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A comparative assessment of land suitability evaluation methods for agricultural land use planning at village level

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ABSTRACT

Defining the relationship between soil characteristics and crop requirements must be the first step in planning future agriculture land use. The aim of the present study is to identify the constraints and potentials of major soils in a block of Telangana, India and evaluate them for crop suitability and propose agricultural land use plans (ALUP) at village level. Using IRS P6 LISS IV, Cartosat-I and DEM data, we identified and mapped six soil series through detailed soil survey. Soils varied in depth (< 25 to > 150 cm), texture, water holding capacity, hydraulic conductivity, pH, organic carbon and other inherent properties. We compared parametric, Storie index and multi-criteria land suitability evaluation (MC-LSE) methods for evaluating land suitability for pigeon pea, maize, cotton, groundnut and rice. The land suitability index (LSI) by the three methods varied for three soil series, but for one series, the methods produced similar results for cotton, maize and pigeon pea. The correlation of LSI with crop yield showed that MC-LSE performed better than other two methods. After analysing the LSE results, existing cropping pattern, potential and adaptability of alternate options through participatory interaction with farmers, ALUP for 19 villages of the study area were developed. Moreover, we also discuss the challenges and opportunities in proposing and implementing ALUP in India. The results of the present study will be helpful for farm managers for making the best use of soils based on their suitability. However, to demonstrate the applicability, practicability, and most importantly, the sustainability of proposed ALUP, coordinated implementation strategies are necessary.

1. Introduction

Being integral to all functions of terrestrial ecosystems, soils are intended to produce food for feeding the ever-increasing population of the world (Bouma, 1989; Paustian et al., 2016). “Food and biomass production” is listed first among the seven functions of soils by European Commission in 2006 (Jónsson et al., 2016). However, soils are under prodigious pressure due to competing demands from various sectors of the society in general and diversion of prime arable lands to non – arable uses like urbanisation and industrialisation, in particular (Foley et al., 2011; Erickson et al., 2013). Owing to the exerting pressure, 24% of the total land area is degraded, increasing at an alarming rate of 5–10 million ha per annum (Lal, 2012) and threatens the livelihood of more than 1.5 billion people (Bai et al., 2013; Stavi and Lal, 2015). India supports 17.5% of world’s population with only 2.4% of geographical area and 9% arable lands (Srinivasarao et al., 2015). The largest share of arable land in India has already been put under use and crop-land expansion is not probable as the untilled lands are mostly not suitable for agriculture. Therefore, agricultural land use planning (ALUP) based on the suitability of soils to support different crops in a particular agro-environment is imperative for making the best use of cultivated soils.

ALUP is defined as “systematic assessment of land and water potential, alternatives for land use and economic and social conditions for the purpose of selecting agricultural land use which is sustainable for farmers, without degrading the environment” (FAO, 1996). With climate change taking centre stage in planning future agricultural land use, defining the relationship between soil characteristics and crop requirements must be the first step towards answering sustainability issues (Bonfante and Bouma, 2015). This has been the motivation for systematic soil surveys, soil survey interpretations and mapping of soils (Bouma, 1989, 1994). The use of soil survey information for ALUP received attention in the recent years (Fontes et al., 2009). For example, De la Rosa et al. (2009) used soil survey data for developing ALUP for

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nine benchmark sites in different agro-ecological regions in Sevilla province, Spain. Rhebergen et al. (2016) used soil texture, depth, drainage and water holding capacity along with climate and land use data for evaluating land suitability for oil palm production in Ghana. Thus, recent studies established the value of soil information in evaluating constraints, potential and suitability of land for cultivation of various crops (Yalew et al., 2016; Bonfante and Bouma, 2015; Akinchi et al., 2013). For quantitative land suitability evaluation (LSE), Bonfante and Bouma (2015) suggested using the soil series data as soils of a given series respond similarly to land use and management practices. Moreover, using soil series can be effective for communicating to the farmers as it carries the location specific name for each soil.

The first step in agricultural land use planning is land-suitability evaluation which is defined as “the process of assessment of land performance when used for alternative kinds of agriculture” (He et al., 2011). Many concepts and methods were developed to evaluate the soils from the early 20th century. Among them, land capability classification (LCC) (Klingebiel and Montgomery, 1966), Storie index (SI) (Storie, 1978), FAO land suitability evaluation (FAO, 1976) and Parametric method (Sys et al., 1991) were the most commonly used methods. More recently, LSE methodologies have shifted from broad-based to specific assessment. Elsheikh et al. (2013) developed an automated system (as per FAO framework) that allows land evaluators to build expert systems for land evaluation. GIS based multi-criteria analysis (MCA) method was developed by Nguyen et al. (2015). However, a quantitative procedure, inclusive of all the factors influencing crop production, for evaluating soil series needs to be developed and evaluated. Using a multi-criteria land evaluation method (MC-LSE) proposed by El Baroudy (2016), the present study aims to fill this gap by including most of the inherent properties of soil series in land suitability evaluation for tropical soils of India.

