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Multivariate and geostatistical analyses of the spatial distribution and sources of heavy metals in agricultural soil in Dehui, Northeast China

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HIGHLIGHTS

- The extent of metal accumulation in agricultural soil in Dehui.
- Potential sources of metals in agricultural soils.
- Spatial distribution of heavy metals in Dehui.

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ABSTRACT

The characterization of the content and source of heavy metals in soils are necessary to establish quality standards on a regional level and to assess the potential threat of metals to food safety and human health. The surface horizons of 114 agricultural soils in Dehui, a representative agricultural area in the black soil region, Northeast China, were collected and the concentrations of Cr, Ni, Cu, Zn, and Pb were analyzed. The mean values of the heavy metals were 49.7 ± 7.04, 20.8 ± 3.06, 18.9 ± 8.51, 58.9 ± 7.16, and 35.4 ± 9.18 mg kg^{-1} for Cr, Ni, Cu, Zn, and Pb, respectively. Anthropic activities caused an enrichment of Cu and Pb in soils. However, metal concentrations in all samples did not exceed the guideline values of Chinese Environmental Quality Standard for Soils. Multivariate and geostatistical analyses suggested that soil Cr, Ni, and Zn had a lithogenic origin. Whereas, the elevated Cu concentrations in the study area were associated with industrial and agronomic practices, and the main sources of Pb were industrial fume, coal burning exhausts, and domestic waste. Source identification of heavy metals in agricultural soil is a basis for undertaking appropriate action to reduce metal inputs.

1. Introduction

Soil contamination with heavy metals draws great attention due to its potential threat to food safety, human health, and its detrimental effects on soil ecosystems (Cui et al., 2004). Excessive accumulation of heavy metals in agricultural soils can be transferred from soil to the other ecosystem components, such as underground water or crops, and can affect human health through the water supply and food web (Micó et al., 2006; Kumar Sharma et al., 2007; Zhuang et al., 2009). Food consumption has been identified as the major pathway of human exposure compared to other ways of exposure such as inhalation and dermal contact (Schuhmacher et al., 1991; Järup, 2003; Notten et al., 2005). Much of the information with regard to the risks associated with lifetime low level exposure from food ingestion derive from studies in Japan and China, where local populations were exposed to contaminated food crops, principally rice (McLaughlin et al., 1999). Hence the accumulation of heavy metals in soil is of increasing concern due to the food safety issues and potential health risks.

The black soil region in Northeast China is one of the major maize-producing areas in China. The cropping area and annual total yield of maize in this region are 6.54 Mha and 42.5 Mt, accounting for 25% of the total national sown area of maize and 31.9% of the total national maize yield (He et al., 2010). The black soil is fertile and productive due to its parent material, climate, and natural vegetation characteristics (Liu et al., 2010), making the black soil region as the major base for commercial grain production. However, cultivated area and tillage intensity increase rapidly with the grain demand, which has resulted in the incorporation of heavy metals to soil due to the excessive use of agrochemicals (Micó et al., 2006). Concentrations of lead, cadmium, and zinc in more than 60% of the samples in the black soil region were higher than the regional background levels (Guo and Zhou, 2006). However,

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few people realize that soil in the black soil region is contaminated, and most of the works carried out on heavy metals in this region have focused on urban and suburban soils (Cao et al., 2009). This has threatened the sustainability of crop production in northeast China, and may poses potential barriers for international trading of foodstuffs (Cui et al., 2004).

In 2011, The World Bank and Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences initiated a collaborative research program to assess the environmental baseline values of agricultural producing area in Jilin province. The present study, as part of this project, addressed the content, spatial distribution and possible sources of heavy metals in agricultural soils in Dehui, a representative agricultural area in Jilin province. The characterization of the content and sources of heavy metals in soil are necessary to reduce metal inputs and to establish quality standards on a regional level that allow the detection of sampling sites affected by pollution (Micó et al., 2006).

2. Materials and methods

2.1. Study area

Dehui County (44°02′–44°53′N, 125°14′–126°24′E) is located in the middle part of Changchun, Jilin province, Northeast China (Fig. 1). The study area is in the North Temperate Zone, with a continental monsoon climate. Average annual temperature is 4.4 °C, with 144 frost-free days. Average rainfall is 520.3 mm, and more than 70% of the rainfall occurs in June, July, and August. The topography in the black soil region is characterized by undulating plateau with slopes of 1–5°. The soils are black soil (Luvic Phaeozem, FAO), chernozem (Haplic Chernozem, FAO), and meadow soil (Eutric Vertisol, FAO) (Liu et al., 2006).

