

Optimal spatial scale determining the response of soil organic carbon to climate change using soil database of China

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Abstract

Climate factors are considered significant in regulating soil organic carbon (SOC), but are not equally important at all spatial scales. The scale which provides the optimal relationship between climate and SOC and how that relationship varies at multiple scales are still unclear. To test the variation, 1,022 uplands profiles in Northeast China were obtained from the second national soil survey of China, and the multiple scales were designed as the regional (whole Northeast China), province, city and county. The relationships between climate factors and SOC content at four scales were evaluated for 0-20 cm and 0-100 soil cm using correlation and regression analysis. The results show that differences exist in the degree of correlation and relative importance of temperature and precipitation at different scales. At the regional scale, temperature is the main climate factor controlling SOC content. At the provincial scale, temperature is also the main climate factor controlling SOC content in the Uplands of Heilongjiang and Eastern Inner Mongolia. Soil organic carbon content in Jilin and Liaoning is influenced jointly by temperature and precipitation. At both the city and county scales, a weak or no relationship is observed between climate factors and SOC content. Climate factors have limited ability to explain SOC content variability given that SOC is affected by multiple factors which were not taken into account by this research.

Key Words

Scale effect, SOC (soil organic carbon) content, climate, main factor.

Introduction

Because of the important role of soil organic carbon (SOC) in terrestrial ecosystems and its large reservoir size, small changes in the SOC pool may influence global climate change. It is often considered that climate, especially temperature and precipitation, is the most important factor regulating SOC as it strongly influences vegetation type, production and decomposition of plant litter (Alvarez and Lavado 1998). Thus, a better understanding of the relationship between climate factors and SOC at different spatial scales is crucial in assessing the possible impact of projected climate change on the global carbon cycle. Recent research progress on the relationship between climate factors and SOC (Homann *et al.* 2007) had been made. However, contemporary research was mainly carried out at a single scale. Based on study area size, completed research can be divided into local, regional, continental, and global scales. Very few studies exist at the global scale that also considers that SOC density increases with increasing precipitation and decreasing temperature (Jobbágy and Jackson 2000). Local scale studies are also rare. At the regional scale, both soil C content and concentration correlated weakly with temperature and precipitation across all soils and within each soil order in New Zealand (Percival *et al.* 2000). At the continental scale, Homann *et al.* (2007) reported positive relationships to MAP (Main Annual Precipitation, negative relationships to a temperature/precipitation index in all regions, and negative relationships to MAT (Main Annual Temperature), except in the northwest temperate forest region. The relationship between climate and SOC at individual scales has been widely reported, but little information is available at multiple scales. The scale providing the optimal relationship between climate and SOC and how that relationship varies at multiple scales are still unclear. By examining four scales (regional, provincial, city and county), the goals of this paper are to show how the relationship between climate and SOC content in the Uplands of Northeast China varies with scales, and explore optimal spatial scale determining response of soil organic carbon to climate change.

Materials and methods

The study area is located in Northeast China (38°40'-53°30'N, 115°05'-135°02'E) covers an area of 1.24 million km², including Heilongjiang Province, Liaoning Province, Jilin Province, and Eastern Inner Mongolia. It has a temperate monsoon climate, but varies across the region. From north to south (~1,600 km)

temperatures generally increase and from east to west (~1,400 km) moisture generally decreases. The data used for this study were obtained from the Second National Soil Survey of China (National Soil Survey Office 1993, 1994a, 1994b, 1995a, 1995b, 1996) conducted in the beginning of 1980s including 1041 upland soil profiles taken from Soil Series of China and Soil Series of provinces, cities, and counties in Northeast China. The SOC content of the 0-20 cm and 0-100 cm depths for each profile were re-calculated based on the total 1041 soil profile data. The spatial resolution of all climatic grid maps is 1 km×1 km. MAT and MAP of 1,022 soil profile points were extracted from the corresponding grid climate data layer using GIS (ESRI, Inc., Redlands, CA). In this study, regional scale refers to all of Northeast China, while provincial scale includes Heilongjiang, Jilin, Liaoning, and Eastern Inner Mongolia. Among 40 cities and 225 counties in the study area, 8 cities and 9 counties were selected as typical areas for the city and county scales, respectively, according to the area of Upland, number of profiles and geographical location. All the statistical analyses were performed with SPSS software 13.0 (SPSS Inc. Chicago, Illinois, USA).

