Soil & Tillage Research 163 (2016) 176–184

Contents lists available at ScienceDirect

Soil & Tillage Research

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

Soil organic carbon and total nitrogen stocks under different land uses in a hilly ecological restoration area of North China

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ARTICLE INFO

Article history:
Received 3 November 2015
Received in revised form 16 January 2016
Accepted 18 May 2016
Available online 20 June 2016

Keywords:
Soil organic carbon
Soil total nitrogen
Soil depth
Land use
Litter biomass
Bulk density

ABSTRACT

In hilly area of North China, massive deforestation of natural forests and extensive use of agricultural lands have resulted in severe soil degradation. Soil organic carbon (SOC) and total nitrogen (STN) are crucial to soil quality. However, knowledge on the efficiency of changes in SOC under various land uses in these areas is very limited. To address this problem, a study was conducted in Songjiagou Catchment of Mount. Taiyue to evaluate the impact of land use change on SOC sequestration and STN accumulation. The results showed that compared with cropland, the SOC stock of shrub land was 10.8% higher and that of forestland 39.8% higher. Comparative values were 55.9% and 64.7% higher for nitrogen accumulation over the entire soil profile. Among that, the topsoil layer in cropland contained 40.7% of the SOC stock and this layer of the secondary shrub 43.6%. It appears that inappropriate tillage practices and anthropogenic disturbances imply a considerable loss of carbon sequestration. Ground litter biomass and live biomass were considered as the main influence factors of STN and SOC variance in surface soil. As well, soil properties, such as bulk density and pH value, were found to have significant and negative effect on SOC and STN concentrations. Therefore, we conclude that the change of land use from cropland to secondary shrub and restoration of forest plantation can improve SOC and STN concentrations and stocks.

1. Introduction

Soil is the largest terrestrial pool of organic carbon (IPCC, 2007). Slightly changes in the soil organic carbon stock (SOC) could cause significant impacts on the atmospheric carbon concentration (Davidson and Janssens, 2006). SOC pool may greatly change response to a host of potential environmental and anthropogenic driving factors (Stockmann et al., 2013). Besides, SOC and total nitrogen (STN) can provide nutrients for plant growth and maintain good soil physical structure. Therefore, the research of SOC and STN concentration and stock is essential in increasing crop productivity and alleviating carbon emissions.

The role of land use in stabilizing CO_2 levels and increasing carbon sink potentials of soils have attracted considerable scientific attention in the recent years (Kumar and Nair, 2011; Arnhold et al., 2015; Fu et al., 2010). Under the changes in land management, soil has historically played the roles of both source and sink of carbon (Torbert et al., 1997). Specifically, it has been well demonstrated that the SOC stock of ecosystem was significantly affected by the land use/cover change especially to agriculture activities (Wu et al., 2003; Gelaw et al., 2014; Gao et al., 2015), deforestation (Kucuker et al., 2015; Fujisaki et al., 2015), afforestation (Bárcena et al., 2014; Omonode and Vyn, 2006). As a summary, most of these studies have largely focused on SOC variability under different land uses and soil depth in horizon and vertical layers. The SOC stocks of forest lands were higher than that in cropland in humid tropics or drought loess region (Fujisaki et al., 2015; Zhang et al., 2013). However, there is still great uncertainty in these studies about the response of SOC to human practices in semi-humid hilly area.

Soil carbon and nitrogen stock can be affected by land use as the result of the different input quantity of organic matter (Gelaw et al., 2014; Kong et al., 2005; Yu et al., 2014; Cambardella and Elliott, 1994) and canopy structure (Finzi et al., 1998), as well as by soil physical (Sakin, 2014; Jiao et al., 2011) and chemical properties (Six and Paustian, 2014). For example, it was found that the carbon stocks in topsoil were lower in agricultural systems compared with the adjacent primary forest in Amazonia for less litter biomass input (Schroth et al., 2002). Gelaw et al. (2014) pointed that SOC under canopies was higher than those outside the tree canopies.

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http://dx.doi.org/10.1016/j.still.2016.05.015
0167-1987/

Enideg (2008) estimated 46.7 and 23.0% higher surface and subsurface SOC content compared to those beyond the canopy zones in a *Ficus thonningii* forest in Gondar district, Northwestern Ethiopia. These studies show that vegetation canopy is a non-negligible factor affecting SOC as well as forest floor. On the other hand, the soil physical properties also influence SOC by affecting soil moisture content, bulk density, aggregate particle-size fractions and soil microbes, etc. (Six and Paustian, 2014; Wei et al., 2014; Sakin, 2014). In general, land use and agricultural management impact on SOC and STN in different ways. Previous studies have given evidences that the effect of individual factors on soil organic carbon, but less attention paid synthetically to environment factors (Stockmann et al., 2013). Therefore, understanding the comprehensive effect of environmental factors on SOC depend on land use change is necessary and indispensable.

