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Spatial scaling effects on variability of soil organic matter and total nitrogen in suburban Beijing

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ABSTRACT

Understanding the spatial distribution of soil organic matter (SOM) and total nitrogen (STN) at different scales is helpful for elucidating relationships between soil properties, environmental factors and human activities. The objectives of this study were to compare the spatial patterns of SOM and STN and to explore the main factors affecting SOM and STN distribution in suburban Beijing at three spatial scales: large-scale (Pinggu County), medium scale (Plain area) and small-scale (Machangying town). For the county and plain scales, a total of 973 soil samples (0–20 cm) were collected on a 400 × 400 m grid across an area of 1075 km^2. For the town scale, a total of 171 topsoil samples were collected on a 100 × 100 m grid within an area of 28.6 km^2. The SOM and STN concentrations were determined for each soil sample. Descriptive statistics and geostatistical methods were used to analyze the data at the three spatial scales. The results showed that the mean values of SOM concentrations at large, medium and small scales were 14.88, 13.14 and 10.91 g kg^{-1}, respectively. The corresponding values for STN were 0.91, 0.79 and 0.66 g kg^{-1}, respectively, which also showed a decreasing trend with downscaling. The SOM and STN concentrations at the county scale had the largest spatial correlation distances, 88.2 km and 25.3 km respectively, while their spatial correlation distances at the town scale were the smallest, 2.5 km and 3.4 km, respectively. The spatial distribution patterns of SOM and STN were different. At county scale, the SOM and STN concentrations showed decreasing trends from the northeast to the southwest across the county, and topography, soil types, soil texture and land use types were the main influencing factors. At the plain scale, the SOM and STN exhibited a similar spatial distribution pattern as at the county scale, and soil types and farming practices were the main factors affecting the SOM and STN distribution patterns. At town scale, SOM and STN showed relatively uniform distributions, and soil texture and farming practices were the main affecting factors. It was concluded that manipulation of farming practices and land use types should be considered for improving SOM and STN levels in soils.

1. Introduction

Soil organic matter (SOM) and soil total nitrogen (STN) are key indicators for assessing soil quality (Pan et al., 2009). They are also important as sources and sinks in global carbon and nitrogen cycles (Lal, 2004). Assessing SOM and STN variability has become one of the most active areas of research in soil and environmental sciences (Garten et al., 2007; Lin et al., 2005; Liu et al., 2008; Yemefack et al., 2005). SOM and STN contents are the result of interactive and complex physical, chemical and biological processes so that the distribution of SOM and STN is characterized by high spatial heterogeneity (Lal, 2004). Since the 1980s, numerous researchers have investigated the spatial variability of SOM and STN and there are many reports on the spatial variability of SOC and STN at field scale (Al-Kaisi et al., 2005; Cambardella et al., 1994; Hu et al., 1999; Liu et al., 2010). These studies revealed that differences in fertilization, cropping system, tillage method, and other farming practices were the main factors responsible for spatial variations in SOM and STN at field scale.

Many studies have also reported spatial variability of SOC and STN at regional scale (Hu et al., 2007; Huang et al., 2007; Liu et al., 2006; Wang et al., 2010a; Yimer et al., 2006; Zhang et al., 2009). They found that the main factors affecting the spatial distribution of SOM and STN at regional scale included climate (Ganuza and Almendros, 2003; Guo et al., 2006; Wang et al., 2010b), topography (Seibert et al, 2007; Yimer et al, 2006), soil types (Liu et al., 2006; Zhang et al., 2009), soil texture (Hu et al, 2007; Kong et al, 2009; McGrath and Zhang, 2003), land use types (Luo et al., 2010; Wang et al., 2009; Yuan et al., 2007), land use change (Liu et al., 2009; Zhang et al., 2007a) and farmer practices (Huang et al., 2007; Zhang et al., 2009).

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SOM and STN possess different spatial structures as a result of differing soil parent material (soil type and texture), climate, topography, land use, and anthropogenic activities, (Lal, 2004). The spatial variabilities of SOM and STN are scale-dependent, e.g. the characteristics of certain spatial structure are manifested at specific spatial scale. Their spatial heterogeneity is also a function of scale (Heuvelink and Webster, 2001; Lin et al., 2005; Walter et al., 2003; Wang et al., 2010c). Hence, research on a single spatial scale cannot fully explore and exploit the information on spatial structures of these soil properties.

Spatial variability of SOM and STN concentrations can vary greatly between scales. Coefficients of variation for SOM in soils under grassland in the USA were found to increase with increasing scale, which was 39% at county scale, 54% at state scale, and 63% at national scale (Conant and Paustian, 2002). It was also reported that variations of mineral soil C concentrations and soil C:N ratios increased when spatial scale increased from small (1 m) to large (1 km) in a forest ecosystem in east Tennessee, USA, but spatial variability of soil mineral N concentration did not increase with increasing spatial scale (Garten et al., 2007). Multi-scale characterization of SOM variability sources within an agricultural landscape mosaic system in southern Cameroon showed that at the regional level it was affected by soil formation factors (i.e. rainfall, geology and elevation), at the local level it was affected by land use, while at within-plot level it was mainly caused by shifting cultivation crop fields (Yemefack et al., 2005). Soil erosion was the main factor affecting spatial variability of SOM and STN at village and watershed scales, whereas soil type was the main factor at farm scale in Lianshuihe watershed, Jiangxi Province of China (Zhang et al., 2007b). At regional scale climatic factors had a larger effect on SOM accumulation than soil texture, whereas at city and county scales, the influence of soil texture on SOM accumulation was more important than climatic factors (Wang et al., 2010b). However, few studies have analyzed the factors that influence the distribution of SOM and STN at a range of spatial scales. There is a lack of information on SOM and STN spatial variability and their links to the overlaying factors of topography, soil types, soil texture, land use types and farming practices.

