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Plastic mulching with drip irrigation increases soil carbon stocks of natrargid soils in arid areas of northwestern China

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ABSTRACT

A cotton field experiment was conducted to study the effects of plastic film mulching cultivation (PC) and non-mulching cultivation (NPC) on soil carbon content of an Aridisol, classified as a typic natrargid, in Xinjiang Uygher Autonomous Region, China. The use of PC enhanced the stock of soil organic carbon (SOC) at depths of 0–30 cm, but not at depths of 30–70 cm, compared with NPC. Furthermore, PC enhanced the stock of soil inorganic carbon (SIC) at depths of 30–70 cm but not at 0–30 cm. Overall, PC increased the total carbon (TC) stock at depths of 0–70 cm. The TC stock was higher in PC (16.37 kg C m^{-2} $year^{-1}$) than in NPC (15.89 kg C m^{-2} $year^{-1}$). The contribution percentage of SIC (52%) to the net soil carbon (C) accumulation was higher than that of SOC (48%). Our results suggested that adoption of PC could be used as an effective way to increase the carbon sequestration of soils under cotton systems in arid areas.

1. Introduction

Increasing carbon (C) stocks in agricultural soils may have important effects on global warming and the mitigation of global CO_2 emissions to the atmosphere (Johnson et al., 2007). In particular, agricultural soils in arid areas with low soil organic carbon (SOC) content are considered to have great potential to sequestrate CO_2 under rational agricultural management systems, such as returning crop residues to the soil, using compost and farmyard manure, as well as adopting techniques of integrated nutrient management (Lal, 2002; Yan et al., 2007). For example, Xie et al. (2007) estimated that agricultural intensification and the adoption of rational agricultural management methods may enhance SOC sequestration at a rate of 200–300 kg ha^{-1} $year^{-1}$ in arid cropland. Similar estimates were made by Lal (2002) who reported that the change from traditional cultivation to recommended management practices for an area of 145 Mha can lead to soil C sequestration at the rate of 14–28 Tg C $year^{-1}$.

In addition to the potential for increased SOC sequestration, there is also an increased potential for soil inorganic carbon (SIC) sequestration in arid soils (Du et al., 2012; Reeder et al., 2004; Wu et al., 2009). The SIC pool is approximately 60 Pg C in the upper 1 m of soil in arid areas of China; these soils cover as much as one-twentieth of the Earth's surface (Pan and Guo, 2000). Recent studies indicated that the amount of SIC and its distribution along the soil profile in arid areas could be influenced by land use changes and management practices that are associated with changes in the soil water content and CO_2 partial pressures (Du et al., 2012; Wu et al., 2009). The change of SIC can be classified into lithogenic inorganic C (LIC) and pedogenic inorganic C (PIC). LIC is inherited from parent material of the soil, with no change for the SIC pool. PIC is formed during the dissolution and precipitation of carbonate parent material, which can fix atmospheric CO_2 and reduce a part of the release of CO_2 from SOC decomposition and root and microbial respiration under the climatic conditions that are typical of arid and semi-arid areas (Chang et al., 2012). The rate of formation of secondary carbonates depends on the intensity of seasonal agricultural practices, quality of irrigation water and agricultural crop type (Chang et al., 2012; Lal, 2002; Wang et al., 2014). Pan and Guo (2000) estimated that the SIC sequestration rate previously ranged from 20 to 400 kg ha^{-1} $year^{-1}$, and the total potential of SIC sequestration ranged from 7 to 138 Tg C $year^{-1}$ over 344 Mha of arid and semiarid soils. Similarly, Li et al. (2012) suggested that alkaline soils in arid regions had the potential ability to sequester 1.5×10^6 tons of atmospheric CO_2 to soils in the form of SIC in northwest China annually, which might play an important role in mitigating CO_2 emissions.

Plastic film mulching cultivation (PC) with drip irrigation has been promoted as a sound agricultural practice designed to improve the efficiency of use of soil nutrients by crops, and to improve the photosynthetic

Abbreviations: PC, plastic film mulching cultivation; NPC, non-mulching cultivation.

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capacity and yield of crops (Danierhan et al., 2013; Dong et al., 2008; Liang et al., 2013). This type of cultivation is now widely applied in China (Li et al., 2004), including 1,000,000 ha in northwestern China in 2009 (Gu et al., 2012). Historically, previous studies have focused on the effects of PC on soil nutrients, moisture, and other aspect of physical soil structure, while relatively few studies have evaluated the response of soil C sequestration to PC. Reliable estimates of the masses and distributions of soil C are therefore limited, and estimates of mulching-induced changes in SOC are variable and sometimes contradictory (Fan et al., 2012; Gu et al., 2012; Li et al., 2007). Inconsistencies in the reported responses of SOC to PC cultivation may result from a number of factors that differ among studies, including differences in climate, crop type, and the duration of mulching (Dong et al., 2009; Fan et al., 2012; Gu et al., 2012; Li et al., 2007). Moreover, many studies have only focused on the changes in SOC in the topsoil (e.g., 0–30 cm) and little attention has been given to the change of SOC in deeper soil layers (Ogle et al., 2005). However, the subsoil has a large capacity to store SOC (Chang et al., 2012); increasing evidence suggests that the SOC content in the subsoil is also sensitive to changes in land use and management (Chang et al., 2012; Lal, 2002; Ogle et al., 2005; Pan and Guo, 2000). Additionally, SIC in the form of carbonates is a principal component of many arid and semiarid rangeland soils; however, studies evaluating the responses of SIC to PC management have not been conducted to our knowledge (Chang et al., 2012; Mi et al., 2008; Wu et al., 2009). Therefore, the objective of this study was to investigate the effect of PC on changes in SIC and SOC, the distribution of SIC and SOC along the soil profile and C sequestration in arid areas under field conditions.

