Catena 166 (2018) 171–180

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Soil organic carbon pool changes in relation to slope position and land-use in Indian lower Himalayas

Pritpal Singh[*], Dinesh K. Benbi

Department of Soil Science, Punjab Agricultural University, Ludhiana, India

ARTICLE INFO

Keywords:
C sequestration
Soil erosion
Labile C
Recalcitrant C
Grasslands
Croplands
Land-use
Macro-aggregates

ABSTRACT

The increase in the atmospheric abundance of CO_2 has raised interest in the potential of soils to sequester carbon (C), which inter alia depends on antecedent C level. While inventories of soil organic carbon (SOC) have been developed for different ecosystems at field or global scales, studies at hill-slope level where SOC redistributes by erosion remain scarce. In addition, quantitative information on the variation in SOC stocks and organic matter quality within hill-slopes would allow to make more realistic estimations of the C sequestration potential of landscapes while suggesting improved land management. The main objective of this study was to evaluate the impact of slope position and land-use (grassland versus cropland) on SOC stocks and organic matter quality (proportion of aggregate associated C and labile pools; water extractable, WEOC; hot water soluble, HWC; potassium permanganate oxidizable, $KMnO_4$-C; microbial biomass, MBC). A total of 108 soil samples from the 0–0.15 m layer were collected from 4 slope positions (forested hilltops, middle slope with bare soils, backslopes under grasslands, cropped bottomlands) at nine catenas with 3 replicates per position. The greatest SOC stocks were found at hilltops and backslopes with respectively 10.1 ± 0.64 and 10.1 ± 0.57 Mg C ha^{-1}. SOC stocks decreased by 17% to 8.4 ± 0.65 Mg C ha^{-1} in bottomlands and by 58% to 4.2 ± 0.26 Mg C ha^{-1} at backslopes. The soil organic matter from the hilltops showed the greatest proportion of recalcitrant components (62%) followed by the backslope and bottomland positions with ~42%, and middle slope position with 9%. In addition to showing a greater occurrence of labile C fractions, bare and eroded backslope soils were also depleted in water soluble C (WEOC and HWC), $KMnO_4$-C and microbial biomass C. The results showed that there is considerable potential for C sequestration at middle and backslope position through land rehabilitation by either planting trees or vegetation by grass.

1. Introduction

The atmospheric concentration of carbon dioxide (CO_2) has increased globally by 47% from 278 parts per million (ppm) in the pre-industrial era to 409 ppm in 2017 (NOAA, 2017). During 2002–2011, the atmospheric concentration of CO_2 increased at a rate (2 ppm $year^{-1}$) higher than any previous decade since direct measurements of atmospheric concentration commenced (Ciais et al., 2013). Increasing concentration of CO_2 is forcing global climate change; and efforts are being made to stabilize the atmospheric abundance of CO_2. A number of strategies have been advocated and are being implemented to achieve this goal, which inter alia include C sequestration in soil and vegetation (Nieder and Benbi, 2008). The rate and magnitude of C sequestration in soil besides depending on soil properties, climatic conditions, land-use and management is influenced to a great extent by antecedent C level. In the last three decades, several studies have enumerated the effect of agricultural management on organic matter turnover and soil's feed-back to global climate change. A number of management practices including intensification of agriculture, no-till farming, planting of cover crops, improved nutrient management and crop residue recycling have been recommended for enhanced soil C sequestration (Lal, 2004; Powlson et al., 2011); and estimates have been made for C sequestration potential from these activities (Follett et al., 2000; Smith, 2004). However, the realizable potential for C sequestration in soils may be much less than that estimated because of the effect of existing soil organic C (SOC) level and the soil's capacity to store C. Therefore, an assessment of SOC content and stocks is imperative for evaluation of C sequestration potential of soils (Batjes, 1996; Eswaran et al., 1993). While several studies have investigated the distribution of soil carbon and SOC stock changes in different ecosystems at a range of scales such as field scale (Paustian et al., 1992; Smith et al., 1997; Schelsinger and Lichter, 2001), regional, sub-national and national scales (Arrouays et al., 2001; Bonfatti et al., 2016; Jones et al., 2005; Milne et al., 2007), studies at hill-slope level remain scarce. This

---

[*] Corresponding author at: Krishi Vigyan Kendra, Khokhar Khurd, Mansa, Punjab 151 501, India.
E-mail address: jasppsingh@gmail.com (P. Singh).

https://doi.org/10.1016/j.catena.2018.04.006
Received 11 July 2017; Received in revised form 28 March 2018; Accepted 4 April 2018

