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Variable decomposition of two plant litters and their effects on the carbon sequestration ability of wetland soil in the Yangtze River estuary

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ABSTRACT

Highly efficient sequestration of carbon into soil by plants is crucial to wetland ecosystems under rising atmospheric CO_2. The carbon sequestration ability of wetland can be roughly evaluated from the amount of carbon fixed through plant's photosynthesis, but the decomposition properties of plant litter returning to soil are also essential to its evaluation. We examined litter decomposition of *Phragmites australis* (*P. australis*) and *Spartina alterniflora* (*S. alterniflora*), two dominant plants from Jiuduansha wetland in the Yangtze River estuary, returned to soil in-situ and ex-situ, to clarify their effect on soil respiration and carbon sequestration efficiency. Both mass and carbon content of *S. alterniflora* were lost faster than *P. australis* when their plant litters were returned to soil. Soil type exerted a significant effect on litter decomposition but not on plant ranking for decomposition rate (k). High moisture and low nitrogen content in the wetland soils resulted in the lower decomposition rates of litter, compared with inland soils. Litter properties were determining factors in ranking of decomposition rate, in which the k was negatively correlated with the lignin/N and C/N ratios, and positively correlated with the initial nitrogen content. *P. australis* had low nitrogen content, high lignin/N and C/N ratios, so it had the lower decomposition rate and soil respiration. Combine the plant biomass, litter decomposition and soil respiration, *P. australis* wetland possesses the higher carbon sequestration ability in the Yangtze River estuary than *S. alterniflora* wetland.

1. Introduction

Soil is the largest terrestrial carbon pool, even small changes in soil carbon could significantly influence CO_2 in the atmosphere (Schlesinger and Andrews, 2000; Nocita et al., 2015; Jiang et al., 2017). In the global carbon cycle, vegetation litter is the primary input of soil organic carbon that is eventually converted into histosol, and soil respiration is the main form of carbon flux from soil to the atmosphere (Whiting and Chanton, 2001; Moriyama et al., 2013).

Wetlands contain about 12–15% of the global carbon pool, and they have been studied as sources or sinks of carbon to discover the relationship with global climate change (Sabine et al., 2004; Erwin, 2009; Means et al., 2016; Cao et al., 2017). The carbon sequestration ability of a wetland is often evaluated by the quantity of plant biomass, which indicates the amount of CO_2 that has been fixed through photosynthesis (Saunders et al., 2012; Hansen and Nestlerode, 2014; Hussain et al., 2015). Mitsch et al. (2014) theorized that carbon sequestration is consistently higher in naturally colonized wetlands than in planted wetlands due to their much greater productivity. Maucieri et al. (2014) claimed that vegetated constructed wetlands are a sink of atmospheric CO_2 after evaluating their total biomass and soil organic carbon over five years. However, photosynthesis is only part of the process of plant's life. After plant litter is returned to soil, the organic carbon in the litter is degraded to CO_2 by soil microorganisms and then released to the atmosphere through soil respiration (SR). Therefore, plants that can efficiently sequester carbon should grow fast but degrade slow when their litter is returned to soil; thus, their organic carbon can retain in soil over a long term. In previous studies, carbon storage capacity for plants or wetlands was mostly focused on the fixed amount of carbon (ie, biomass) and did not take into account of the associated carbon

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losses (ie, litter degradation and soil respiration). Therefore, we studied the carbon sequestration ability of the plant and the carbon sink capacity of the wetland on the basis of the continued study of the degradation of two wetland plant litter, combined with biomass and soil respiration.

Jiuduansha wetland is the sole original landform wetland in the Yangtze River estuary, and it plays an important part of the natural and ecological conservation network in China by providing carbon sink capability and other ecological services (Tang et al., 2011). Natural wetlands are usually characterized by high plant biomass, low temperature and waterlogged; such conditions lead to weak microbial activity in soil and slow litter degradation (Zhang et al., 2011). But the decomposition properties of various plant litters and their impacts on soil respiration and carbon sequestration remains unclear. To date, there is no systematic understanding of the degradation properties of returning wetland plant litter, nor of the relationship among plant decomposition, soil respiration and carbon sequestration.

In this study, we assessed litter decomposition of *Phragmites australis* (*P. australis*) and *Spartina alterniflora* (*S. alterniflora*), two dominant plants in Jiuduansha wetland, by conducting in-situ and ex-situ litter-returning experiments, and analyzed SR in two different vegetation wetland zones. The objective was to develop an understanding of the wetland's capability to sequester carbon with different vegetation, via the relationship between plant biomass, litter decomposition and SR, as well as to determine the most efficient carbon sequestering wetland in the Yangtze River estuary.

