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Variability in soil microbial community and activity between coastal and riparian wetlands in the Yangtze River estuary – Potential impacts on carbon sequestration

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ABSTRACT

Wetlands are an important part of the global soil organic carbon pool and microorganisms play a pivotal role in carbon exchange between soils and atmosphere. Most wetland carbon studies have focused on boreal freshwater wetlands, especially peatlands. Less attention has been paid on the estuarine wetlands where variation in tide salinity can highly affect microbiology and carbon sequestration ability of the wetland soils. In this study, two representative estuarine wetlands in the Yangtze River estuary were chosen to determine the possible differences in microbial communities and activities between coastal (high salinity) and riparian (low salinity) zones of both wetlands. Over a 4-year period, the mean soil respiration of the coastal zones was significantly lower ($P < 0.05$) than that of the riparian zones in each wetland. Soil respiration activities measured in laboratory as well as dehydrogenase activity were also lower in the coastal than in the riparian zones of the wetlands. The differences in the microbial activities could be a result of the differences in the microbial community structure. The riparian wetlands had e.g. more β-Proteobacteria with strong heterotrophic metabolic activity than the coastal wetlands. Soil salinity correlated negatively to the abundance of β-Proteobacteria and thus respiration. The riparian wetlands received approximately the same organic matter from plant biomass compared with the coastal wetlands but have lower soil carbon content than the coastal wetlands. This could be associated to the higher microbial decomposition capacity in soils with low salinity.

1. Introduction

The soil carbon pool consists of soil inorganic carbon (SIC), which is relatively stable, and soil organic carbon (SOC), which is about three-fifths of the soil carbon pool (Lal, 2004). Organic carbon stored in soils has a dynamic exchange with atmospheric carbon. Small decrease in the SOC content can lead to a rise in the atmospheric CO_2 concentration (Mullen et al., 1999). Soil respiration (SR) is a primary way of soil carbon release (German et al., 2012) and annual emissions of CO_2 from human activities such as fossil fuel burning are small compared with that from SR (Singh et al., 2010; Nielsen et al., 2011). SR arises from plant root respiration, which includes the root-associated microorganisms, and respiration of microorganisms living in the soil (Gomez-Casanovas et al., 2012). Consequently microorganisms play a pivotal role in carbon exchange between land and atmosphere (Bardgett et al., 2008; Singh et al., 2010) and changes in soil microbial community composition, physiology, and activity may affect soil CO_2 emissions as well as soil carbon loss (Carney et al., 2007; Allison et al., 2010). On the other hand microorganisms can also promote carbon sequestration in soils and oceans (Six et al., 2006; Hu et al., 2010).

Wetlands are highly productive ecosystems with low rates of decomposition because of frequent flooded conditions, resulting in low microbial activity (Bernal and Mitsch, 2012). Therefore, wetlands have an important ecological and environmental function as a carbon sink (Brevik and Homburg, 2004; Bernal and Mitsch, 2008). Much attention has focused on interior freshwater wetlands, especially boreal peatlands (Gorham, 1991; Hirota et al., 2006). However, with increasing global warming, more studies have started to focus on carbon sequestration in estuarine and coastal

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salt marshes (Callaway et al., 2012; Kirwan and Mudd, 2012), which are generally characterized by high primary productivity (Palomo and Niell, 2009; Gonzalez-Alcaraz et al., 2012). Estuarine wetlands are an ecotone between river and marine ecosystems, where freshwater meets salt water and the land connects to the sea (Cowardin et al., 1979). Estuarine wetlands often have a combination of riparian mud flats and coastal mud flats. In addition, estuarine areas are generally economically developed, which means land use and human disturbances often threaten the preservation of the wetlands and their ecological function (Barbier et al., 2011). Therefore, understanding the differences between riparian and coastal mud flats in terms of ecological functions especially carbon sequestration is of great significance.

The Yangtze River Delta is the most economically developed area of China. The Yangtze River estuary possesses two major wetlands, the Jiuduansha wetland and the Chongming Dongtan wetland. Jiuduansha is the original wetland and is an important nature reserve in Shanghai (Qiao et al., 2012) spanning about 40 km from west to east. The western area is a riparian wetland, and the eastern area is a typical salt marsh. Chongming Dongtan is a young tidal wetland with the Yangtze River to the southeast and the East China Sea to the east and northeast (Li et al., 2010). Similar to Jiuduansha, the water salinity in the Chongming Dongtan wetland varies, increasing from south to north. The soil carbon sequestration capability of the Yangtze River estuarine wetlands and the factors influencing soil microbial respiration (SMR) in those areas have been reported in many studies (Yan et al., 2008; Guo et al., 2009; Li et al., 2010, 2011; Tang et al., 2011). Nevertheless, few studies have compared soil microbial properties of coastal and riparian areas in the estuarine wetlands and its implications for carbon sequestration.