2. Materials and methods

2.1. Description of the study area

The study area Thimmajipet is located between 16° 35′ 13″ to 16° 44′ 31″ N latitude and 78° 07′ 37″ to 78° 18′ 36″ E longitude in Mahabubnagar district, Telangana, India and covers an area of 215.6 km^2 (Fig. 1). The topography comprises of an undulating terrain and the ground surface slope is towards north-eastern direction with micro-topographical variations and intermittent hillocks. The study area forms a part of the stable Dharwar Craton of south Indian shield. It consists of exposed rocks of Peninsular Gneissic Complex (PGC) of Archaean to Paleoproterozoic age, Dharwar super group, Cuddapah supergroup, Kurnool and Bhima groups and also alluvium of basaltic Deccan traps (CGWB, 2013). The PGC, which covers most of the area, is composed of granites, gneisses and migmatites with undigested patches of older metamorphic rocks. Rocks of PGC and Dharwar supergroup are intruded by younger granitoids of tonalite – trondhjermite – grandodiortite composition. These rocks are generally medium to coarse grained and are foliated due to alternate arrangements of minerals and the dimensional orientation of light minerals such as quartz and feldspar (Balakrishnan et al., 1990).

The area falls under agro-ecological subregion 7.2 and characterized by *ustic* soil moisture and *hyperthermic* soil temperature regimes (Mandal et al., 2014). The length of growing period is 120–150 days in a year with medium to high available soil water content. Typically, summer period is from April to June when the temperature ranges from a maximum of 46 °C to a minimum of 27 °C. During winter (December to February), the maximum temperature is around 33 °C and the minimum temperature is 18 °C. The study area is in the rain shadow of the Indian monsoon and the average annual rainfall is around 500–600 mm most of which occurs during southwest monsoon (July–-September). The data for potential evapotranspiration (PET), mean annual rainfall (MAR) and maximum recorded summer temperature over a period (2003–2015) of 13 years were collected from Department of Agriculture, Government of Telangana, Hyderabad (Fig. 2). Thimmajipet comprises of 19 villages. Agriculture is the main occupation and livelihood with 15,020 ha of the cultivated area out of which only 1960 ha (13%) are irrigated with bore-well water. The total number of farm holdings is 13,123. The natural vegetation comprises of Acacia (*Acacia nilotica*); ber (*Ziziphus jujuba*), palas (*Butea monosperma*), buffel grass (*Cenchrus ciliaris*), datura (*Datura stramonium*), teak (*Tectona grandis*), bamboo (*Dendrocalamus calostachyus*), prosopis (*Prosopis juliflora*) and tamarind (*Tamarindus indica*). The major crops grown during monsoon season (June-September) are cotton (*Gossypium hirsutum*), maize (*Zea mays*) followed by rice (*Oryza sativa*), pigeon pea (*Cajanus cajan*), sorghum (*Sorghum bicolor*) and castor (*Ricinus communis*). In *rabi* (October-January) rice is the major crop followed by groundnut (*Arachis hypogaea*), and chillies (*Capsicum annuum*). Sunflower (*Helianthus annus*), tomato (*Solanum lycopersicum*) and watermelon (*Citrullus lanatus*) are grown in patches.

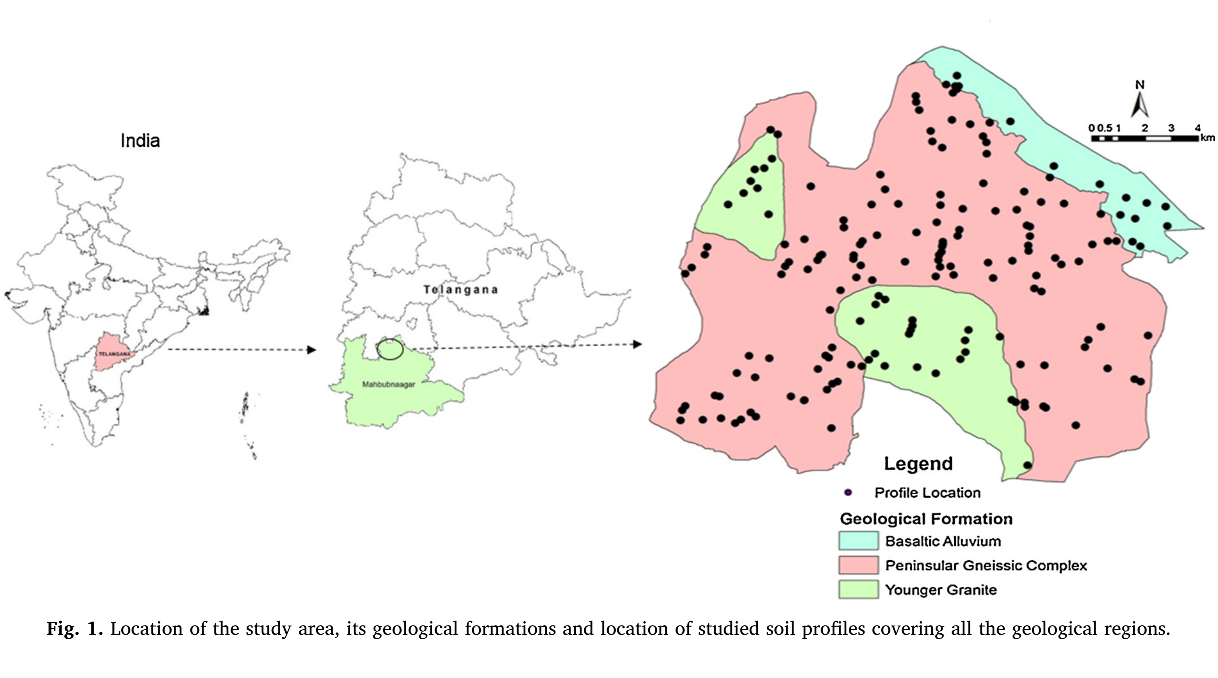

Fig. 1. Location of the study area, its geological formations and location of studied soil profiles covering all the geological regions.