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Impact of land use change on profile distributions of soil organic carbon fractions in the Yanqi Basin

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ABSTRACT

Land use change is recognized as one important driving force for soil organic carbon (SOC) dynamics. The arid regions in China have experienced significant land use changes over the past decades. A study was carried out to evaluate the impacts of land use change on SOC fractions in the Yanqi Basin, northwest China. Soil samples were collected from 24 profiles in cropland and native land, and labile, semi-labile, and recalcitrant organic carbon were measured. All SOC fractions showed a gradual decrease with depth over the 0–100 cm in the native land. However, SOC fractions in the cropland revealed uniform distributions over the 0–30 cm and 30–100 cm. On average, labile, semi-labile, and recalcitrant carbon contents in the cropland were 2.2 ± 0.3 (1.3 ± 0.4), 1.5 ± 0.4 (0.7 ± 0.3), and 8.5 ± 2.0 (3.1 ± 1.8) g kg^{-1} over the 0–30 cm (30–100 cm), respectively. Converting native land to cropland resulted in significant increases of recalcitrant (2.0 kg m^{-2}), semi-labile (0.3 kg m^{-2}), and labile carbon (0.3 kg m^{-2}) over the 0–30 cm. The proportion of recalcitrant SOC stock increased from 59.9% in the native land to 64.8% in the cropland. This study suggests that converting native land to cropland in arid region not only enhances SOC stocks but also leads to longer-term SOC storage.

1. Introduction

Soil organic carbon (SOC), the largest carbon pool on land, plays an important role in the global carbon cycle. The global SOC pool is proximately 1500 Pg C in the top 1 m, which is two times of the global terrestrial biomass (Amundson, 2001; Jobbágy and Jackson, 2000). Thus, small changes in the SOC stock may have large impacts on the atmospheric CO_2 concentration. Therefore, the stability of SOC is critical to the global carbon cycle and climate change (Belay-Tedla et al., 2009).

Soil organic carbon dynamics is determined by the balance between inputs (e.g., addition of plant residues) and outputs (e.g., SOC decomposition), which is influenced by many factors, such as climate conditions, soil properties, and land use management (Jobbágy and Jackson, 2000; Wang et al., 2001). Temperature has a large effect on both carbon fixation and SOC decomposition in humid climate zones whereas precipitation constrains plant growth (thus carbon inputs) and SOC decomposition in arid regions (Jobbágy and Jackson, 2000). Soil properties, especially texture can affect SOC decomposition because clay may act as aggregates by binding particles together, which provides physical protection (Bronick and Lal, 2005). On the other hand, land use change may impact SOC dynamics by changing the rates of carbon inputs and decomposition of SOC in soil (Li et al., 2010; Poeplau et al., 2011).

In addition to these external factors, SOC stability is also influenced by the chemical structure of SOC, which is a heterogeneous mixture of compounds with various turnover times (Krull et al., 2003; Parton et al., 1987). Generally, SOC pool can be chemically divided into labile, semi-labile, and recalcitrant pools that have different sensitivities to changes of environmental conditions (Parton et al., 1987; Rovira and Vallejo, 2002). For example, labile pool is more active and sensitive to physical and chemical disturbances than other fractions (Purakayastha et al., 2007; Zhang et al., 2012). Changes in SOC fractions may provide an early indicator of changes in total SOC (Banger et al., 2009).

There has been evidence of land use change impacts on SOC dynamics. For instance, a few studies indicated that converting lands with native vegetation (i.e. forest and pasture) to cropland resulted in loss of SOC in tropical and temperate humid regions (Del Grosso et al., 2009; Dinesh et al., 2003; Post and Kwon, 2000; Wang et al., 2001). However, some other studies in arid regions showed different results. For example, Fallahzade and Hajabbasi (2012) reported that SOC content increased 3–7 times for the upper 30 cm after converting desert land to cropland in arid land of the Central Iran. Cochran et al. (2007) suggested that converting shrub land to cropland increased labile and semi-labile SOC fractions in the 0–20 cm in a semi-arid region of the Columbia Basin. Zhang et al. (2012) also showed that conversion from desert steppe to

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arable land led to an increase in total SOC stock and labile SOC stock after 50 years cultivation in the Longzhong region of Loess Plateau, China.

Here, we present a study carried out in a typical arid area, the Yanqi Basin that is located in Xinjiang, northwest China. There have been land use changes since 1950, i.e., converting native land to cropland. We collected soil samples from 1 m soil profiles in both native land and cropland, and determined labile, semi-labile, and recalcitrant SOC fractions. The objective of our study is to examine the vertical distributions of SOC fractions, and to evaluate the impacts of land use change.

2. Material and methods

2.1. Experimental site

The Yanqi Basin (41°53′–42°51′N, 86°46′–85°08′E, 1037–1339 m in altitude) is in a transition region between the northern and the southern part of Xinjiang, with the continental desert climate condition. Average annual precipitation is less than 80 mm, with 60% of the rainfall during summer. Annual evaporation varies from 2000 to 2449 mm. Annual mean temperature is 8.5 °C, annual cumulative temperature above 10 °C is 3414–3694 °C, and sunshine time from 3074 to 3163 h yr^{-1}. Brown Desert soil and Grey-brown Desert soil, developed from limestone parent material, are the main soil types, and classified as a Haplic Calcisol (FAO-UNESCO-ISRIC, 1988). Sampling sites span both sides of the Kaidu River (Fig. 1). The typical native vegetations are *Phragmites australis* (Cav.) Trin. ex Steud., *Alhagi sparsifolia* Shap., and *Tamarix ramosissima* Ledeb. Main crops are hot pepper (*Capsicum annuum* Linn), tomato (*Solanum lycopersicum*), and corn (*Zea mays*) et al.

