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ORIGINAL ARTICLE

# Temporal variation of soil carbon stock and its controlling factors over the last two decades on the southern Song-nen Plain, Heilongjiang Province

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**Abstract** Against the current background of global climate change, the study of variations in the soil carbon pool and its controlling factors may aid in the evaluation of soil's role in the mitigation or enhancement of greenhouse gas. This paper studies spatial and temporal variation in the soil carbon pool and their controlling factors in the southern Song-nen Plain in Heilongjiang Province, using soil data collected over two distinct periods by the Multi-purpose Regional Geochemical Survey in 2005–2007, and another soil survey conducted in 1982–1990. The study area is a carbon source of 1479 t/km$^2$ and in the past 20 years, from the 1980s until 2005, the practical carbon emission from the soil was 0.12 Gt. Temperature, which has been found to be linearly correlated to soil organic carbon, is the dominant climatologic factor controlling soil organic carbon contents. Our study shows that in the relevant area and time period the potential loss of soil organic carbon caused by rising temperatures was 0.10 Gt, the potential soil carbon emission resulting from land-use change was 0.09 Gt, and the combined potential loss of soil carbon (0.19 Gt) caused by warming and land-use change is comparable to that of fossil fuel combustion (0.21 Gt). Due to the time delay in soil carbon pool variation, there is still 0.07 Gt

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in the potential emission caused by warming and land-use change that will be gradually released in the future.


## 1. Introduction

Globally, two thirds of organic carbon in terrestrial ecosystems is stored in soils in the form of organic matter, and the total amount of organic carbon in soils is twice that of the atmospheric carbon pool. Therefore, the stability, increase, or release of soil organic carbon (SOC) all exerts significant influences on $CO_2$ concentration in the atmosphere. Soil carbon sequestration has become the most simple and effective method for reducing the atmospheric concentration of greenhouse gases and slowing down global warming (Pan et al., 2007; Sun et al., 2008). Studying soil organic carbon storage, its spatial distribution, and its dynamic changes is prerequisite to building a soil carbon pool inventory, assessing its historical deficit or surplus, and predicting the potential for soil carbon sequestration. These steps are also essential to the study of the carbon cycle and climate change as well as developing future land-use policies (Pan et al., 2000, 2007). In addition, because soil organic matter has an important relationship with soil quality and function, and because it is a natural resource, the yield of the study of temporal variation in the soil organic carbon pool and its controlling factors will also be of great relevance to agricultural production and national food security concerns (Pan and Zhao, 2005). For a long time a lack of data spanning different time periods has meant that the study of the soil carbon pool has been confined to carbon reserve estimates made at specific points in time (Wang et al., 2000; Li et al., 2003; Zhou et al., 2007), and there has, therefore, been a dearth of analyses of its changes. Additionally, although some researchers have studied the factors that control soil organic carbon change, they have only carried out qualitative analyses, leaving much quantitative research to be done (Su and Zhao, 2002; Jiang et al., 2007; Xu et al., 2007).

China carried out national soil surveys twice in the last century, and the second soil survey in particular, conducted in the early 1980s, provides a dataset ideal for research on soil carbon evolution. Another dataset used in this study is from the Multi-purpose Regional Geochemical Survey carried out by the China Geological Survey since 1999, which uses a scheme of double layer and grid sampling. As of 2008, this survey has covered 1.6 million $km^2$, and its data can be used to estimate the soil carbon pool in the early 21st century (Xi et al., 2009). The data from these two surveys serve as vast seas of information that are key to the study of temporal variations in the soil carbon pool. Using the southern part of Song-nen Plain in Heilongjiang Province as a representative model, and using soil organic carbon data from the two periods mentioned above, this article studies the distribution characteristics of the soil organic carbon pool. In particular we study change in the soil carbon pool in a recent 20 year period and its controlling factors, and quantitatively analyze the relative contribution of these factors to soil carbon pool variations.

## 2. Data and methods

The study area is located in the southern part of the Song-nen Plain in China's Heilongjiang Province, has an area of 81,500 $km^2$, is located at east longitude 122°20′−128°00′, north latitude 44°40′−48°00′, is administered by Harbin, Daqing, Qiqihaer, and Suihua, and altogether involves 28 counties and cities. The range of annual average temperature is 1.7−4.0 °C and there are four distinct seasons, with winter being long and cold and summer being short and hot. The annual average precipitation is 370−670 mm, with 500−600 mm falling on the eastern plain and less than 500 mm falling on the western and northern part of the region. April−September precipitation accounts for 83−94% of annual precipitation. Soil parent materials in the Song-nen Plain include residual deposits, slope wash, layered alluvial gravel, loess-like clayey soil, alluvium, and aeolian sand. Soil types in the Song-nen plain are mainly dark brown soil, white slurry soil, black soil, chernozem, meadow soil, swamp soil, alkaline earth, blown sandy soil, and paddy soil, amounting to a total of nine types. Black soil, chernozem, and meadow soil account for over 90% of the soil in the Song-nen Plain area.

### *2.1. Data for 1982−1990*

This data comes from the Second National Soil Survey, conducted from 1982 to 1990, and represents the local soil carbon pool of the 1980s. Data is from "Chinese Soil Species, vol. 2". The organic and inorganic carbon densities of surface (0−20 cm) soil were calculated using Microsoft EXCEL software and the calculation method is described in the relevant literature (Pan, 1999; Xi et al., 2009). Data on carbon density was imported to a soil map as the attribute value in ArcGIS software, and raster data was formed by inverse distance weighted interpolation.

### *2.2. Data for 2005−2007*

This data represents the soil organic carbon pool in the early 21st century. The data's sampling density is one sample per $km^2$, and four samples for each 4 square kilometers were mixed together for chemical analysis, which included analysis of soil total carbon and organic carbon. Sampling points were made in the form of point shape files in ArcGIS, and raster dataset files were formed by inverse distance weighted interpolation. Using map algebra methods, we carried out subtraction calculations with carbon pool grid data from the two periods, and then obtained the map of increased organic carbon density. Overlay analysis was made between the raster data and the polygon data on soil type and land-use types.

## 3. Results and discussion

### *3.1. Proportion and distribution of soil carbon*

The soil carbon pool is composed of two parts: the organic and inorganic carbon pools. Soil organic carbon (SOC) comes from the bodies of animals, plants, and microorganisms; their excreta, secretion, and degradation products; and humus, the organic matter in soil science. Soil inorganic carbon (SIC) generally exists in the