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RESEARCH PAPER

Estimation of accumulated soil organic carbon stock in tropical forest using geospatial strategy

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Regression analysis

Abstract Soil organic carbon (SOC) is a dynamic soil property that represents the key component of the forest ecosystems. The main objective of the present study is to evaluate SOC using the remote sensing images as well as field methods at Ranthambhore Tiger Reserve Forest area. The soil samples were collected randomly from the region at several field locations, to estimate the surface soil carbon concentrations in the laboratory. The study derived results for bare soil index, NDVI, SOC and relationship of SOC with NDVI using regression analysis, while comparing reference SOC (field measured SOC) and predicted SOC (estimated from satellite image). The remote sensing images were used to predict the precise carbon content associated with organic matter in the soil using NDVI and related equations, to prepare digital soil organic carbon map. The relationship between the NDVI and both reference/predicted SOC is established using the equation to derive the digital SOC for the study area using remote sensing data. The statistical relationship between reference SOC, pH concentrations, and NDVI values were presented against the predicted SOC to provide the variation between each variable.

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1. Introduction

Forest ecosystem has a high carbon density and is considered to have a considerable potential as carbon sinks (Halliday et al., 2003; Perruchoud et al., 1999) containing about 80% of terrestrial above ground carbon on one hand and more than 70% of all soil organic carbon on the other (Batjes, 1996; Jobbágy and Jackson, 2000). The soil carbon is almost three times that in the aboveground biomass and about double that in the atmosphere. Reliable estimates have been difficult to obtain due to a lack of global information on varieties of soils and the amount of soil carbon in each territory (Eswaran et al., 1993). Soil carbon adds up to the principal terrestrial pool of carbon playing considerable function in the universal carbon cycle. Forest is a natal unit having a gargantuan social organisation of living communities at work. The quantity of carbon exchanged between the forest and the atmosphere in the form of CO_2 via photosynthesis and respiration was found to be seven times the anthropogenic carbon emission. An increase in soil respiration increases the CO_2 emission from forest ecosystems. The soil organic matter on the surface is directly related to the carbon input. Forests present considerable resources and carbon storage put to one side of the earth's surface, where soil store carbon double and triple the amount of carbon in above ground biomass and available in the atmosphere (Kumar et al., 2013).

In the forest, the different tree species have a different outcome along the carbon storage of ecosystem, for example superficial rooting coniferous species tend to accumulate Soil Organic Matter (SOM) in the forest floor, but are low in the mineral soil, compared with deciduous trees (Jandl et al., 2007). At identical biomass volumes, trees with a high wood density such as deciduous tree species, accumulate more carbon than trees with light wood like Coniferous tree species i.e. pines (de Vries et al., 2002; Fissore et al., 2008; Jandl et al., 2007). Moreover, the boreal forests accumulate carbon in woody biomass as well as in litter, coarse woody debris, and peat (Kurbanov, 2000). Fissore et al., 2008 demonstrated that the SOC rate in quality and in terms of quantity may have decreasing trends in response to global heating, instead of soil decomposing favouring conditions of soil chemistry.

The balance between the carbon input by the forest and microorganism determines the soil carbon pool. Soil organic carbon is the amount of carbon present in the organic matter of the soil. Soil organic matter includes all the material of biological origin found in soil like plant residues, living roots, biological organism, and decomposing, decomposed or burnt material of varying sizes. The amount of soil organic carbon has direct relation with the crop productivity, fertility, soil type, physical characteristics and health of vegetation as well to list. Soil organic carbon is the largest terrestrial carbon pool playing as a key variable in the estimation of the terrestrial carbon dynamics. Whenever the organic matter is decomposed it releases some amount of carbon dioxide (CO_2) in the atmosphere. There is always a cycle of entry and exit of the amount of carbon between the terrestrial ecosystem and the atmosphere, making variable amount or level of carbon content in the soil (Fung et al., 2007; Hese et al., 2005; Houghton, 2005; IPCC, 2014; Penman et al., 2003; Ramankutty et al., 2007). Hence, soil carbon acts as a major determinant of the amount of CO_2 released into the atmosphere.

Soil acts as a source or sink of greenhouse gases like CO_2, CH_4, N_2O etc., depending on the management and land use (Lal, 1999). Further, CO_2 that forms a part of chemical processes, also controls the pH value of the soil as well as Soil Inorganic Carbon (SIC). The spatial pattern of the SIC is basically controlled by chemical and physical processes of the soil formation while biotic processes drive the spatial pattern of the SOC (Shi et al., 2012). Previous studies have shown the relationship of temperature and precipitation with inorganic carbon of the soil (Li et al., 2007; Mi et al., 2008; Yang et al., 2010). The negative correlation between the pH and SOC is also confirmed in the studies (McIntosh and Allen, 1993; Shi et al., 2012), concluding that acidified soil inhibits the decomposition of SOC, thus avoids loss of carbon from the soil to the atmosphere (Shi et al., 2012). This is further confirmed that soil pH declines when soil organic carbon increases under Hieracium species (also known as the *hawkweed*) in New Zealand (McIntosh and Allen, 1993). There is also a reporting of positive correlation of SOC quality to pH, but negatively related to cation exchange capacity CEC (Fissore et al., 2008). They also provided that the SOC quality varies according to mean annual temperature and forest types, and is well studied along the forest in North America. As discussed above, SOC is related to soil chemistry (chemical or physical), its concentration varies with silt, clay (not sand), and pH. SOC is also correlated with temperature, rainfall, and forest types and SOC concentration decreases exponentially with the time period (1987–2001) in the extensive cultivation conditions in agricultural regions, while the modeled SOC remains stable in that time period (1987–2001) as demonstrated by Brye et al. (2004).

Previously, SOC was determined using the visible and infrared channels of hyperspectral images with a field spectrometer to match the spectra of field and satellite images (Gomez, 2008). The Indian terrestrial ecosystem has variant carbon source and sink due to varied land use, land cover management, monsoon based climate and so on due to which the ecosystem is spatially and temporarily variable. The soil carbon is estimated for the Amazon forests, Boreal forests, tropical forest, coniferous forest, etc. using either field investigations or remote sensing applications (Davidson et al., 2008: Frolking et al., 1999; Cochrane et al., 1999; Gupta et al., 2014). Land use, land cover, climate, soil texture, topography, hydrology and other primary variables influence the production as well as decomposition process of soil carbon stocks (Houghton and Hackler, 1999; IPCC, 2014; Rani et al., 2011; Righelato and Spracklen, 2007). The recent advances in remote sensing and mapping have helped in detailed mapping of soil organic carbon, in analyzing soil properties its characteristics and heterogeneity of soil.

There are studies related to digital soil mapping (Abdel-Kader, 2011; Ismail and Yacoub, 2012) to predict the soil distribution in reference to soil maps and field data. These types of studies can be used to evaluate the variation in soil properties (Ali and Moghanm, 2013) using the remote sensing techniques. These digital soil mappings were also used to assess the soil degradation (El Baroudy and Moghanm, 2014) which may affect the soil productivity (Abdel Kawy and Ali, 2012). The assessment and digital soil mapping along with soil organic carbon is not only important for soil protection, assessing forest canopy density, but also for strategies to mitigate global warming, (Cochrane et al., 1999; Davidson et al., 2008; Houghton et al., 2000; Hirsch et al., 2004;