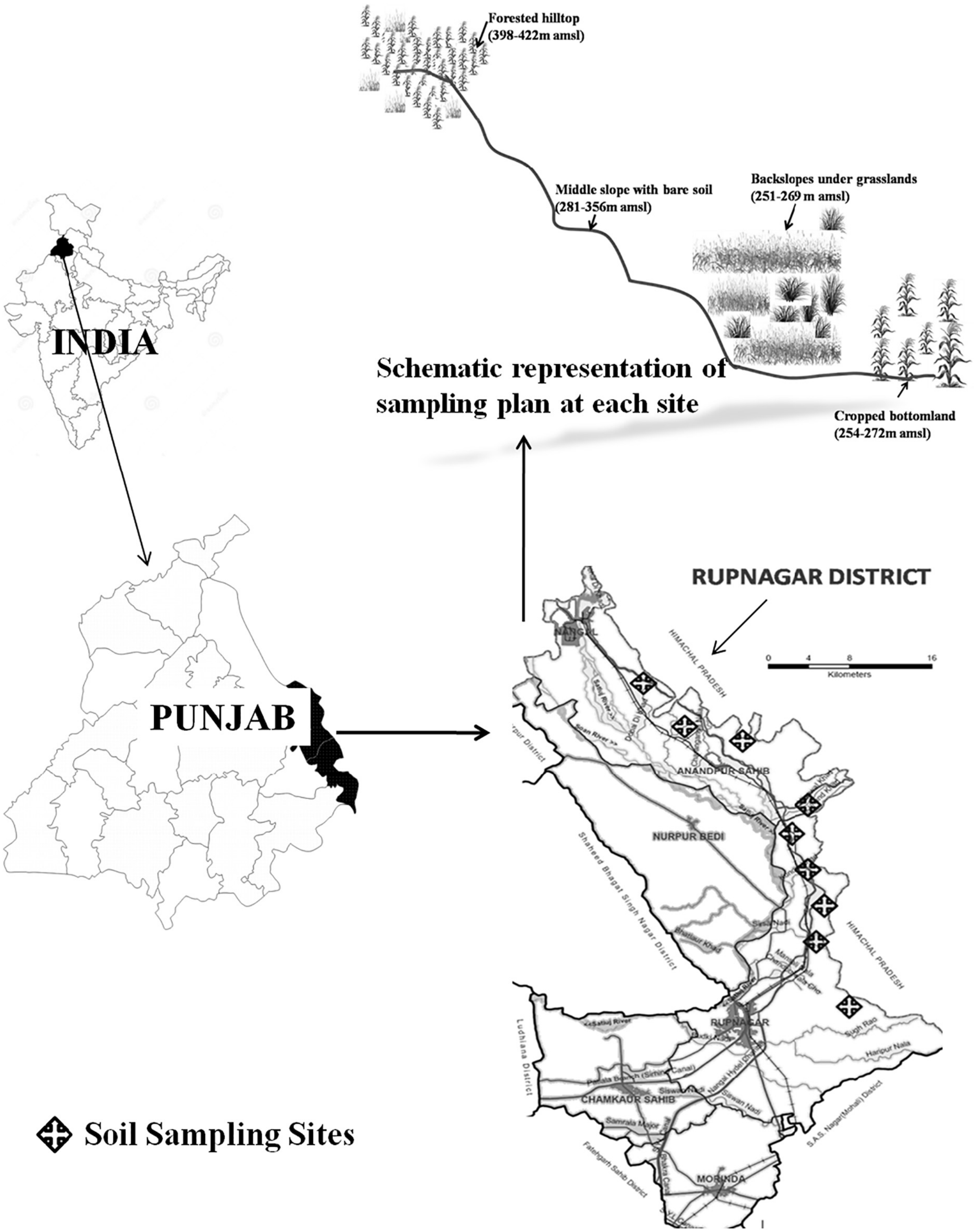

Fig. 1. Soil sampling sites and schematic representation of sampling plan at typical hill-slopes in the *Siwalik* foothills of Punjab, India.

could lead to large uncertainties in estimates of regional SOC stocks. Studies at the field scale use site-specific data in relatively homogenous conditions and have limited wider applicability. Studies at large scale such as Chaplot et al. (2010) in Laos showed that SOC stocks are significantly affected by land-use, rainfall and hill-slope level. On sloping landscapes, considerable amounts of SOC, especially black carbon are lost by water erosion (Chaplot et al., 2005). Landscape level differences in soil C in relation to land cover and topography in the eastern US showed that effects of topography were usually secondary to those of land cover (Garten and Ashwood, 2002).

Spatial distribution of SOC vary widely across landscapes leading to large uncertainties in the SOC budget especially for mountainous landscapes susceptible to erosion where a tight coupling between geomorphic processes and soil C turnover exists (Doetterl et al., 2012). Combining anisotropy analysis with discrete wavelet transform, Guo et al. (2018) observed that topography and local climate may have a strong influence in controlling SOM spatial distribution in mountain regions. Organic C storage and loss from soil depends on soil type (Six