2. Materials and methods

2.1. Site description

The in-situ study was conducted in the Jiuduansha wetland (31°06′20″–31°14′00″N, 121°53′06″–122°04′33″E), a typical salt marsh ecosystem located in the Yangtze River estuary, China. The wetland covers 420 km^2 and consists of two main sandbanks: Shangsha and Zhongxiasha (Fig. 1).

The vegetation of Shangsha and Zhongxiasha mainly include mud flat pioneer plant *Scripus triqueter*, and the dominant plant *P. australis* (Tang et al., 2011; Xi et al., 2014). The soil textures were similar among the different vegetation zones (Huang and Zhang, 2007).

The in-situ experiment was conducted in two vegetation zones where samples were collected (*P. australis*: Shangsha 121°54.574′E, 31°13.394′N; *S. alterniflora*: Zhongxiasha, 121°57.815′E, 31°10.576′N), about 20 m away from the tidal channel. The ex-situ litter-returning experiment was conducted in the urban green belt (121°49.74′E, 31°28.46′N), typical inland soil that differs from wetland which is located in Yangpu District, Shanghai (Fig. 1), in order to eliminate the impacts of litter quality and soil environment on the litter degradation.

2.2. Litter collection and pretreatment

The freshly senesced and standing litter, consisting of leaves and stems, were collected in January 2011. To prevent transformation and loss of the chemical composition of the samples, we initially terminated the enzymes by drying the samples at 105 °C for 15 min, then lowered the temperature to 70 °C and dried the samples until a constant weight.

2.3. Experimental design

2.3.1. Litter returning and sampling

The litter returning experiments were conducted in March 2011, using the litterbag method (Sala et al., 2000; Kampichler and Bruckner, 2009). The dried plants were cut into 15-cm long and equal weights (30 g) of the different plant litters were placed separately into nylon bags (20 cm × 20 cm, 200 μm mesh). The mesh excluded the influence of invertebrates > 200 μm. Three points were chosen randomly within a radius of 5 m of the region at both in-situ and ex-situ experimental sites, 20 litterbags were buried 20–30 cm depth underground (considering the sediment deposition and avoiding the interference of tidal scouring) at each point. Three bags of each plant litter were collected after 0, 90, 180 and 270 d, in the in-situ experiment in Jiuduansha wetland and after 0, 30, 60, 90 and 180 d in the ex-situ experiment in the urban green belt soil. After debris and soil in the bags were removed by hand, the litterbags were washed with distilled water and dried. Subsequently, the samples were weighed, crushed and sieved for further analysis.

2.3.2. Soil sampling and pretreatment

When the litterbags were retrieved, soil samples were collected using the quincunx-point method. Random cores were obtained from each of the five points using a 5-cm diameter auger and then bulked (Carter and Gregorich, 2008). Roots and debris were removed, and the samples were immediately packed into individual plastic bags and stored at 4 °C. Subsamples of the fresh soil samples were used to determine soil enzyme activity and soil microbial biomass (SMB), and the remainder was air dried and stored at room temperature for further physicochemical analysis.

2.4. Analysis methods

2.4.1. Analysis of plant litter characteristics

The rate of mass loss was measured by weighing the litter, which had been cleaned and dried. Data were expressed as a percentage of the initial mass of litter.

The contents of carbon and nitrogen in 5–10 mg plant samples after sieving through a 60-mesh (0.3 mm) were measured using a Vario EL III analyzer (Elementar Analysensysteme GmbH, Germany).

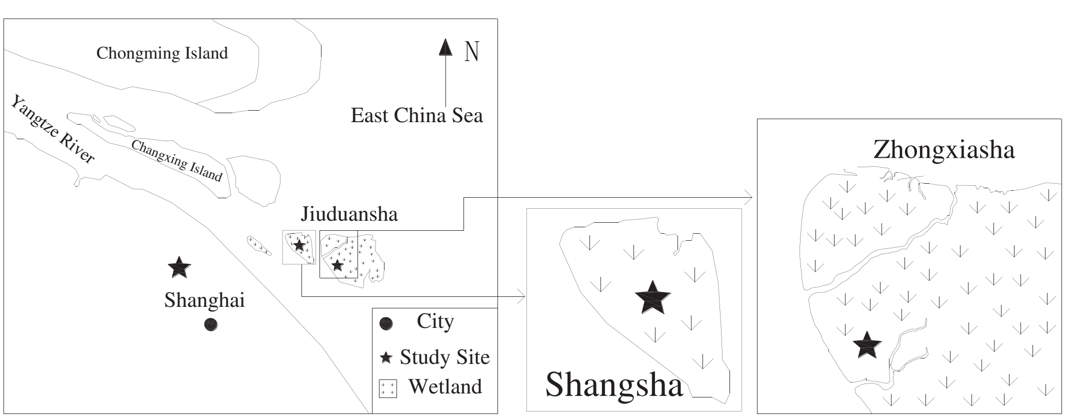

Fig. 1. Map of study areas in Jiuduansha wetland and plant litter sampling points.