Songjiagou catchment once belonged to hilly regions of Loess Plateau, well known for its long agricultural history and land degradation. It has experienced remarkable changes in land use since the 1950s (Zhang et al., 2013). Historically, the native vegetation was destroyed to meet the food supply needs of an expanding population, thereby resulting in severe land degradation (Fu et al., 2010). Compared with the non-cultivated soils, a reduction of 10% to 40% of SOC in cultivated soils had been reported in China with the highest losses experienced in the semi-arid and sub-humid areas (Wu et al., 2003). For restoration vegetation, considerable work has been performed by the Chinese government since the 1950s. The most important extensive reforestation project was the long term, policy-driven "Grain-for-Green" eco-restoration program since 1970s. Subsequently, a series of national conservation projects were launched in 1999, focusing on ecological restoration. As a result of land cover change, the efficacy of these restoration strategies for increasing SOC have not yet been fully elucidated in semi-humid hilly area in North China (Powlson et al., 2012; O'Connell et al., 2016). Thus, it is therefore important to understand the synthetic influence of SOC difference driven by land cover changes in order to assess the regional carbon budget andto improve SOC sequestration.

The objectives of this study were to (1) estimate SOC and STN concentrations and stocks under different land uses across soil depth in this region; (2) assess the relative importance of canopy structure, biomass characteristic, and soil physical properties affecting on SOC and STN.

2. Materials and methods

2.1. Site description

Field measurements for the indicators were carried out in Songjiagou catchment (36°31′–36°44′N, 112°15′–112°33′E)at Maquan Forestry Centre of Taiyue ForestBureau, Shanxi Province (Fig. 1). The study site has an area of 12.8 km^2, an elevation ranging from 1043 to 1350m. There are forestland (47.5%), secondary shrub

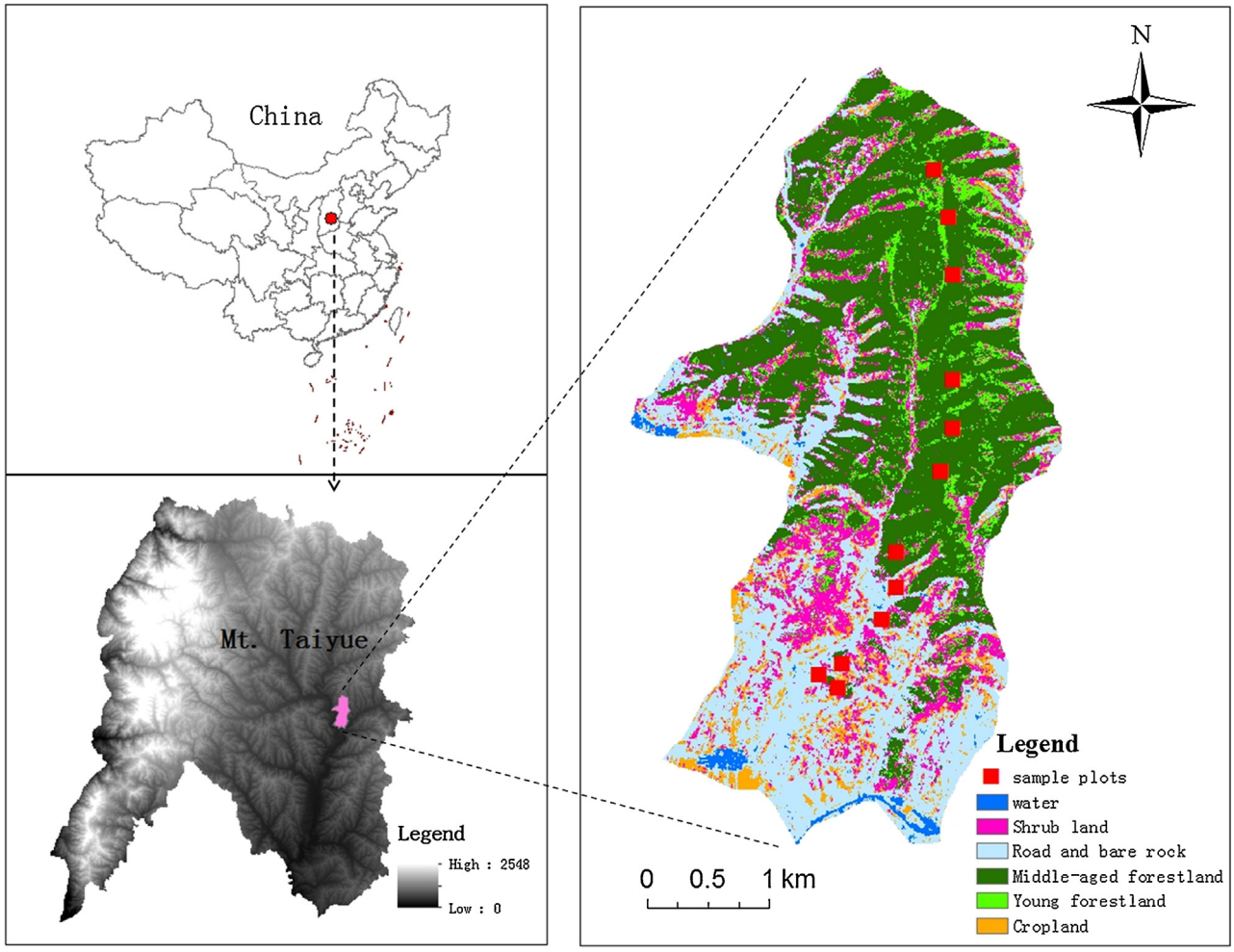

Fig. 1. Location of the study area and sampling points: (a) location of Mt. Taiyue; (b) location of the study area at the Mt. Taiyue Forestry Bureau; (c) distribution of main land use types and sampling points in the Songjiagou catchment.