Catena 171 (2018) 588–601

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

# The influence of the conversion of grassland to cropland on changes in soil organic carbon and total nitrogen stocks in the Songnen Plain of Northeast China

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ARTICLE INFO

*Keywords:*
Land use change
Cultivation
Random forest
Digital soil mapping
Uncertainty

ABSTRACT

The soil organic carbon (SOC) and total nitrogen (TN) of topsoil could be greatly affected by the conversion of grassland to cropland (CGC) due to vegetation harvesting and soil erosion. However, few studies have evaluated the effects of these changes in the subsoil and distinguished its main controls at the regional scale. This paper investigated the total changes in the SOC stock ($SOC_S$) and TN stock ($TN_S$) of soils from 0 to 30 cm and 0–100 cm in depth over the past three decades in the Songnen Plain, China, a typical Mollisol region. The CGC resulted in a moderate loss of topsoil C and N but an increase in subsoil C and N, and the soil mapping results showed that approximately $7.47 \times 10^{11}$ kg C and $1.51 \times 10^{11}$ kg N were accumulated during the past three decades. Prediction uncertainty was assessed by 100 model runs with random jackknife partitions, and high uncertainty was found in the areas with rapidly changing $SOC_S$ and $TN_S$ levels. Our findings indicated that subsoil should be considered in the estimation of the $SOC_S$ and $TN_S$ at the regional scale. The $SOC_S$ and $TN_S$ of the CGC areas were anticipated to increase after long-term cultivation. In view of ongoing cropland expansion, up-to-date land use and soil type data are vital for selecting monitoring sites and understanding long-term soil evolution at the regional scale.

## 1. Introduction

At least one-third of total terrestrial C is stored in the grassland (Ding et al., 2013). The conversion of grassland to cropland (CGC) can directly cause the emission of soil C and N due to anthropogenic disturbances such as vegetation harvesting and potential soil erosion. As critical indicators of soil quality, the soil organic carbon (SOC) and total nitrogen (TN) concentrations greatly impact soil functions and global climate change. Soil respiration is the second-largest terrestrial carbon flux and has generated 10 times more C than fossil fuel burning (IPCC, 2007). N cycling also has significant impacts on soil nutrient status and $NO_x$ levels in the atmosphere. Therefore, investigating the effect of CGC on the SOC stock ($SOC_S$) and TN stock ($TN_S$) is necessary for understanding global C and N dynamics.

In the past 30 years, wide attention has been drawn to the soil degradation of Mollisols (USDA Soil Taxonomy) (Soil Survey Staff, 2010) in the Songnen Plain of Northeast China, which is famous for its productivity and fertility. Mollisols have been referenced in other classification systems as Phaeozems, Chernozems and Kastanozems (World Reference Base (WRB), IUSS Working Group WRB, 2006); as Isohumosols (Chinese Soil Taxonomy) (Gong, 1999); and as black soils (Chinese Soil Genetic Classification) (Xiong, 1987). The USDA Soil Taxonomy was adopted in this study. The land use of the Songnen Plain rapidly changed and the cultivation of grassland mainly contributed to the cropland (Ding et al., 2013; Tian et al., 2016). Many studies on the factors influencing SOC changes (Zhao et al., 2006) and $SOC_S$ and $TN_S$ have been conducted (Zhang et al., 2012). Nevertheless, information on $SOC_S$ and $TN_S$ in the Songnen Plain remains inconsistent. Some results reported that the $SOC_S$ continuously decreased under various land use types and ecosystems (Xi et al., 2011; Zhao et al., 2015). Up to 24.8% of the SOC content in the plow layer was lost after 200 years of tillage (Yu et al., 2004). However, an increasing trend in $SOC_S$ was observed by Pan et al. (2010) and Zhang et al. (2010). Most of the published studies focused on the topsoil, which might underestimate SOC storage (Han et al., 2004; Xia et al., 2017). Therefore, accurately accounting for soil variation within 1 m of soil depth remains a challenge for evaluating

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https://doi.org/10.1016/j.catena.2018.07.045
Received 15 December 2017; Received in revised form 22 July 2018; Accepted 31 July 2018
0341-8162/ 

the effects of the CGC on soil C and N storage.

Spatial prediction of SOC and TN by digital soil mapping techniques (Harrison et al., 2011; Zhang et al., 2011) requires sufficient environmental information to account for the spatial soil patterns. Detailed information on tillage management is necessary for evaluating the effect of anthropogenic disturbances on agricultural soil. Nevertheless, recordings of these data over long periods are usually hard to collect, especially for farmlands whose ownership is very scattered. Indirect and cheap covariates, such as terrain attributes and land use, are usually adopted. Thus, revealing the causative factors for changes in SOC and TN stocks is helpful to selecting appropriate covariates for soil mapping at the regional scale.

This paper investigated the changes in the $SOC_S$ and $TN_S$ after the CGC in the Songnen Plain over the past three decades. The black soil regions, rather than the continuous pure area of Mollisols, were investigated. The SOC density ($SOC_d$) and TN density ($TN_d$) were predicted for the soil depths of 0–30 cm and 0–100 cm as the amount of topsoil only represented a portion of the total stocks in the soil profile. Our main objectives were to i) quantify the effects of the CGC on the $SOC_S$ and $TN_S$ as a function of depth, ii) identify the main factors controlling the $SOC_S$ and $TN_S$, and iii) estimate the regional changes in the $SOC_S$ and $TN_S$ in terms of different soil types, land use and vegetation types.

