Research of the diurnal soil respiration dynamic in two typical vegetation communities in Tianjin estuarine wetland

Q Zhang[1], W Q Meng[2] and H Y Li[1, 3]

[1]College of Environmental Science and Engineering, Nankai University, Tianjin, China

[2]College of Urban and Environment Science, Tianjin Normal University, Tianjin, China

Email: eialee@nankai.edu.cn

Abstract. Understanding the differences and diurnal variations of soil respiration in different vegetation communities in coastal wetland is to provide basic reliable scientific evidence for the carbon "source" function of wetland ecosystems in Tianjin.Measured soil respiration rate which changed during a day between two typical vegetation communities (*Phragmites australis*, *Suaeda salsa*) in coastal wetland in October, 2015. Soil temperature and moisture were measured at the same time. Each of the diurnal curves of soil temperature in two communities had a single peak value, and the diurnal variations of soil moisture showed a "two peak-one valley" trend. The diurnal dynamic of soil respiration under the two communities had obvious volatility which showed a single peak form with its maximum between 12:00-14:00 and minimum during 18:00. The diurnal average of soil respiration rate in *Phragmites australis* communities was 3.37 times of that in *Suaeda salsa* communities. Significant relationships were found by regression analysis among soil temperature, soil moisture and soil respiration rate in *Suaeda salsa* communities. There could be well described by exponential models which was $y = 0.245e^{0.105t}$ between soil respiration rate and soil temperature, by quadratic models which was $y = -0.276x^2 + 15.277x - 209.566$ between soil respiration rate and soil moisture. But the results of this study showed that there were no significant correlations between soil respiration and soil temperature and soil moisture in *Phragmites australis* communities (P>0.05). Therefore, under the specific wetland environment conditions in Tianjin, soil temperature and moisture were not main factors influencing the diurnal variations of soil respiration rate in *Phragmites australis* communities.

Keywords: soil respiration; *Phragmites australis* communities; *Suaeda salsa* communities; regression analysis

1. Introduction

Soil, considered as the largest and the slowest turnaround time carbon pool in the terrestrial ecosystem [1], is one of the important source or sink of atmospheric CO_2. Soil respiration is a major way of CO_2 emission from the land into the atmosphere [2-3], and is considered to be one of the largest flux in the global carbon cycle [4-5].The amount of carbon released from soil respiration is about 50-76 Pg every year [6], about 10 times larger than the carbon released by fossil fuel combustion [7]. In recent years, studies on soil carbon flux of forest ecosystems [8-9], farmland ecosystems [10-11], grassland ecosystems [12] and wetland ecosystems [13-14] are relatively abundant but researches in Tianjin coastal wetland are still less. Wetland known as the "kidney of the Earth" is the transition zone between terrestrial ecosystems and aquatic ecosystems, with abundant biodiversity and more complex habitat, is one of the most productive ecosystems in the world. The area of wetlands is about 5.14 million square kilometers, only accounting for 4% to 6% of the Earth's land area. However, it is the largest carbon pool in the world with its carbon stocks of about 770×108t which account for 35% of the terrestrial biosphere carbon [15], and plays an important role in global carbon cycle. Therefore, the impact of soil respiration to the wetland carbon cycle should not be overlooked.

In this paper, the typical vegetation communities of estuary wetland in Tianjin were chosen as the research objects. In October, the diurnal dynamics of soil carbon flux of two typical vegetation communities (*Phragmites australis, Suaeda salsa*)surrounding the wetland were separately measured by LI-8100A (LI-COR, Lincoln, NE, USA), and the differences in soil respiration in different vegetation types and the diurnal variation of soil carbon flux were analyzed in order to provide basic reliable scientific evidence for the carbon "source" function of wetland ecosystems in Tianjin.

2. Study area and research method

2.1. Study area

Yongding River, located in the north of Tianjin, was built in 1971 with the total length of 66km. Yongding River is situated in the coastal plain with the flat terrain which tilts from west to east. Elevation above sea level is smaller and the ground elevation is about 2.5m. The regional climate is warm temperate semi-humid monsoon with the characteristics of significant monsoon and four distinctive seasons. The average annual precipitation for the area is 566.1 mm, mainly concentrated in June to September. The average air temperature is 12.6℃ for many years [16]. The regional soil is salinization soil, which gives priority to with saline damp soil. Halophytes of estuary area are abundant in Yongding River, such as *Phragmites australis* and *Suaeda salsa*, which are in zonal distribution in general.

2.2. Research method

2.2.1. Experimental design. Two kinds of typical vegetation communities(*Phragmites australis, Suaeda salsa*) which were distributed widely in the surrounding wetland, were chosen as research objects through a preliminary comparison and analysis of field survey data. Five sample plots in size of 20m x 20m were laid in each vegetation community along the wetland from far and near, of which plot one to four for *Suaeda salsa* community and plot five for *Phragmites australis* community. The study was conducted to do measure in mid-October 2015. At each plot three monitoring points were randomly set, and the distance between adjacent monitoring points was not less than 5m. Each monitoring point soil set a PVC soil isolation ring whose front end inserted into the soil surface. In order to reduce the effects of the PVC ring placed on soil respiration rate, it should be balanced after 24-48 hours before measurement. The soil surface litter and fresh plant seedings were removed before measuring so as to reduce the impact of CO_2 released by woody debris decomposition and aerial parts of plants on measurement results [15]. The diurnal variations of soil respiration at three monitoring sites in each sample plots were measured during one day, every two hours from 6:00 to 18:00 by LI-8100A (LI-COR, Lincoln, NE, USA). Each monitoring point measured continuously three times during the same period. Soil moisture and soil temperature were measured at the same time. In addition, the topsoil of each monitoring point was collected for measuring the total nitrogen and total carbon contents after being air drying and sieving.

