpolation of SOC spatial distribution.

1. Introduction

Spatial variability of soil organic carbon (SOC) is an important indicator of soil quality, as well as carbon pools in the terrestrial ecosystem and it is important in ecological modeling, environmental prediction, precision agriculture, and natural resources management (Wei et al., 2008; Zhang et al., 2012; Liu et al., 2014). Revealing the characteristics of SOC's spatial pattern will provide the basis for evaluating soil fertility, and assist in the development of sound environmental management policies for agriculture. Scientific management of SOC nutrient is important for its sustainable development in agricultural system. So, there is a need of adequate information about spatio-temporal behavior of SOC over a region. SOC measurements, however, are inherently expensive and time consuming, particularly during the installation phase, which requires soil sampling. Consequently, the number of soil sampling that is

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available in a given area is often relatively sparse and does not reflect the actual level of variation that may be present. Therefore, accurate interpolation of SOC at unsampled locations is needed for better planning and management.

Different statistical and geostatistical approaches have been used in the past to estimate the spatial distribution of SOC (Kumar et al., 2012, 2013). Classical statistics could not make out the spatial allocation of soil properties at the unsampled locations. Geostatistics is an efficient method for the study of spatial allocation of soil characteristics and their inconsistency and reducing the variance of assessment error and execution costs (Saito et al., 2005; Liu et al., 2014; Behera and Shukla, 2015). Earlier researchers have applied geospatial techniques to appraise spatial association in soils and to evaluate the geographical changeability of soil characteristics (Wei et al., 2008). Zare-mehrjardi et al. (2010), reported that ordinary kriging (OK) and cokriging methods were better than inverse distance weighting (IDW) method for prediction of the spatial distribution of soil properties. Robinson and Metternicht (2006) used three different techniques including kriging, IDW and Radial basis function (RBF) for prediction of the levels of the soil salinity, acidity and organic matter. Pang et al. (2011) reported that ordinary kriging is most common type of kriging in practice and provides an estimate of surface maps of soil properties.

Hussain et al. (2014) reported that Empirical Bayes kriging (EBK) is most suitable for spatial prediction of total dissolved solids (TSD) in drinking water. Mirzaei and Sakizadeh (2015) reported that EBK model is best of all the geostatistical models such as OK and IDW for estimation of groundwater contamination.

These five widely used interpolation methods (RBF, IDW, OK, LPI and EBK models) have led to the quest about which is most appropriate in prediction of soil organic carbon in deferent soil depth. Therefore, the objective of this study was to conduct a thorough comparison of the GIS based interpolation techniques for estimating the spatial distribution of SOC in Medinipur Block, West Bengal, India, and apply cross validation to evaluate the accuracy of interpolation method through the root mean square error (RMSE) measurement.

2. Materials and methods

2.1. Study area

The study was conducted in Medinipur block of Paschim Medinipur district in West Bengal (India). It is extended between 22°23′45″N–22°32′50″N latitude and 87°05′40″E–87°31′01″E longitude covering an area of 353 sq km (Fig. 1). The area is dry and the land surface of the block is characterized by red lateritic covered area, flat alluvial and deltaic plains. Extremely rugged topography is seen in the western part of the block and rolling topography is experienced in lateritic covered area (Shit et al., 2013). The maximum temperature recorded in April is 43 °C and minimum temperature is 9 °C. The average annual rainfall is about 1450 mm. Number of rainy days per annum is nearly about 101 days.

2.2. Sampling and estimate of soil properties

A pilot study was conducted to analyze the soil particles under different land use characteristics. Reconnaissance soil survey of Medinipur Block was carried out on 1:50,000 scale during 2014–2015 using the Survey of India (SOI) Toposheets as base maps. The Geo-coded Landsat 4–5 Thematic Mapper (TM) false color composite images were visually and digitally interpreted for physiographic analysis. Land use map was generated based on supervised classification technique using maximum likelihood algorithm technique in ERDAS Imagine software v9.0. The entire block has been classified into eight classes following the forest, fallow land, scrub land, agricultural land, river, sand and settlement area. To validate the classification accuracy, an error matrix table was generated and accuracy assessment analysis was performed. The study of soil profile in all physiographic units was done under different land use to develop soil–physiography relationship. Using the base

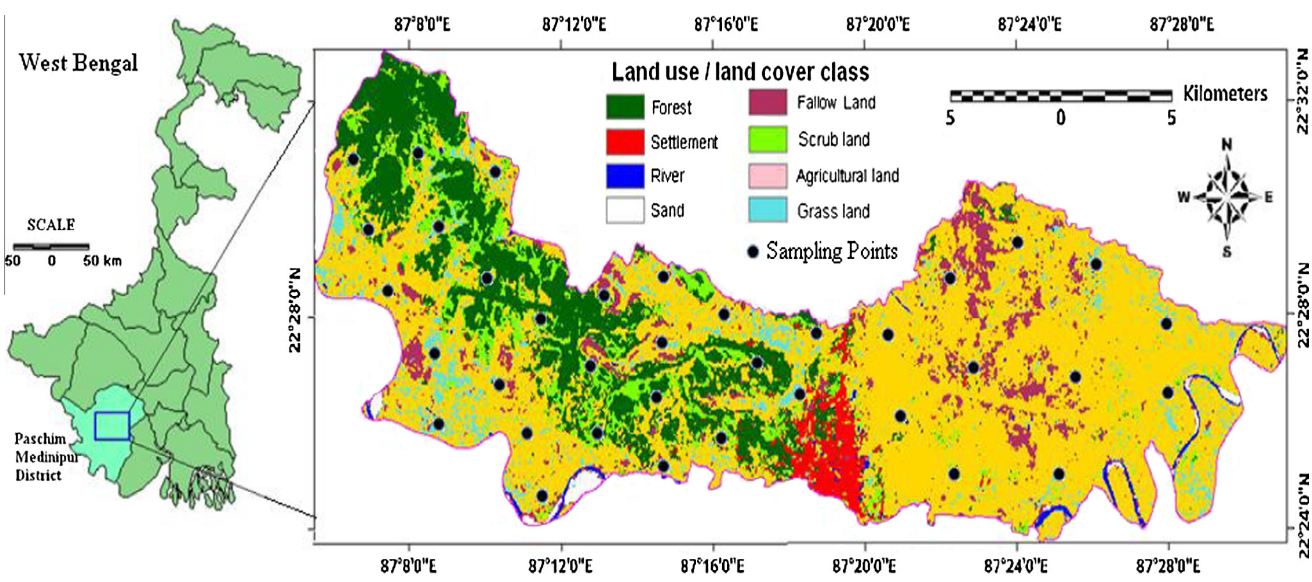

Figure 1 Location of the study area and sampling design with land use land cover of Medinipur block derived from Landsat Thematic Mapper data.

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