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Changes of soil labile organic carbon fractions and their relation to soil microbial characteristics in four typical wetlands of Sanjiang Plain, Northeast China

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ABSTRACT

Soil labile organic carbon (LOC) fractions can response rapidly to environmental change and are essential to soil C cycling. There has been very little evaluation about the distribution differentiation of soil LOC factions in high-altitude wetlands. In this study, four typical wetland types were investigated in Sanjiang Plain of northeast China, including: (1) a mixed *Calamagrostis angustifolia* and *Salix brachypoda* (CSW), (2) *Calamagrostis angustifolia* wetland (CAW), (3) *Carex lasiocarpa* wetland (CLW) and (4) *Phragmites australis* wetland (PAW). The variation in soil LOC fractions of these wetland soils and their relationship with microbial characteristics were studied by analyzing the changes of dissolved organic carbon (DOC), microbial biomass carbon (MBC), easily oxidation carbon (EOC), soil microorganisms (bacteria, fungi, and actinomyces) and enzyme activities (invertase, cellulase and catalase). The results indicated that the contents of soil LOC fractions declined with increasing of soil depth in each wetland. At 0–30 cm depth, the highest mean DOC content in seasonal flooded CAW, while the greatest average content of both MBC and EOC was in the drained CSW. The proportions of soil DOC, MBC and EOC to SOC account for 0.27–0.63%, 1.27–5.94% and 19.63–41.25%, respectively. Compared with two long-term flooded CLW and PAW, CAW and CSW showed higher soil LOC concentrations and proportions. In terms of soil microbial flora, bacteria number was the most, followed by actinomycetes and fungi number was the least in each wetland. The three microbial species populations decreased with soil depth in the four wetlands. The average microbial total amount was ranked in the order of CAW > PAW > CSW > CLW at 0–30 cm depth. The higher soil activities of invertase, cellulase and catalase were observed in the surface soil layer for all wetlands. The three enzyme activities in CSW and CAW were significantly higher than that in CLW and PAW at 0–30 cm depth. Soil LOC fractions were significantly related to SOC in the four wetlands ($p < 0.01$), and positive correlation with microbial total number, bacteria, fungus and actinomyces in CSW and CAW ($p < 0.01$). Whereas no significantly correlated were observed between LOC fractions and fungus or actinomyces in CLW and PAW. Except for catalase activity of CAW, soil LOC fractions had significantly correlation with three enzyme activities in the four wetlands ($p < 0.05$). The results have important implications that microorganism and enzyme activities are good indicators for predicting minor changes of soil LOC fractions, especially in no-flooding CSW and CAW.

1. Introduction

Wetland soils store 45–70% of terrestrial organic carbon (Mitra et al., 2005) and are responsible for nearly 25% of global methane (CH_4) emissions (Conrad, 2009). Hence, wetland ecosystems may play a pivotal role in global warming, due to their high soil carbon density. Soil labile organic carbon (LOC) fractions (i.e., dissolved organic carbon (DOC), microbial biomass carbon (MBC) and easily oxidizable carbon (EOC)) can respond to soil disturbance more rapidly than total organic carbon (SOC) (Ghani et al., 2003; Hanes, 2005), they are good indicators for predicting minor changes of SOC. Although LOC accounts for a small part of total SOC pool, it is vital in regulating nutrients availability to plants and microbes, as well as catalyzing the transformations of these nutrients in the soil

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(Haubensak et al., 2002). Furthermore, it is very sensitive to changes in the vegetation community and soil microclimate, which can result from environmental changes (Cheng et al., 2008). Any changes in these factors would necessarily alter soil LOC content.

Soil microorganism plays a vital role in soil structure maintenance, organic matter decomposition, biogeochemical cycling, and plant nutrient availability (Douterelo et al., 2010; Falkowski et al., 2008). The change of microorganisms not only may affect soil CO_2 emissions and soil carbon loss (Carney et al., 2007; Allison et al., 2010), but also promote carbon sequestration in soils (Six et al., 2006). Some studies have indicated that soil microbial community structure and diversity are correlated with the variations of soil organic carbon (Marschner et al., 2003; Cookson et al., 2005). Soil enzymes produced by microbes play key roles in the process of SOC mineralization (Ahn et al., 2009). They catalyze the decomposition of different organic substrates, release plant nutrients and influence whether SOC is depleted or sequestrated (Fansler et al., 2005). Some of the enzyme activities were correlated with the LOC fractions, which were confirmed by some previous studies (Brzezińska et al., 2005; Acosta-Martínez et al., 2007). Therefore, soil microorganism and enzymes are important factors on influence the process of soil carbon cycle.

