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Soil organic carbon patterns under different land uses in South India

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ABSTRACT

Soil organic carbon (SOC) is the largest terrestrial organic carbon pool; thus, there is a growing interest in its spatial distribution and potential for carbon sequestration. However, our knowledge about spatial distribution in different soil depths and under different land uses is still limited in many regions of the world. The aim of this study was to analyse the soil depth and land use specific SOC contents in a small catchment (6.46 km²) located in the tropical monsoon climate of South India and to determine potential auxiliary variables suitable to derive high resolution maps. A soil survey was carried out, taking 112 soil cores representing three soil depth increments each (< 0.2 m, 0.2 - 0.5 m, and 0.5 - 0.9 m, respectively) and a number of spatially distributed auxiliary variables (slope; curvature; elevation above the next potential irrigation source; water erosion; wetness index; mean NDVI) were determined. The interrelationship between SOC contents and these variables and their principal components were analysed with a combination of an ANCOVA, an iterative linear regression and a multivariate non-linear regression procedure. The mean SOC contents of 3.4 g kg^{-1} (upper 0.9 m) are consistent with large scale data. The more detailed analysis of land use specific differences in SOC contents showed that the sampling points of irrigated arable land had the highest mean contents in topsoil and over the whole measured depth. SOC contents under arable land were followed by those under plantations, forests/shrubland and grassland. Within the different land use categories SOC under arable land declines with increasing elevation above the next potential irrigation source, SOC under grassland is positively correlated with mean NDVI, and SOC under forest/shrubland is best described by variables indirectly related to the accessibility of forest areas. Overall, this study indicates that the commonly used relations to estimate spatial distribution of SOC on larger scales might not be adequate for large areas in South India, which are dominated by pronounced dry and wet seasons, intensive irrigation farming and human-induced forest degradation.

1. Introduction

Soil organic carbon (SOC) is the largest terrestrial organic carbon pool. The latest global SOC map based on the Harmonized World Soil Database (FAO, 2009) was derived by Hiederer and Köchy (2011). It reported global SOC contents of 1417 Gt C in the upper meter and 699 Gt C in the top 0.3 m (Hiederer and Köchy, 2011). Hence, small changes in rates of mineralization of this pool due to climate and/or land use and management change will directly affect atmospheric CO_2 concentrations (Stockmann et al., 2013). For both climate mitigation and amelioration of soil quality and fertility, there is a growing interest in adopted agricultural soil management to stabilize or increase soil SOC contents (Lal, 2007; Stockmann et al., 2013). Moreover, considerable efforts to reduce forest degradation, which leads to a decline in SOC stocks (e.g. Chhabra and Dadhwal, 2004), are taken in many parts of the world.

Despite the improved SOC maps available on the global scale, e.g. Hiederer and Köchy (2011) with a resolution of 30 × 30″, there is still limited knowledge on the small scale SOC patterns in many regions of the world. Today, more detailed SOC maps are mostly available from OECD states where a large number of studies focus on in-field SOC variability (e.g. Bornemann et al., 2010; Dlugoß et al., 2010) or SOC inventories are combined with models to estimate the spatial distribution of SOC in different soil depths (Lacoste et al., 2014; Meersmans et al., 2009). Depending on spatial scale and data availability, different auxiliary variables are used in these studies to estimate the spatial distribution of SOC contents or stocks. On the larger regional to global scale, the spatial distribution of SOC contents (partly stocks) is mostly estimated combining SOC data with typological soil units available in global soil maps (e.g. Hiederer and Köchy, 2011), combinations of soil units with land use information or ecosystem categories (D'Acqui et al., 2007; Don et al., 2011). On smaller scales from single fields to landscape segments, a wide variety of auxiliary variables were successfully tested for 3D SOC mapping. These range from high resolution terrain attributes, geological variables, detailed land use information and soil

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properties to modeled or measured erosional status (Dlugoß et al., 2010; Lacoste et al., 2014; Minasny et al., 2013; Quine and Van Oost, 2007).

In India, considerable efforts have been made over the last decades to provide modern and homogenous soil maps (Harindranath et al., 1999; Krishnan et al., 1996; Natarajan et al., 1996; Shiva Prasad et al., 1996). Despite the well-known relations between land use and SOC contents, most estimates of SOC contents or stocks available in India are based on relations between soil units or groups of soil units from these maps and SOC data (Bhattacharyya et al., 2000). Regional studies focusing on the spatial distribution of SOC in South India are relatively rare (Krishnan et al., 2007) and mostly limited to differences in SOC stocks under forest with different degradation status (Chhabra and Dadhwal, 2004) or effects of land use change on SOC stocks (Jenny and Raychaudhuri, 1960). Generally, it can be concluded from these land use change studies in India as well as from more extensive meta-analyses in the tropics (Don et al., 2011) that SOC contents or stocks decline from primary forest to grassland and to cropland. Besides these soil degradation studies, which allow addressing some spatial variation in SOC stocks, there is a large number of recent studies from India dealing with SOC contents in different agricultural regions and the potential benefits from SOC sequestration due to adopted agricultural soil management (Brar et al., 2013; FAO, 2004; Pathak et al., 2011; Srinivasarao et al., 2013). However, studies focusing on more small-scale patterns in SOC contents within small catchments with different land uses, which also take different soil depths into account, are to our knowledge missing. Nevertheless, soil depth-specific spatial SOC patterns are of major importance to understand processes of carbon sequestration on the landscape scale affected by the different carbon saturation status of soils (Qin et al., 2013; Wiesmeier et al., 2013).

