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RESEARCH ARTICLE

Effects of land use change on the spatiotemporal variability of soil organic carbon in an urban-rural ecotone of Beijing, China

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Abstract

Understanding the effects of land use changes on the spatiotemporal variation of soil organic carbon (SOC) can provide guidance for low carbon and sustainable agriculture. In this paper, based on the large-scale datasets of soil surveys in 1982 and 2009 for Pinggu District — an urban-rural ecotone of Beijing, China, the effects of land use and land use changes on both temporal variation and spatial variation of SOC were analyzed. Results showed that from 1982 to 2009 in Pinggu District, the following land use change mainly occurred: Grain cropland converted to orchard or vegetable land, and grassland converted to forestland. The SOC content decreased in region where the land use type changed to grain cropland (e.g., vegetable land to grain cropland decreased by 0.7 g kg^{-1}; orchard to grain cropland decreased by 0.2 g kg^{-1}). In contrast, the SOC content increased in region where the land use type changed to either orchard (excluding forestland) or forestland (e.g., grain cropland to orchard and forestland increased by 2.7 and 2.4 g kg^{-1}, respectively; grassland to orchard and forestland increased by 4.8 and 4.9 g kg^{-1}, respectively). The organic carbon accumulation capacity per unit mass of the soil increased in the following order: grain cropland soil<vegetable land/grassland soil<orchard soil<forestland soil. Therefore, to both secure supply of agricultural products and develop low carbon agriculture in a modern city, orchard has proven to be a good choice for land using.

Keywords: land use change, soil organic carbon, spatiotemporal variability, urban-rural ecotone

1. Introduction

Soil is the largest reservoir of carbon in the terrestrial biosphere. The total stores of soil carbon is 3.3-fold larger than the atmospheric carbon pool and 4.5-fold greater than the biological carbon pool, and the soil organic carbon (SOC)

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pool accounts for more than half of the soil carbon pool (Lal 2004). Therefore, a small variation in soil carbon pool could lead to marked change in the CO_2 concentration of atmosphere (Luo *et al*. 2010; Smith and Fang 2010). There is sufficient evidence that land use/land cover change (LUCC) is a major driving factor for the balance of SOC stocks and the global carbon cycle in terrestrial ecosystems (Watson *et al*. 2000; Wilson *et al*. 2008; Luo *et al*. 2010; Poeplau *et al*. 2011; Dunn *et al*. 2013; Gerber *et al*. 2013). In particular, changes among land use types such as cropland, forestland, and pastureland will result in clear changes in SOC reserves (Smith 2008; Poeplau *et al*. 2011). According to an Intergovernmental Panel on Climate Change (IPCC) report, 1.6 Pg carbon is emitted into the atmosphere in association with LUCC each year, which is the second largest atmospheric carbon source after the carbon emitted from the combustion of fossil fuels (7.2 Pg C per year) (Solomon *et al*. 2007). Numerous studies reported decreasing SOC stocks after a land use change from natural or semi-natural ecosystems (forestland and grassland) to cropland, and a cultivation induced SOC decline of about 20–60% when forestland and grassland were converted to cropland (Guo and Gifford 2002; Murty *et al*. 2002; Poeplau *et al*. 2011; Wiesmeier *et al*. 2012, 2015; Oberholzer *et al*. 2014). Also, the SOC stocks increased by 20–50% after land use changes from cropland to grassland or forestland reported by Guo and Gifford (2002), who also indicated that wherever one of the land use changes decreased soil C, the reverse processusually increased soil carbon and *vice versa*. However, the results of changes between grassland and afforestation land are uncertain. This land use change could result in either a slight decrease in net SOC sequestration rate or an increase in net SOC sequestration rate (Soussana *et al*. 2004; Davis *et al*. 2007; Ritter 2007). Moreover, the recovery rate of SOC is greater at the early stage after a land use change than during the later stages (Coleman *et al*. 1997).

City suburb is an urban-rural transition zone. The rapid progression of the urbanization process in recent years has resulted in constant increases in the degree of agricultural intensification and land use intensity. In particular, the progression of urbanization has resulted in relatively large changes in land use types and management practices for agricultural lands, which will have important impacts on SOC content (Fu *et al*. 1999). The Pinggu District, located in a northeastern suburb of Beijing, China, has evolved from an agricultural area that mainly focused on grain production to an important fruit and vegetable production base for Beijing. Thus, the Pinggu District is highly representative of an urban-rural ecotone. Hence, an evaluation of the effect of land use change on the spatiotemporal variation in organic carbon in this area is of utmost significance for implementing urban low-carbon and sustainable agriculture.

To date, numerous researchers have used geostatistical methods to study the spatial variability of SOC. Field-scale studies have mainly revealed the effects of random factors, such as agricultural management practices, on the spatial variation of SOC (Cambardella *et al*. 1994; Yanai *et al*. 2005). Regional-scale studies have mainly revealed the effects of structural factors, such as climate, terrain, soil type, cropping system and land use type, on the spatial variation of SOC (Sun *et al*. 2003; Huang *et al*. 2007; Liu *et al*. 2014). However, there have been few studies on the spatiotemporal variation of SOC in an urban-rural ecotone, particularly the effects of land use change on the spatiotemporal variation of SOC. In addition, many studies have only conducted parallel comparisons for SOC contents among different land use types (Rodríguez-Murillo 2001; Davy and Koen 2013), but neglected the longitudinal historical processes associated with the land use change dynamics over different time periods (Schulp and Verburg 2009). Therefore, the results of these studies cannot satisfactorily assess the effects of time and changing process on SOC.

In this paper, we chose the Pinggu District in Beijing City, China, as a typical urban-rural ecotone for the following aims: (1) to investigate the temporal variation and spatial variation of SOC content in the Pinggu District from 1982 to 2009. (2) to evaluate the effects of different land use types and dynamic land use changes on the spatiotemporal variability of SOC content from 1982 to 2009. The results can provide guidance for the implementation of low-carbon and sustainable agriculture in an urban-rural ecotone.

2. Results

2.1. Characteristics of spatiotemporal changes of land use

Generally, the changes in land use between two time periods can be classified into two types: (1) the original type of land use is maintained, i.e., maintained land (denoted by the symbol "—"); or (2) there is a change in land use type, i.e., changed land (denoted by the symbol "→"). The transfer of land use matrix was generated by overlaying the maps of land use in Pinggu District in 1982 and 2009 (Table 1). In the urban-rural ecotone of Beijing, there were three major land use types, including urban building land, ecological regulation land (mainly forestland and grassland), and agricultural production land (mainly grain cropland, vegetable land, and orchard). This study focuses primarily on the effects of land use dynamics on SOC content in the ecological regulation land and agricultural production land.

The main land use type in Pinggu District in 1982 was grain cropland (Table 1 and Fig. 1). Grain cropland covered 472.1 km^2, which accounted for approximately half of the