2.2. Soil sampling and analyses

Soil samples were collected in August and November, 2010 from the native land (12 pits) and cropland (12 pits). We collected 120 soil samples from five layers, i.e., 0–5 cm, 5–15 cm, 15–30 cm, 30–50 cm, and 50–100 cm. These samples were air-dried, thoroughly mixed, and passed through a 2 mm sieve for pH and electrical conductivity (EC). Representative sub-samples were crushed to 0.25 mm for total SOC, SOC fractionation, and total nitrogen (TN) measurement. Soil pH and EC were measured at 1:5 soil-to-water ratio using pH and conductivity meters. Total SOC was measured by the Walkley–Black method (Walkley and Black, 1934). Soil TN was determined by a KJELTEC 2300 type fully automatic azotometer (Shiyomi et al., 2011). Soil bulk density (BD) was also measured in this study, by the core method (Blake and Hartge, 1986).

We used the two-step acid hydrolysis procedure with H_2SO_4 as the extractant to determine labile and semi-labile carbon, which was reported by Rovira and Vallejo (2002). Briefly, 20 mL of 5 N H_2SO_4 was added to 0.5–1.0 g soil, and hydrolyzed for 30 min at 105 ºC in sealed Pyrex tubes. The hydrolysate was recovered by centrifugation and decantation, and prepared for labile carbon analysis. The remaining residue was hydrolyzed with 2 mL of 26 N H_2SO_4 overnight at room temperature under continuous shaking. The concentration of the acid was then brought down to 2 N by dilution with de-ionized water and the sample was hydrolyzed for 3 h at 105 ºC with occasional shaking. The hydrolysate was recovered and prepared for semi-labile carbon analysis. The remaining residue was dried at 60 ºC, then prepared for recalcitrant carbon analysis by the Walkley–Black method (Walkley and Black, 1934).

2.3. Statistical analysis

We use independent sample t-test to determine the significance for the differences in SOC fractions for each layer among land use types. All the statistical analyses are carried out using SPSS 18.0 (Statistical Package for Social Science) and all the figures are produced using Origin 8.5 software.

3. Results

3.1. Soil properties

Soil properties in surface layer are shown in Table 1. Generally, soil pH is higher than 8 in this region, with no significant difference between the native land and cropland. On average, soil BD is 1.5 g cm^{-3} for the

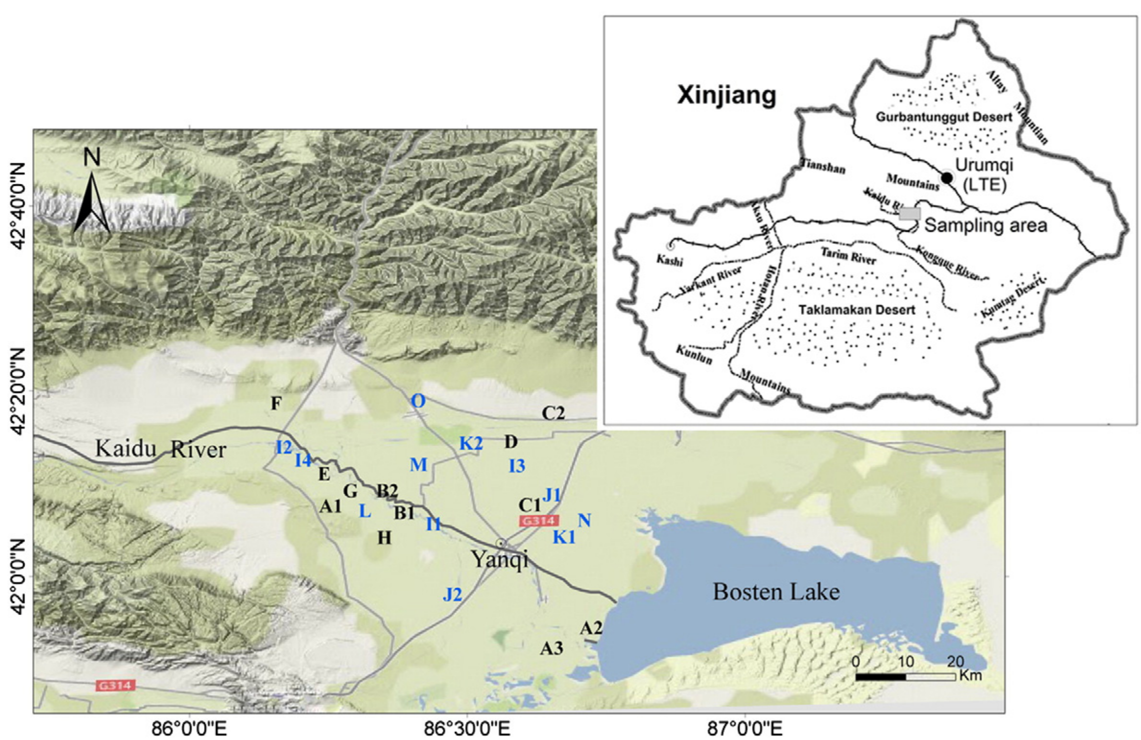

Fig. 1. Map of Xinjiang and locations of soil sampling in the Yanqi Basin.