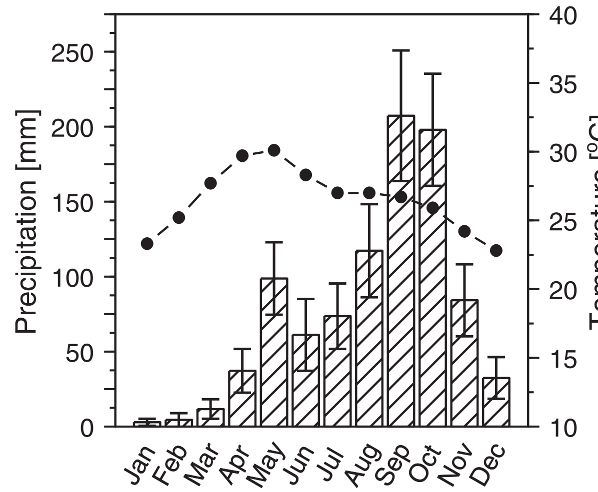

Fig. 2. Long-term (1981–2011) monthly precipitation measured in a distance of 4 km from the test site at the Krishnagiri reservoir; error bars give 95% confidence intervals; mean monthly temperatures taken from climate-data.org (Anon., 2013).

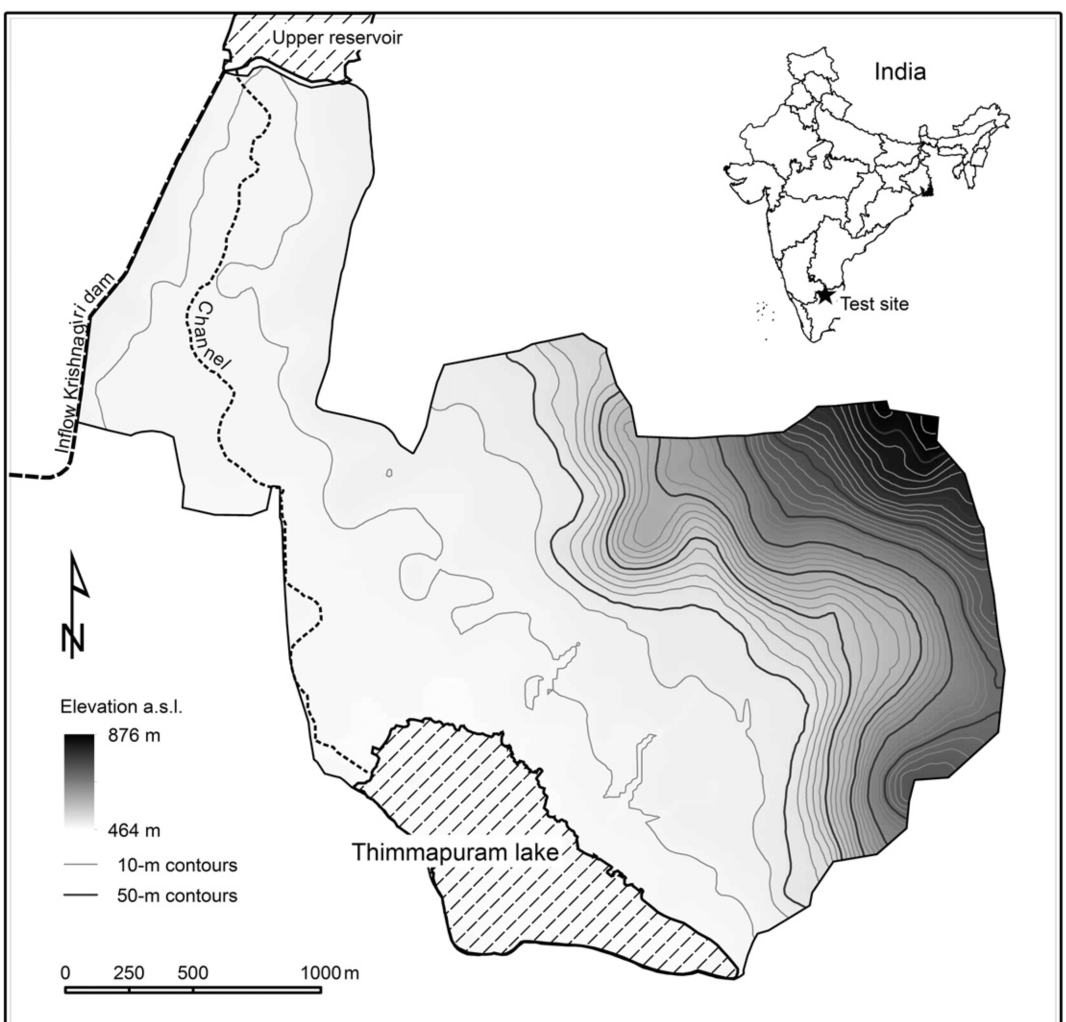

Fig. 1. Computed extent of the test catchment with topography and hydrological situation.