The Sanjiang Plain in the northeast China has the largest distribution area of fresh water wetlands about 1.04×10^4 km^2. More than 60% of the wetland soil is gley, which occurs in the floodplains adjacent to the rivers and is largely devoid of peat (Zhao et al., 2011). The wetlands of Sanjiang Plain are noteworthy for its rich biodiversity, but they continue to decline in area and deteriorate in quality currently. Nowadays, as concern about global warming has intensified, numerous studies on the ecological functions of Sanjiang Plain wetlands mainly pay attention to greenhouse gas emission, soil respiratory processes, carbon sinks and carbon storage capacity, as well as soil organic carbon content (e.g., Li et al., 2012; Zhao et al., 2012; Bao et al., 2011). However, few studies have considered the factors influencing the variability of soil SOC pools from microbial characteristic aspects. Therefore, clarifying the dynamic changes of soil LOC fractions associated with the microbial mechanisms in different types of wetlands could guide management practices aimed at maximizing carbon storage in wetlands.

In this study, four typical wetlands, which located in Honghe International Nature Reserve of Sanjiang Plain, were selected for this investigation. Our aims were to: (i) assess the differences of the several soil LOC fractions (i.e., DOC, MBC and EOC) among the four typical wetlands; (ii) analyze the relationships between soil LOC fractions and microorganism, enzymes activity; (iii) explore the major impact factors of soil microbial characteristics. Our results will make clear the mainly microbe factors influencing the distribution of soil LOC fractions and provide valuable information for improvement of carbon sink capability in the wetlands of Sanjiang Plain.

2. Materials and methods

2.1. Study areas

The study was conducted in October 2013 in Honghe International Nature Reserve (133°34′38″–133°46′29″E, 47°42′18″–47°52′00″N), which is located at the junction of Tongjiang city and Fuyuan county of Sanjiang Plain in China. The wetland, with an area of 250.9 km^2, is a typical alluvial floodplain which was formed by the Heilongjiang River, the Songhuajiang River and the Wusulijiang River (Fig. 1). This district is characterized by a temperate humid continental monsoon climate. The annual mean precipitation is 585.9 mm, and 58.5% of the gross precipitation falls between July and September. The average monthly temperature ranges from −23.4 °C in January to 22.4 °C in July, and with a mean annual temperature of 1.9 °C. The annual average relative humid is 67.5% and wind speed is 6.5 m/s. The annual average sunshine hours are 2356.4 h, with effective accumulated temperature above 10 °C ranges from 2165 °C to 2624 °C. The climate data mentioned above comes from statistical data of Tongjiang city weather station from 1970 to 2013. The soil freeze period is more than five months each year and frozen depth reaches 160–180 cm (Li et al., 2011). Due to high primary productivity and rich biodiversity, Honghe International Nature Reserve has been listed as the International Importance Wetland by the Ramsar Convention since 2001 (Ref.). Nevertheless, there has been excessive excavation channels and farming around the reserve over the last 50 years, this has inevitably led to the damage

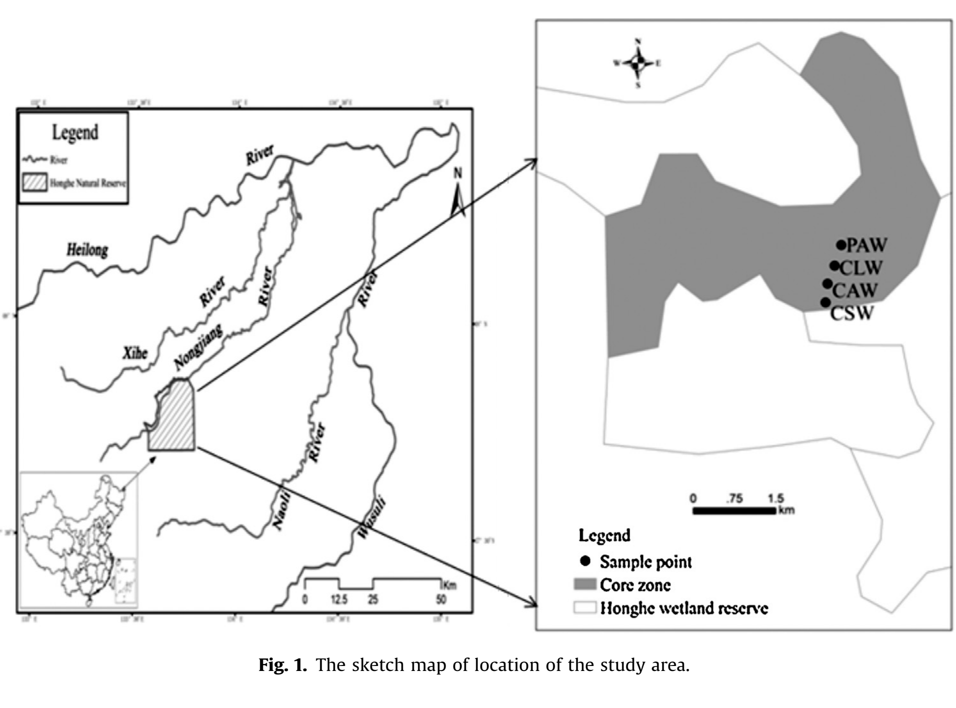

Fig. 1. The sketch map of location of the study area.