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Organic carbon and total nitrogen dynamics of reclaimed soils following intensive agricultural use in eastern China

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ABSTRACT

In past decades, coastal tidal flats in China have experienced rapid and extensive agricultural reclamation due to the increasing pressure of population growth. With more coastal land likely reclaimed in the future, an increase in the understanding of the effects of the reclamation history and changes in land use on soil properties is essential. In this study, a total of 746 surface soil/sediment samples were collected from three study areas with different reclamation durations and land use patterns on the coasts of Dafeng, Rudong and Cixi in eastern China, covering a total area of 1926 km^2. The results showed that mean soil organic carbon (SOC) and soil total nitrogen (STN) in the three study areas differed slightly and ranged from 7.24 to 7.69 $g\,kg^{-1}$ and from 0.71 to 0.76 $g\,kg^{-1}$, respectively. SOC and STN increased significantly with an increase in reclamation duration in all of the study areas, except for the early stage of land conversion in Cixi and the late stage of conversion in Dafeng, which highlighted that the accumulation of SOC and STN was positively correlated with reclamation duration. In Dafeng and Rudong, land dominated by human uses had much higher levels of SOC and STN than those in the tidal flats. For the same duration of reclamation, paddy land had higher levels of SOC and STN than those in the upland, with the exception of the 10-year-old land in Cixi. Our results also indicated that reclaimed coastal soils can sequester considerable amount of OC through improved land management. The differences in the sequestration potential for OC and the dynamics of SOC and STN among the three chronosequences were attributed to specific land use patterns in each study area.

1. Introduction

Soil organic carbon (SOC) and soil total nitrogen (STN) are two important components with key roles in mitigating global warming, alleviating land degradation, enhancing crop production and improving food security (Davidson and Janssens, 2006; Lal, 2003, 2004). Globally, approximately two- or threefold more SOC is stored in the upper 100 cm of soil than the carbon stored in either the atmosphere or terrestrial vegetation (Lal, 2004; Schmidt et al., 2011). Thus, a slight reduction in SOC could significantly increase atmospheric CO_2 concentrations (Liu et al., 2011). Nitrous oxide (N_2O) is also a potent greenhouse gas, with a 100-year global warming potential 298-fold greater than that of CO_2 (Butterbach-Bahl et al., 2013). The emission of N_2O from soils represents 56–70% of all global N_2O sources (Syakila and Kroeze, 2011). SOC and STN are primary determinants and indicators of soil fertility and quality and are closely correlated with soil productivity (Lal, 2004; Wang et al., 2009). To predict greenhouse gas emissions and develop strategies for sustainable land use, a better understanding of SOC and STN dynamics and the factors that affect these parameters at different scales is essential (Hu et al., 2007; McGrath and Zhang, 2003). Tidal flats reclamation has been a common practice to obtain new land in China and many other countries for thousands of years (Cheng et al., 2009; Fernández et al., 2010; Wolff, 1992). In China, approximately 51% of natural coastal wetlands have been converted to other types of land use since the 1950s (An et al., 2007). The total area of reclaimed land reached more than 260,000 ha from 1951 to 2007 in eastern China (Zhang et al., 2011), and the trend in coastal land conversion will continue into the foreseeable future (Yin et al., 2016). Therefore, a further understanding of soil property dynamics following reclamation is required for the sustainable management of reclaimed land.

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The soil chronosequence, the result of lands reclaimed at different periods, is a very useful tool for a space-for-time approach in the study of the evolution of soil properties (Walker et al., 2010). Studies using this approach demonstrate clear temporal dynamics of soil properties (Kölbl et al., 2014; Zou et al., 2011). In some studies, reclamation of coastal wetlands has positive effects on SOC and STN accumulation (Jin et al., 2013; Roth et al., 2011), and the SOC sequestration potential of reclaimed soils was not exhausted even after 2000 years of rice cultivation (Wissing et al., 2011). By contrast, SOC and STN of reclaimed soils derived from coastal wetlands decreased at certain stages after reclamation in some studies (Fu et al., 2014; Iost et al., 2007). Thus, further studies are required to reveal the factors leading to these differences.

