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Research article

Carbon Sequestration Anticipation Response to land use change in a mountainous karst basin in China

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ABSTRACT

The present article reports an assessment of afforestation potential and anticipation of carbon sequestration in the Houzhai River Basin in Guizhou Province in southwestern China. Total of 2755 soil profiles consisting of 22,057 soil samples were collected according to a grid-sampling method at a 150 m scale in the Houzhai River basin, and the SOC contents in soil samples were analyzed using a titration method. General information regarding the geographic characteristics of each sampling grid was recorded in the field. The results indicate that land use in the Houzhai River Basin is very complex. Land use status and land use change in the study area were closely associated with local geographic characteristics and variations in economic structures. There were approximately 15.26 km^2 of land that could or should be rearranged as afforestation land in the Houzhai River Basin. The increased SOC storage (0.00–1.00 m soil horizon) would be up to 5.48×10^4 Mg, 6.42×10^4 Mg, 4.77×10^4 Mg and 3.18×10^4 Mg when all of the calculated lands became shrub-grass lands, shrub lands, arbor-shrub forest lands and arbor forest lands, respectively. The increased SOC percentages would be 52.16%, 61.13%, 45.39% and 30.32%, respectively, in comparison with the present SOC storage in these lands.

1. Introduction

In the context of green agriculture and global warming, soil organic carbon (SOC) has become a worldwide concern during the past several decades (Veum et al., 2011; Wiaux et al., 2014). The SOC is one of the central issues related to soil fertility and environmental safety, i.e., greenhouse gas fluxes (Yang et al., 2010; Dorji et al., 2014). Variation in the abundance and composition of SOC will cause important effects on many of the processes that occur within the soil system (Batjes, 2014). It is widely acknowledged that SOC in global soils is the largest terrestrial pool of carbon, and it is at least three times larger than the pool of atmospheric carbon dioxide (Lal, 2008; Han et al., 2010; Smith, 2012). A tiny change in the SOC pool may lead to a considerable change in atmospheric carbon dioxide concentration. Therefore, SOC plays a critically important role in the terrestrial carbon sink and a key role in the global carbon budget (Bohn, 1982; Swift, 2001; Taghizadeh-Toosi and Olesen, 2016).

There is a carbon capacity and equilibrium of carbon content, which depends on the nature of precipitation, temperature and vegetation, for each ecosystem (Jobbágy and Jackson, 2000). Land-cover change may alter the storage of organic carbon in the soils (Guo and Gifford, 2002; Deng et al., 2014; Zhang et al., 2012). Land-cover change will cause a change in vegetation cover. Additionally, land-cover change will cause some variation in the physical, chemical and biochemical processes of SOC that take place underground by changing the soil circumstances. The equilibrium between carbon inflow and outflow in the soil will be disturbed by land use change until a new equilibrium is eventually reached in the new ecosystem (Guo and Gifford, 2002; Deng et al., 2014). With the progress of society, economy structures are reforming. Therefore, it is probably advisable to rearrange land use to increase the SOC storage in soils. In southwest China, the conversion of land from agricultural production to ecological and tourism development is one of the critical processes of change that has led to present improvements in rural economic structures.

Guizhou Province, in southwestern China, is a karst mountainous area characterized by a weak ecosystem with many ecological problems (Su, 2005). It has experienced the most severe contradiction between humans and the environment over the past ninety years. During that period, a large number of forestlands and grasslands were reclaimed for croplands to temporarily solve a starvation problem. Along with the

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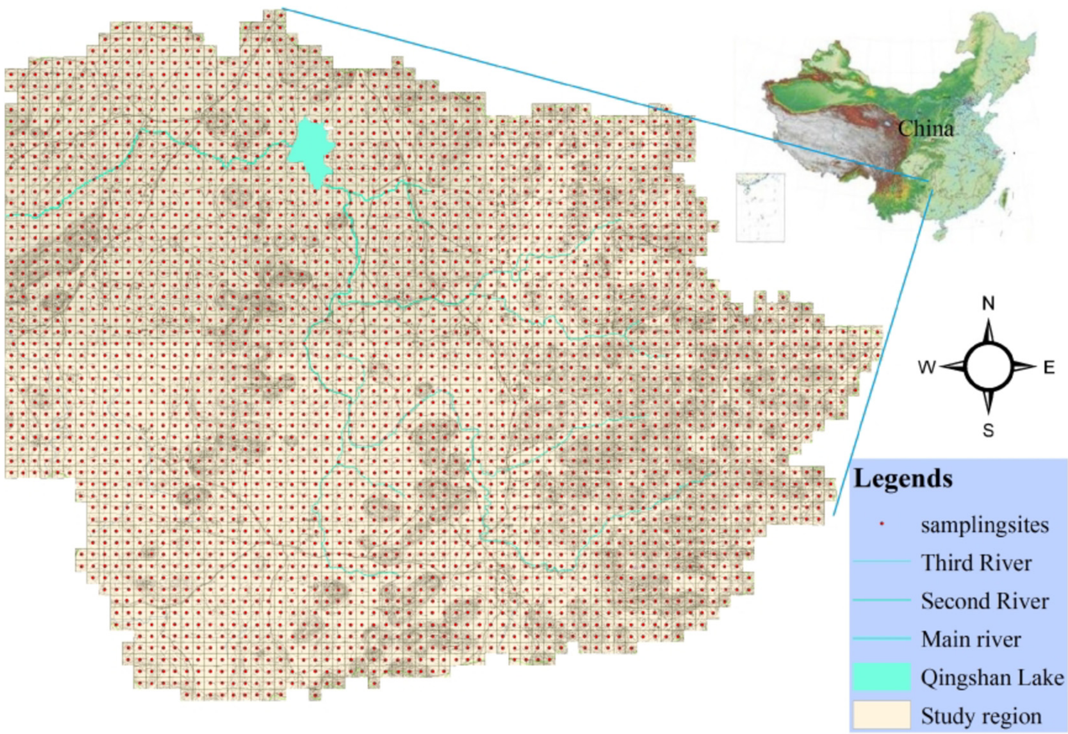