Therefore, the objective of the current work was to describe the variability of soil microbial community and activity between coastal and riparian areas in the estuarine wetlands of Yangtze River and to consider if the carbon sequestration of the wetlands has links to their microbial characteristics. To accomplish this, we obtained soil samples from Jiuduansha and Chongming Dongtan over a 4-year period, and investigated the variability in plant biomass and respiration rates between coastal and riparian wetlands and if the physicochemical and microbial characteristics of the wetlands were associated to the respiration activity, i.e. loss of carbon.

2. Materials and methods

2.1. Site description

The Jiuduansha and Chongming Dongtan wetlands are the two main wetlands in the Yangtze River estuary (Fig. 1). The Jiuduansha wetland (31°03′ N–31°17′ N, 121°46′ E–122°15′ E) initially emerged above the water surface in the 1920s and rapidly became an independent wetland in the 1960s. After a half-century of dynamic evolution, the Jiuduansha wetland has become more or less stable. The wetland covers 423.2 km^2 and consists of the following three shoals: Jiangyananasha, Shangsha, and ZhongXiasha. The wetland was designated as a National Wetland Nature Reserve in 2005. The vegetation mainly includes *Zizania latifolia*, *Phragmites australis*, *Spartina alterniflora*, and *Scirpus mariqueter*. Chongming Dongtan wetland is a Ramsar wetland of international importance and is located at the east of Chongming Island (31°25′ N–31°38′ N, 121°50′ E–122°05′ E). The wetland covers 326 km^2, and the vegetation mainly includes *P. australis*, *S. alterniflora*, and *S. mariqueter*. The two wetlands are subject to the East Asia subtropical monsoon climate with an average annual temperature and precipitation of 15–17 °C and 1117–1200 mm, respectively.

2.2. Experiment design

After an in-depth field survey, Jiuduansha wetland (JW) and Chongming Dongtan wetland (DW) comprising coastal and riparian zones were selected for the study. The wetlands were close to their natural state. Two zones were selected in both wetlands. In JW, Jiuduansha Zone 1 (JZ1) was a riparian wetland at Jiangyananasha (near the Yangtze River, Fig. 1) with *Z. latifolia* being the dominant tidal plant (Table 1). Jiuduansha Zone 2 (JZ2) was a coastal wetland at ZhongXiasha in JW (near the East China Sea, Fig. 1) with *P. australis* and *S. alterniflora* being the dominant tidal plants (Table 1). *S. mariqueter* was distributed in the low tidal part of both

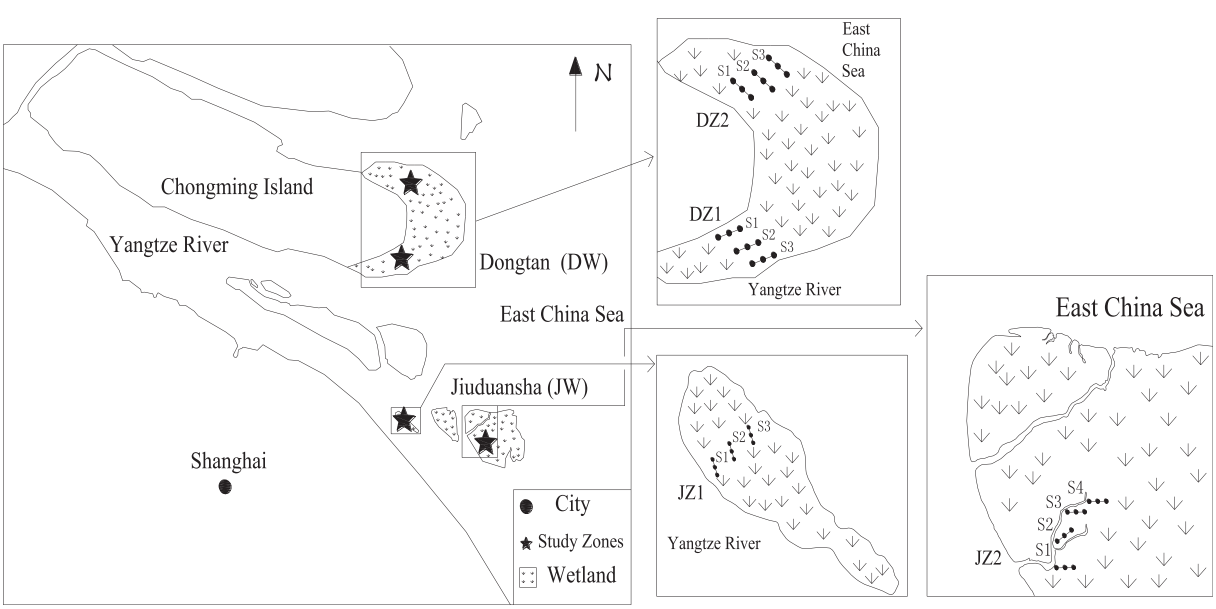

Fig. 1. Map of the study zones in the riparian (1) and coastal (2) wetlands of Jiuduansha (JZ) and Chongming Dongtan (DZ) of the Yangtze River estuary. S1, S2, S3, and S4: Sampling sites in each studying zone.