## 2. Materials and methods

### 2.1. Study area

The study area is located in the Songnen Plain (Fig. 1) and ranges from 122°16′ to 128°19′E and 43°06′ to 50°17′ N with an area of 211,400 km$^2$. The Songnen Plain is often considered the typical Mollisol area (Duan et al., 2010). The climate is temperate and cold temperate continental monsoon, with a mean annual air temperature (MAAT) of 3.3 °C and a mean annual precipitation (MAP) of 504 mm. The summers are cool and short, but the winters are cold and long. The elevation ranges from 83 to 916 m, and the average slope is 1.9%. There are three main soil types (suborder): Udolls, Udepts and Udalfs (Soil Survey Staff, 2010). Soil type was interpreted to USDA Soil Taxonomy from the classifications of Chinese Soil Taxonomy and Chinese Soil Genetic Classification and profile descriptions. Grasslands diminished significantly in the twentieth century, with the area of cropland cover rapidly increasing from approximately 10% to 60% (Ye and Fang, 2011). Since the 1940s, the area of grassland in Northeast China has declined steadily, and > 62.6% of the land has been reclaimed for agriculture.

### 2.2. Soil database

Two soil sampling campaigns, including the Second State Soil Survey of China (SSSSC) in the 1980s (The National Soil Survey Office, 1995) and the soil series survey in the eastern region of China from 2010 to 2012, were conducted in this area. The SSSSC was the most comprehensive soil survey in the 1980s (Shangguan et al., 2013) and recorded detailed pedological information and chemical and physical properties. In view of the representative soil-forming environment (e.g., soil type and land use), 103 soil profiles with a depth of 1 m or to bedrock were collected from the SSSSC. The numbers of soil samples taken in the 1980 study from barrens, grasslands, croplands, forests and wetlands were 14, 26, 59, 1 and 3, respectively.

The national soil series survey of the 2010s aimed to identify a group of soil pedons developed from similar environments (i.e., parent materials, climate and land cover). In theory, the SOC or TN values in the 1980s should be taken as the reference baseline, and repeated samplings should be taken at the settled points of the 1980s. Therefore, the sampling sites were comprehensively guided by the soil-forming information of the points of the 1980s study to be as similar as possible to those points. Composite samples of 1 kg mass were taken at each genetic horizon, and their pedogenetic features were described in field according to the Soil Taxonomy guidelines. The duration of cropland cultivation was determined by communicating with local farmers in

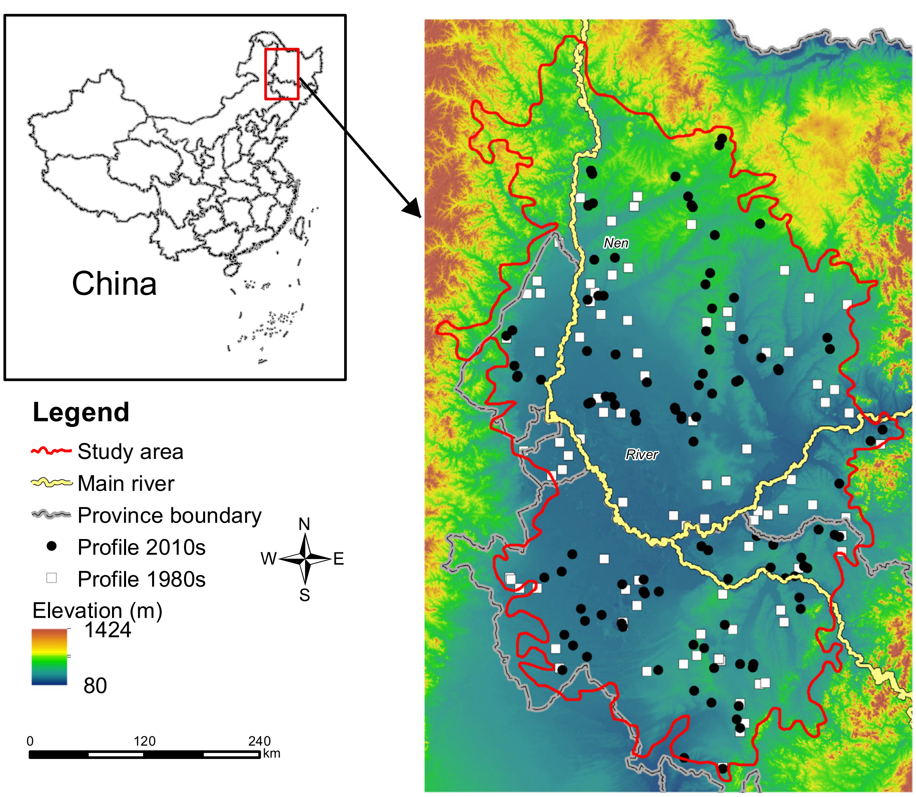


**Fig. 1.** Distribution of sampling sites in the study area. The white solid squares and black solid circles denote the sampling sites in the 1980s and 2010s, respectively.