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Assessment of spatial variability of soil properties using geospatial techniques for farm level nutrient management

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ABSTRACT

Crop productivity under rainfed farming systems in India is low due to poor water and nutrient management. The available small scale information of soil nutrients is inadequate to effectively manage individual farms held by small and marginal farmers. Large scale spatial variability assessment using grid sampling method is a feasible option to identify critical nutrient deficiency zones. The present study was conducted in a part of semi-arid tropical Deccan plateau region, India, to assess the spatial variability of soil pH, organic carbon (OC), soil available nitrogen (N), phosphorus (P), potassium (K) and sulphur (S). A total of 1508 composite samples (0–15 cm) were collected by adopting 325 × 325 m grid interval (one sample for 10 ha area) and they were analysed for soil fertility parameters. Coefficient of variation (CV) indicated that OC, N, P, K and S were high in heterogeneity (CV > 35%). Moreover, pH, P, K and S were non-normally distributed and log transformation produced normalised dataset. The semivariogram parameters (nugget to sill ratio, range and slope) indicated that the spatial distribution of soil properties were inconsistent. The spatial variability of parameters were mapped by ordinary kriging using exponential (pH and OC) and spherical (N, P, K and S) models selected based on root mean square error (RMSE) and r^2 values. Multi-nutrient deficiencies were observed in most parts of the study area and N was acutely deficient. Farm level nutrient availability status was derived from spatial variability maps and critical nutrient deficiency zones were identified. Nutrient management recommendations based on soil test results were delivered to farmers for adopting need based variable rate of fertilizer application. The generated maps can serve as an effective tool for farm managers and policy makers in site specific nutrient management.

1. Introduction

Indian agriculture is predominantly rainfall dependent and rainfed farming contributes 45% to the total food grain production. Among the total cultivated area of 141 million hectare (M ha), 61% (86 M ha) is under rainfed farming (Srinivasarao et al., 2015). The Deccan plateau covers an area of 0.42 million km^2 in central and southern parts of India and is characterised by semi-arid tropical (SAT) climate (Vasu et al., 2016b). Crop productivity is low in most parts of this region with an average of less than1600 kg ha^{-1} (ICAR, 2011) due to poor water availability and soil fertility (Sahrawat and Wani, 2013). The SAT soils are low in organic carbon (~0.5%) due to oxidation enhanced by hyperthermic soil temperature regime and low biomass addition. They are also low in available nitrogen, phosphorus, potassium and sulphur (Sahrawat et al., 2010). The adverse effect of SAT environment is also pronounced in the form of natural soil degradation indicated by increase in subsoil sodicity (Pal et al., 2016), accelerated soil erosion and multi nutrient deficiency (Chauhan et al., 2014).

In general, the rate of fertilizer application is low under rainfed conditions due to uncertain water availability. The deficiencies of major nutrients are considered important but minimum research effort was made to identify the spatial extent of their deficiencies in SAT soils of India (Sahrawat et al., 2013; Sahrawat, 2016). On-farm soil fertility testing across different states in Indian SAT areas during 2001–2012 showed widespread deficiencies of sulphur (46–96%), phosphorus (21–74%) and nitrogen (11–76%) (Sahrawat et al., 2010). Therefore, diagnosis of nutrient related limitations

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and their management assumes a greater significance to sustain or improve the crop productivity. Assessment of spatial variability of available soil nutrients is a viable option to identify and delineate critical nutrient deficiency zones. This will enable farm managers to strategize site specific nutrient management (SSNM) based on soil and crop requirements.

Large scale mapping was recommended to identify nutrient deficiencies at farm level (Vasuki, 2010). The spatial variability of soil properties can be mapped using interpolation technique (Cambardella and Karlen, 1999). For example, spatial variability of organic matter, pH and potassium were mapped using kriging by Lopez-Granados et al. (2005) in a 40 ha field located in southern Spain. Soil pH, electrical conductivity, organic carbon and exchangeable bases varied highly in acid soils of India (Behera and Shukla, 2015). Using spline method of interpolation, Patil et al. (2011) mapped the spatial variability of organic carbon, available N, P and K of Karlawad village in Dharwad district of Karnataka and found that except K all properties varied to great extent. Thus, geostatistical tools can be effectively used to map soil fertility parameters. However, with fertilizers becoming expensive, farm level information such as farm size, number of crops cultivated in a year, and level of management hold importance in quantifying the farm nutrient use efficiency (Cherry et al., 2012). In the present study, we used farm level information from all the 19 villages of the study area with spatial variability maps for identifying critical nutrient deficiency zones. The study was carried out in a part of Deccan plateau region with the objectives: (i) to assess the status of soil pH, organic carbon, available N, P, K, and S; (ii) to study the spatial variability of soil fertility parameters, and (iii) to identify critical nutrient deficiency zones for site specific nutrient management.