Results and discussion

Relationship between temperature and SOC content at different scales

Based on soil profile and climate grid data, partial correlation analysis between MAT and SOC content taking MAP as the controlling variable were conducted. The relationships between temperature factors and SOC content are diverse at different scales in the Uplands of Northeast China. At the regional scale, SOC content is highly significant and negatively related to MAT not only at 0-20 cm, but also at 0-100 cm. This indicates that increasing temperature generally enhances decomposition more than detrital production. At the provincial scale, SOC content at 0-20 cm in the Uplands has a highly significant and negative correlation with MAT. The relationship between temperature factors and SOC content in Liaoning is significantly different compared with that in Eastern Inner Mongolia and Heilongjiang. A significant difference in Heilongjiang and Jilin is observed in the relationship between temperature factors and SOC content. No difference is observed in the relationships between temperature factors and SOC content in Heilongjiang and Eastern Inner Mongolia. At the city scale, there is a significant negative correlation between temperature factors and SOC content at 0-20 cm in four cities. The results indicate that the relationship between temperature factors and SOC content in the Uplands of Northeast China is scale dependent, and weakens with decreasing scale, especially from provincial to city scales.

Relationship between precipitation and SOC content at different scales

The partial correlation coefficients between MAP and SOC content taking MAT as the controlling variable were calculated. At the regional scale, MAP has a strong and significantly positive relationship with SOC content ($P < 0.001$) at 0-20 cm in the Uplands of Northeast China, and a weak relationship with SOC content at 0-100 cm. At the provincial scale, SOC content has a significant and positive relationship with MAP except for Liaoning at 0-100 cm and Eastern Inner Mongolia at 0-20 cm and 0-100 cm. At the city scale, no relationship is observed except for a significant positive relationship between MAP and SOC content at 0-20 cm in Siping and a significant negative relationship between MAP and SOC content at 0-100 cm in Chifeng. The relationship between MAP and SOC content weakens from provincial to city scales (Wang *et al.* 2009).

The Optimal spatial scale determining the response of SOC to climate change

The level of SOC content influences food productivity directly, so it is significant in maintaining food security (Lal, 2004; Johnston *et al.* 2009). Also, global warming will result in decreasing SOC content which has a negative impact on food security by reducing the food productivity of soil. Therefore, there is a growing concern on the relationship between global climate change and SOC content in recent years (Powlson 2005; Smith *et al.* 2008). Presently, there is a steady increase by about 6 million per year in population in China due to the large population base. Conversely, Northeast China is the second largest grain producing area and the largest commodity grain production base. It is considered to have the most potential for increasing food production in the future. Thus, it is very important to examine whether global warming influences SOC content and then food production or not. Our study shows that the relationship between climate factors and SOC content varies with scales. Soil organic carbon content is significant related to climate factors at regional, provincial, and partly city scales, especially for temperature, rather than for the county scale. Different scales contributed to the difference in the relationship between climate factors and SOC content. It is optimal to select provincial scales to study response of SOC content to global warming. However, County is not a suitable scale for the study of the issue.

Conclusion

The relationship between climate factors and SOC content weakens with decreasing scale, especially from the provincial to city scale. In general, the main climate factor controlling SOC content varies at different scales. Temperature is the main climate factor influencing SOC content. At the provincial scale, regional differences were observed in the main climate factor controlling SOC content in the Uplands. Due to the impact of soil texture, human activities and other influencing factors on SOC content, climate factors are not the main factors controlling SOC content at the city and county scales. Regional scale is not the optimal scale to study the relationship between climate factors and SOC content in the Uplands of Northeast China, because regional differences among provinces may be covered up at this scale. As such, the provincial scale is optimal for studying the effect of climate factors on SOC content.

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