Fig. 1. Designed sampling sites in Houzhai River basin.

development of agriculture and society, the rural economic structure has improved dramatically in China over the past decade, and starvation problem is not a problem anymore since the beginning years of the 21st century. Great numbers of young village laborers left their villages and were employed by various factories or companies in developed coastal cities. Consequently, only elderly people were left for farming activities. Then, many croplands (especially with poor soils) were abandoned and became wasteland for several years. Recently, increased attention has been paid to soil organic carbon variation coupled with various natural condition alterations and human disturbances (Gregorich et al., 1997; Nicoloso et al., 2016). In Guizhou Province, Provincial and local governments are trying to develop the tourism industry, and improving the environmental quality is a critical step in that progress. Therefore, uncultivated lands and some croplands with poor quality, including shallow soils, large rock exposure, large slope degree, etc., will be rearranged for afforestation (Xiong et al., 2007). It is necessary to conduct some studies on SOC change response to land use change for carbon management.

There were many studies referred to SOC distribution or storage in Guizhou province (Li et al., 2007; Zhang et al., 2008). Study on SOC storage in karst mountainous areas as Guizhou Province is a huge challenge since soils in these areas are discontinuous and land uses are of high diversity. Traditional method is not suitable for assessing the SOC storage in these unique areas. Li et al. (2007) suggested that the total SOC in Guizhou Province is about 1.97 Gt (10^{15} g) in 0.00–1.00 m soil horizon. To our knowledge, there are few literatures that exactly refer to the SOC stock in Guizhou province at present. In this literature, SOC storage was calculated from soil organic matter content and bulk density based on soil types, and rock outcrops were not taken in consideration. However, SOC contents in karst mountainous areas were mainly affected by vegetation cover (land use) rather than soil types (Huang et al., 2017). Though, it is believed that their result was overestimated.

In the present study, we have done a systemic investigation on the geographic characteristics, land use, and SOC spatial distribution in the Houzhai River Basin. Based on detailed information of different land uses, this study focused on the afforestation space potential (i.e., how much land could or should be rearranged for afforestation) and carbon sequestration potential (i.e., how much carbon could be sequestrated as SOC due to environmental improvements) in the Houzhai River Basin. The main objectives of this study were: (a) to study the relationship between the complexity of land use and heterogeneity of geographic characteristics in the Houzhai River Basin, and (b) to assess the potential afforestation space and anticipated carbon sequestration in this basin.

2. Materials and methods

2.1. Site description

The Houzhai River Basin (105°40′43″–105°48′2″E, 26°12′29″–26°17′15″N) is a part of the watershed of the Yangtze River Basin and the Pearl River Basin. It covers an area of 72 km^2. This region is a typical karst landform in the Yun-Gui Plateau (Zhang et al., 2018). The study area has a subtropical humid monsoon climate. The mean annual temperature and mean annual precipitation were approximately 15.1 °C and 1378.2 mm, respectively. The main ecosystem types in the study area include evergreen broad-leaved forest, coniferous and broad-leaved mixed forest, and montane elfin forest (Zhang et al., 2017, 2018). The eastern part of the Houzhai River Basin is mainly a karst peak-cluster depression area, and the central and west parts are mainly flatland interspersed with small hills or mountains. There is a small reservoir named Qingshan Lake in the northern part of the study region.

2.2. Sampling and field investigation

According to a grid-based sampling method (Zhang et al., 2017), sampling sites were designed with ARCGIS at a 150 m scale, and a total of 3194 sites were defined in the Houzhai River Basin (Fig. 1). At each site, the soil profile was divided into 12 layers (0.00–0.05 m, 0.05–0.10 m, 0.10–0.15 m, 0.15–0.20 m, 0.20–0.30 m, 0.30–0.40 m, 0.40–0.50 m, 0.50–0.60 m, 0.60–0.70 m, 0.70–0.80 m, 0.80–0.90 m and 0.90–1.00 m) if the soil thickness was equal to or greater than 0.95 m. Otherwise, sampling was carried out to the actual depth of the soil. The