2. Materials and methods

2.1. Study area, soil sampling, and analysis

The study area, Thimmajipet (16° 35′ to 16° 44′ N latitude and 78° 07′ to 78° 18′ 3 E longitude) is located 100 km south from Hyderabad city, and part of Mahabubnagar district, Telangana, India. It comprises of 19 villages, and covers an area of 215 km^2. The total cultivated area is 15,020 ha with 13,123 farm holdings. The average size of farm holding is 1.2 ha and 68% of the farmers belong to small and marginal category (≤2 ha). The major crops grown during southwest monsoon season (June-September) are cotton (*Gossypium hirsutum*), maize (*Zea mays*), pigeon pea (*Cajanus cajan*), sorghum (*Sorghum bicolor*), and castor (*Ricinus communis*). In winter season (October-January), groundnut (*Arachis hypogaea*) is the major crop followed by rice (*Oryza sativa*). The mean temperature is 36 and 25° C during summer and winter, respectively. The mean annual rainfall (MAR) is 550 mm which mostly occurs during southwest monsoon (Vasu et al., 2016a). The data on cultivated area of major crops for both monsoon and winter

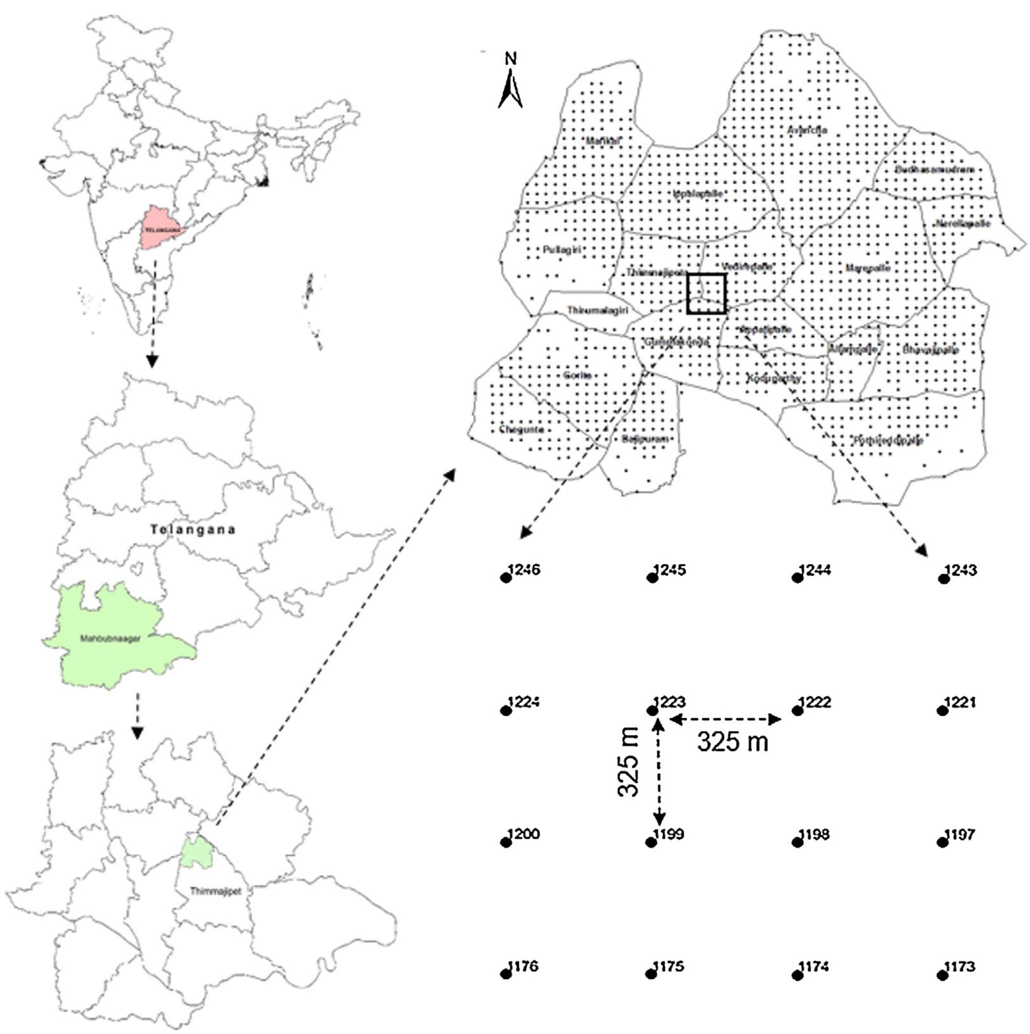

Fig 1. Location of study area and adopted grid sampling scheme.