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Cultivation effects on temporal changes of organic carbon and aggregate stability in desert soils of Hexi Corridor region in China

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Abstract

Sustainable agricultural use of cultivated desert soils has become a concern in Hexi Corridor in Gansu Province of China, because loss of topsoil in dust storms has been recently intensified. We chose four desert sites to investigate the effects of cultivation (cropping) on (i) soil organic C and its size fractions and (ii) soil aggregate stability (as a measure of soil erodibility). These parameters are of vital importance for evaluating the sustainability of agricultural practices.

Total organic C as well as organic C fractions in soil (coarse organic C, 0.1–2 mm; young organic C, 0.05–0.1 mm; stable organic C, <0.05 mm) generally increased with the duration of the cultivation period from 0 (virgin soil, non-cultivated) to more than 30 years ($p < 0.05$). Compared to total organic C in virgin soils (2.3–3.5 g kg^{-1} soil), significantly greater values were found after 10 to >20 years of cultivation (6.2–7.1 g kg^{-1} soil). The increase in organic C in desert soils following prolonged cultivation was mainly the consequence of an increase in the coarse organic C. The increase in total organic C in soil was also dependent on clay content [total organic C = 0.96 + 0.249 clay content (%) + 0.05 cultivation year, $R^2 = 0.48$, $n = 27$, $p < 0.001$]. This indicates that clay protected soil organic C from mineralization, and also contributed to the increase in soil organic C as time of cultivation increased.

There was a significant positive correlation between aggregate stability and total organic C across all field sites. The water stability of aggregates was low (with water-stable aggregate percentage ~4% of dry-sieved aggregates of size 1–5 mm). There was no consistent pattern of increase in the soil aggregate stability with time of cultivation at different locations, suggesting that desert soils might remain prone to wind erosion even after 50 years of cultivation. Alternative management options, such as retaining harvested crop residues on soil surface and excluding or minimizing tillage, may permit sustainable agricultural use of desert soils.

Keywords: Agricultural land uses; Cropping; Desert soils; Organic carbon size fractions; Water-stable aggregates

1. Introduction

Hexi Corridor is very dry with annual precipitation from about 200 mm in the east (Gulang county) to <50 mm in the west (Dunhuang city). Ample sunlight, several inland-rivers, and flat landform result in the

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region having huge agricultural potential. As early as 221 BC, ancestors from other parts of China immigrated to the Hexi Corridor and began practicing agriculture using irrigation from inland rivers.

The history of Hexi Corridor's agricultural exploitation is one of land transition from desert to arable soil, and of continuous process of enlarging the cultivated areas or oases. With an increase in population, especially during the period from the middle to the end of the last century, and a consequent increase in food demand, the transition from virgin desert to agricultural use has intensified. However, with increasing water resources shortage, environmental risks such as wind erosion and dust storms have become more serious.

Based on remote sensing, wind erosion area is estimated as 230×10^6 ha in China (Yan et al., 2005). The highly intensified wind erosion is mainly distributed in large area of northwestern China and Inner Mongolia, where the annual average precipitation is less than 150 mm (Yan et al., 2005). In winter and spring seasons, cold wind blows away surface soil from desert (including from cultivated areas), causing serious soil erosion. Several studies (Yang et al., 1995; Zhang et al., 1998; Ta et al., 2003) reported that dust particles carried by recent wind storms in northern China originated, at least partly, from the topsoil of newly exploited farmlands in Gansu province. The loss of soil by wind erosion also decreases soil organic C contents in the surface soil layer (Bajracharya et al., 1998). The soil organic C loss in China due to wind erosion was approximately 75×10^6 Mg C each year in 1990s (Yan et al., 2005).

Organic C in soil plays an important role in maintaining and improving soil fertility and quality via nutrient cycling, formation and stabilization of soil structure, reduction of soil erosion, aiding the infiltration of air and water, and promoting water retention (Gregorich et al., 1994; Bhupinderpal-Singh et al., 2004). Moreover, soil organic C represents a large component of the global C cycle. Therefore, the impact of land-use and/or land-cover change on soil fertility, particularly on organic C, is an increasing concern to the scientific community.

It has been well documented that the transition of forestland and grassland to arable land decreases soil organic C content in semiarid and humid regions (Johnson, 1992; Davidson and Akerman, 1993; Tiessen et al., 1994; Haynes and Tregurtha, 1999; Lal et al., 1999; Solomon et al., 2002). However, changes in soil organic matter after agricultural exploitation in arid and hyper-arid regions are not well understood. Identifying changes in organic matter content and quality is important in defining sustainable agricultural practices over the longer term. This could be facilitated by, for example, physical separation of soil organic matter into pools of discrete size, bioavailability and turnover rates, with the smallest pools (light C fraction or coarse/particulate organic matter) responding the quickest to changes in soil management and to input of plant biomass, including roots (Quiroga et al., 1996; Six et al., 1998, 1999; McLauchlan and Hobbie, 2004; Bhupinderpal-Singh et al., 2005). There is also little information available on the changes in soil aggregate stability, which has been shown to provide a good index of soil erodibility (Kay, 2000; Díaz-Zorita et al., 2002).

The objective of this study was to investigate the effects of cultivation on temporal changes of total soil organic C, its size fractions, and soil aggregate stability, thereby interpreting the significance of cultivation on soil fertility and erodibility.

2. Materials and methods

2.1. Site description

Hexi Corridor, located in Gansu Province of northwestern China, stretches more than 1000 km, with width varying from 30 to 500 km. The study was conducted at four locations in the northwest part of Gansu Province: Yongchang (38° 20′ N, 102° 30′ E), Jiuquan (39° 28′ N, 99° 05′ E), Wuwei (37° 45′ N, 102° 53′ E) and Gulang (37° 35′ N, 103° 42′ E), with altitudes ranging from 1520 m in Jiuquan to 1700 m in Yongchang. These four locations have similar topography, climate, and vegetation conditions. The climate is very dry and relatively cold, with long-term averages (>50 years) in annual rainfall and temperature of 140 mm and 7.3 °C in Yongchang, 61 mm and 8.1 °C in Jiuquan, 158 mm and 7.6 °C in Wuwei, and 150 mm and 6.8 °C in Gulang, respectively. Because of the very dry climate, natural vegetation is sparse. The dominant plant species are some xerophil and ultra-xerophil types such as *Nitraria sibirica* Pall., *Alhagi pheud alhagi* Desv., *Calligonum* sp., and *Artemisia* sp. Soils were classified as grey brown desert soil (Institute of Soil Science and Chinese Academy of Sciences, 1978a), which are similar to Aridisols.

2.2. Soil sampling and preparation

In each of the four locations, experimental field sites for which the start of cultivation of desert soils could be ascertained from farmers were chosen along a line from farms' residential area to the edge of desert (non-cultivated) for soil sample collection in April 2003.