Pinggu County is located in the northeast of Beijing, and has a complex topography with various land uses and soil types. Three nested spatial scales, including the entire Pinggu County, the plain area and the town of Machangying, were selected for study due to the geographic, agricultural and economic importance of the areas. The objectives of the study were to compare the spatial patterns of SOM and STN at three spatial scales: county, plain-area and town levels, and to explore the main factors affecting SOM and STN distribution at each scale.

2. Materials and methods

2.1. Study area

The study was conducted in Pinggu County with an area of 1075 km^2, located in the eastern part of Beijing City (116°55′-117°24′ E, 40°02′-40°22′ N). Pinggu County is situated at the intersecting area of southern Yanshan Mountain and northern North China Plain. The entire county slopes from the northeast towards the southwest with relative elevation varying between 13 and 1230 m (Fig. 1). The main soil types are brown soil, cinnamon soil and aquic soil (Shi et al., 2006). The soils correspond with Udalfs, Ustalfs or Ustepts, and Fluvents, respectively, according to the USDA Soil Taxonomy (Soil Survey Staff, 1998). The county has a mean annual precipitation of 639.5 mm, of which 75% is concentrated in the summer season. The average annual air temperature is 11.5 °C and frost-free period is 191 days. The region is classified as having a temperate monsoonal climate.

The county has 17 towns and 275 villages with a total agricultural land of 950 km^2. The county is also an important peach fruit production area for Beijing. The overall vegetation coverage is 51%. *Tabulaeformis*, *Oriental arborvitae* and *Aspen* dominate the medium-elevation mountains in the northeastern part of the county. Low- and medium-elevation hills and tableland are mainly distributed in the northwest, north, east and southeast of the county, forming a semi-circular strip where most of orchards can be found. The plain area (elevation <50 m) is distributed in the center and southwest, which is the main production area for grains and vegetables (Fig. 1).

2.2. Sampling at different scales and laboratory analysis

The entire Pinggu County was treated as the large scale for the study. For medium-scale analyses, we selected the plain area of the county with a total agricultural land area of 289.4 km^2 (Fig. 2b), which is mostly used for grain and vegetable production. The investigation of small scale spatial variability was conducted at Machangying Town in southwestern Pinggu, with a total agricultural land of 28.6 km^2, and an elevation of 13–30 m (Fig. 2a), with the objective of gaining more precise information on the impacts of human activities and farming practices on spatial variability of SOM and STN.

Information of soil type and land use were collected for the entire county. We defined the sampling locations on a relatively large grid (about 400 m × 400 m) for the entire Pinggu County and plain area scales, and on a relatively small grid size (about 100 m × 100 m) for

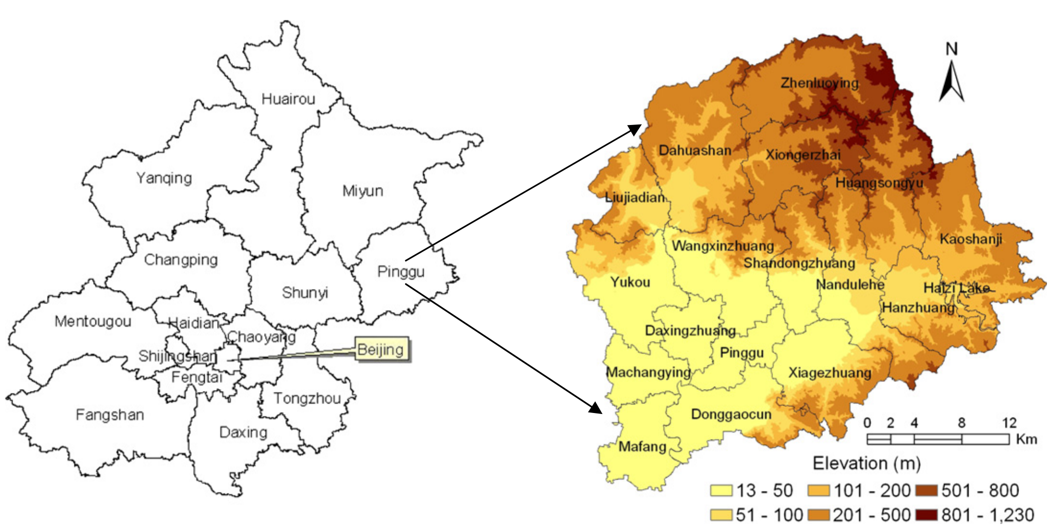

Fig. 1. Elevation and towns of Pinggu County, Beijing.