The study area has been traditionally associated with agricultural activities, and is the base for commercial grain production. The county covers 3435 km^2 and approximately 2146 km^2 are agri-

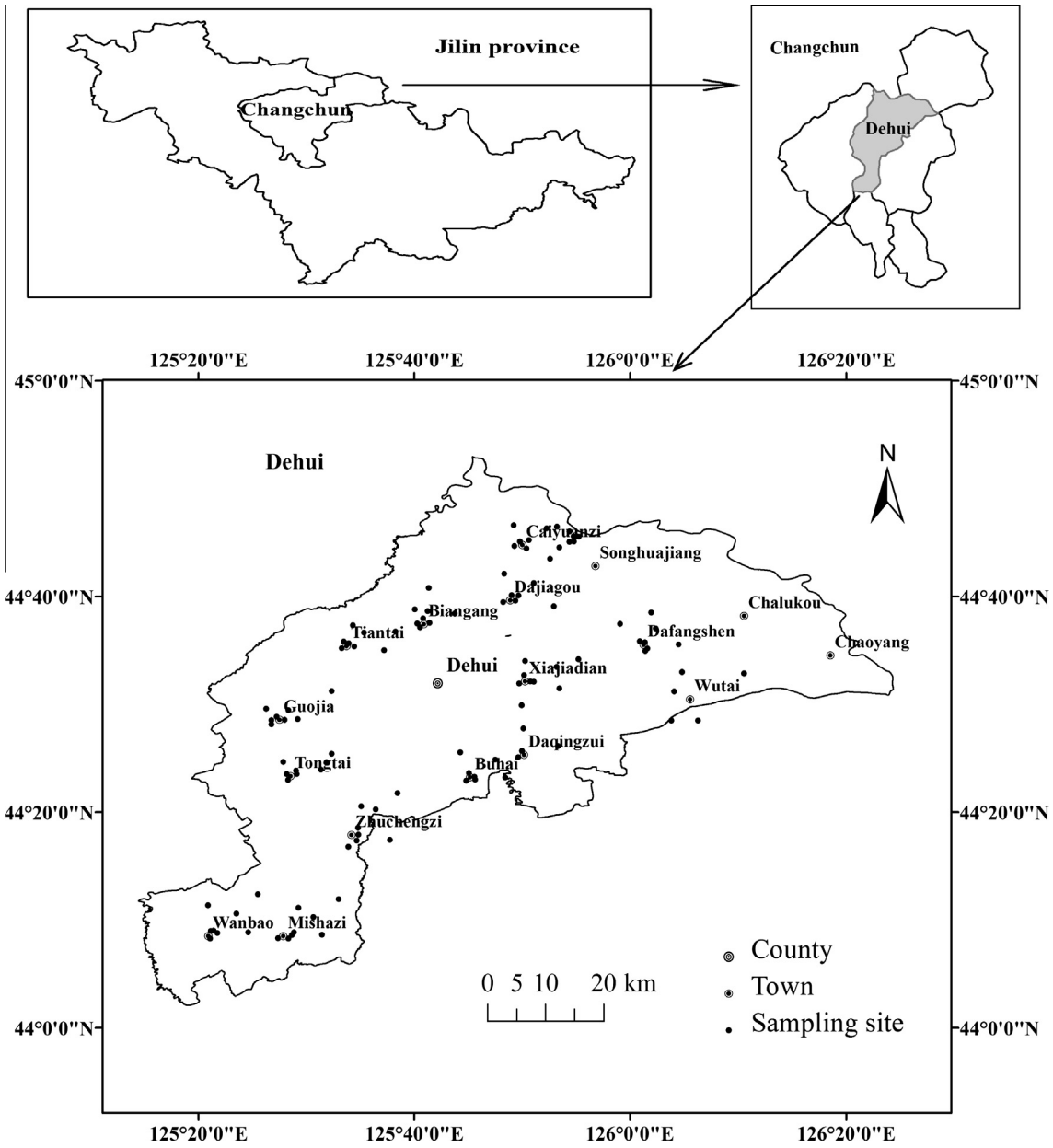

Fig. 1. Location of the sampling sites.