2. Materials and methods

2.1. Site description and experimental design

The present study was conducted in a cotton field located in the alluvial plains of the northern Tianshan Mountains at the Fukang Station of Desert Ecology, Chinese Academy of Sciences, Xinjiang, China (Fig. 1, 44°17′ N, 87° 56′ E, 450–460 m a.s.l.). The typical arid continental climate of the study region receives between 105 mm and 390 mm of rainfall annually; the mean was 164 mm from 1971 to 2009. In 2010, annual rainfall was ~160 mm and the mean annual temperature was 6.6 °C (Fig. 2). The typic natrargid soil (USDA, 1975) was a silt loam, with sand, silt and clay content of 21%, 73.2% and 5.8%, respectively (Table 1). The total soil organic matter concentration was 6.23 g kg^{-1}

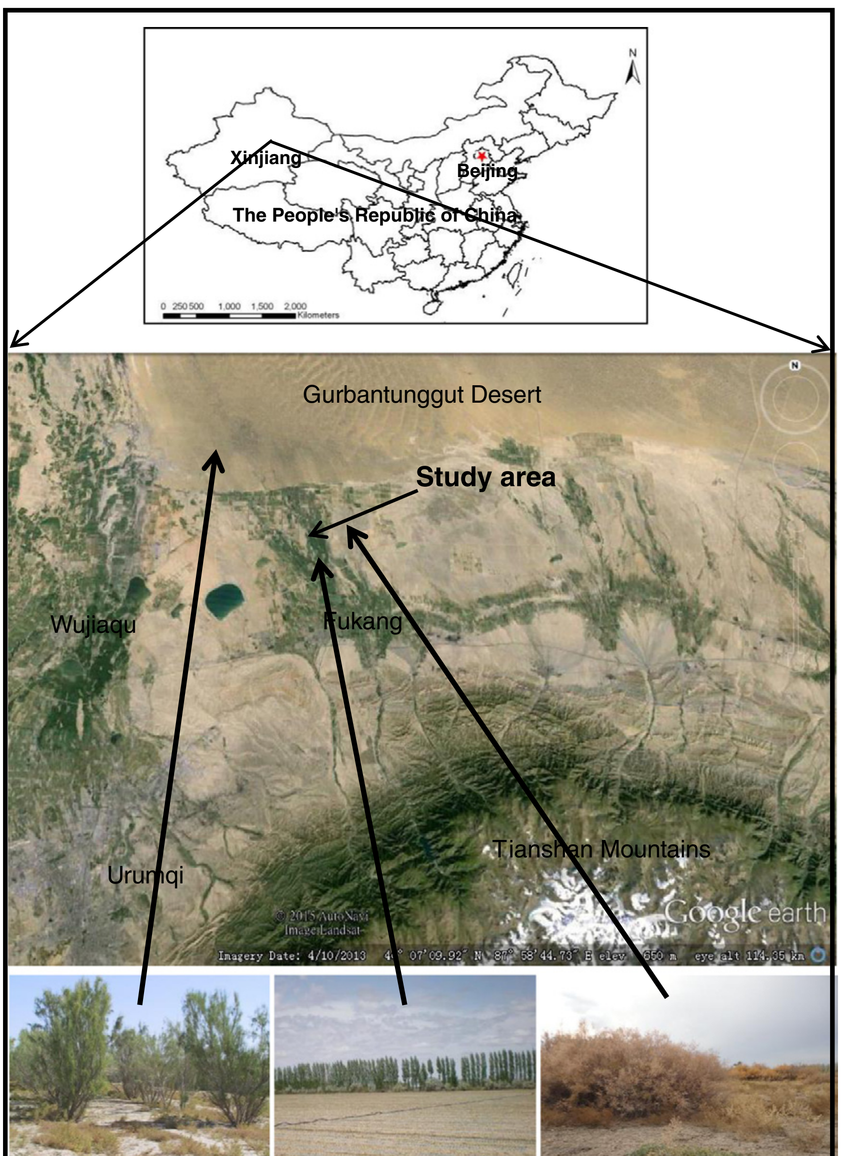

Fig. 1. Location of the study sites.