Land use and changes in land use are primary driving factors that significantly affect carbon and nitrogen cycles in terrestrial ecosystems and are the second largest source of human-induced greenhouse gas emissions (Don et al., 2011; Houghton et al., 2000; Watson et al., 2000). Considerable efforts are expended to study the effects of land use and land use change on SOC and STN sequestration and greenhouse gas emissions (Cookson et al., 2007; Miles and Kapos, 2008; Deng et al., 2014; Schaufler et al., 2010; Wiesmeier et al., 2015). In reclaimed coastal lands, SOC and STN are widely used as sensitive indicators of land use and land management (Bai et al., 2013; Roth et al., 2011; Santín et al., 2009). Several studies revealed significant differences in levels of SOC and STN between paddy land and non-paddy land over a thousand-year time scale in the coastal region of eastern China (Cheng et al., 2009; Cui et al., 2012; Kölbl et al., 2014; Roth et al., 2011; Wissing et al., 2014). Laudicina et al. (2009) reported that land management practices also had considerable effects on SOC and STN levels in reclaimed saltmarsh by altering rates of OM decomposition and nutrient removal. However, few studies have addressed the effects of different land uses and land management practices on the dynamics of SOC and STN over a time scale of decades in a reclaimed coastal region. The response of soil properties to changes in land use is more sensitive at the early

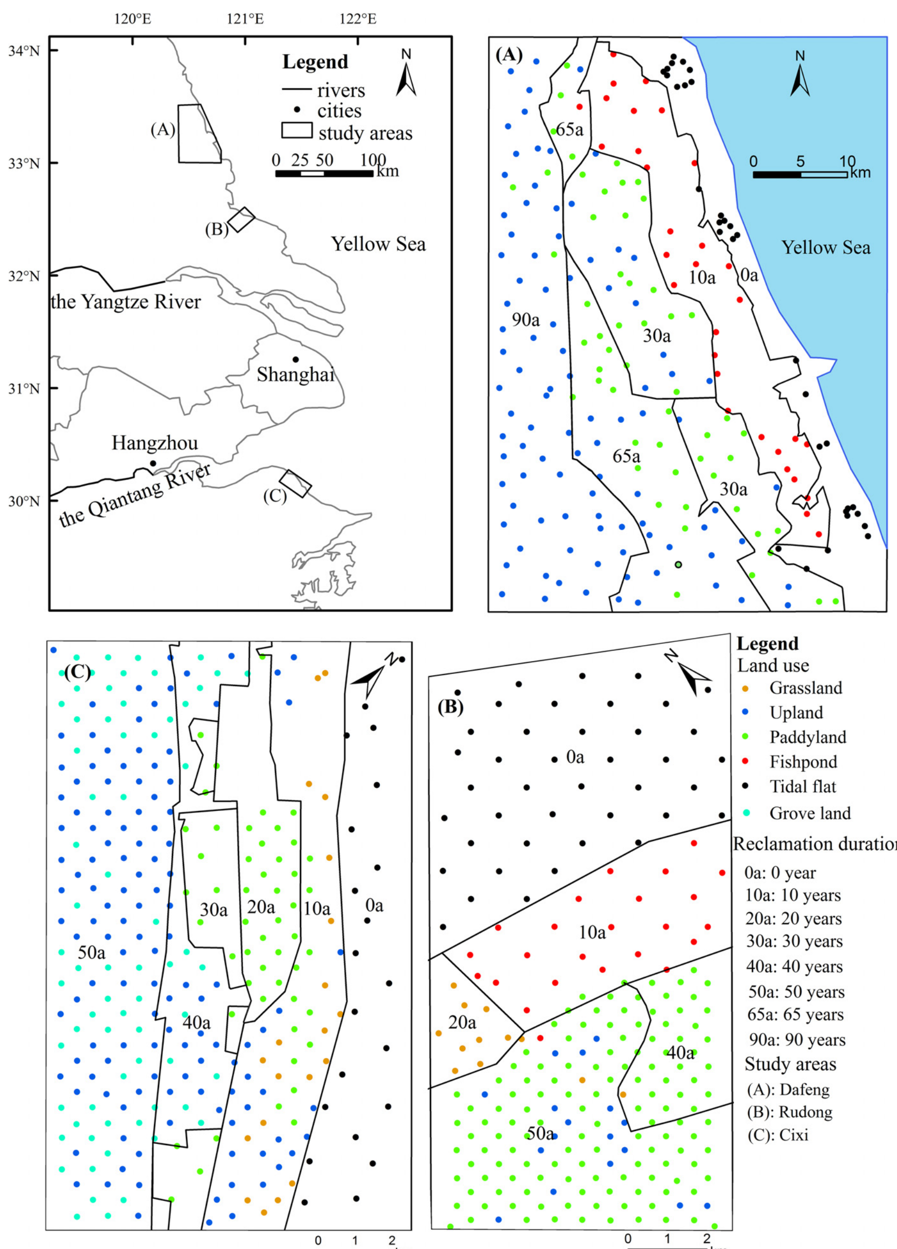

Fig. 1. Locations of the study areas and the sampling sites.