2.2.2. Assay method of soil properties. Soil total nitrogen content was determined by the Kjeldahl method (K-370).Soil total carbon content was determined by the potassium dichromate external heating method.

2.2.3. Statistical analysis. All the data was sorted by EXCEL, and the regression analysis was conducted by SPSS 22.0.

3. Results

3.1. Comparative analysis of environmental factors characteristics

Different vegetation types in the wetland had different soil physical and chemical properties. This study analyzed the soil physical and chemical properties of two vegetation types (*Phragmites australis*, *Suaeda salsa*) (Table1). Soil temperature varied widely in two researched. The ranges in *Suaeda salsa* communities and *Phragmites australis* communities were 9.842℃(minimum of 9.308℃, maximum of 19.15℃) and 8.7℃(minimum of 10.15℃, maximum of 18.85℃) respectively. The diurnal average soil temperature (13.714℃) in *Phragmites australis* communities was higher than that in *Suaeda salsa* communities (12.907℃). Compared with the *Phragmites australis* communities, the range of soil moisture in *Suaeda salsa* communities was smaller. But the soil moisture in *Phragmites australis* communities was significantly greater than that in *Suaeda salsa* communities. The soil total carbon content was similar in two vegetation communities, but the soil total nitrogen content was higher in *Phragmites australis* communities, 2.332 mg/g.

Table 1. Soil environmental factors of two vegetation communities.

Environmental Factor	Statistics	Type of Community	
		Suaeda salsa	*Phragmites australis*
Soil Temperature/℃	Mean	12.907	13.714
	Range	9.308—19.15	10.15—18.85
Soil Moisture/％	Mean	27.792	32.2
	Range	26.01—29.68	25.65—37.65
Total Carbon(mg/g)	Mean	1.349	1.423
Total Nitrogen(mg/g)	Mean	1.569	2.332

Table 2. Statistics of soil respiration rate in two vegetation communities.

Type of Community	N	Maximum /[umol/(m^2 · s)]	Minimum /[umol/(m^2 · s)]	Range /[umol/(m^2 · s)]	Mean /[umol/(m^2 · s)]	Standard Deviation /[umol/(m^2 · s)]	Standard Error /[umol/(m^2 · s)]	Coefficient of Variation
Suaeda salsa	7	1.711	0.409	1.302	1.036	0.436	0.165	0.421
Phragmites australis	7	4.645	2.075	2.570	3.493	1.040	0.393	0.298

3.2. Diurnal dynamic variation of environmental factors

The major environmental factors that affected the soil respiration were atmospheric temperature, atmospheric humidity, soil temperature, soil moisture, etc [14]. The diurnal dynamic variation of soil temperature in two vegetation communities between 6:00 and 18:00 was shown in Figure 1. Each of the diurnal curves of soil temperature in two communities had a single peak value. Both of the two communities reached a minimum at 6:00, increased gradually between 8:00-10:00, and the maximum at 12:00, then gradually decreased between 14:00-16:00 to about 10℃ at 18:00.

The diurnal dynamic variation of soil moisture in two vegetation communities between 6:00-18:00 was shown in Figure 2. The diurnal variations of soil moisture showed a "two peak-one valley" trend in both of two communities, but the *Phragmites australis* communities were significant. Soil moisture reached a minimum at 6:00, and the maximum at 16:00 which in *Phragmites australis* communities was higher of 37.65 % . Soil moisture increased slowly between 6:00-10:00 in *Suaeda salsa* communities, probably because *Suaeda salsa* communities distributed intensively with a higher canopy density and limited light of the surface made soil temperature vary slightly and moisture evaporate slowly.

3.3. Diurnal variation of soil respiration rate

Differences of the factors such as vegetation type and soil property influenced on diurnal variation pattern of soil respiration rate in sample plots [17]. The diurnal dynamic of soil respiration under the two communities both had obvious wave which showed a single peak form with the maximum between 12:00-14:00 and the minimum at 18:00(Figure 3). Different vegetation communities had different diurnal average, maximum, minimum and variation range of soil respiration(Table 2). The maximum and minimum soil respiration rate in *Phragmites australis* communities were higher than that in *Suaeda salsa* communities. The diurnal variation range of soil respiration in *Phragmites australis* communities was larger. But the smaller coefficient of variation explained that soil respiration rate on diurnal variation scale had a high variation degree in *Phragmites australis* communities. The diurnal average of soil respiration rate in *Phragmites australis* communities was 3.37 times higher than that of *Suaeda salsa* communities. The diurnal variation trend of soil respiration rates in two communities were consistent with the soil temperature. Since the temperature difference was larger in autumn, and soil temperature in vegetation communities is closely linked to changes in regional temperature, the peak-valley value of soil respiration rate had a significant relationship with soil temperature. But soil respiration rates in two communities had begun to decline before soil moisture reaching the peak(Figure 4).

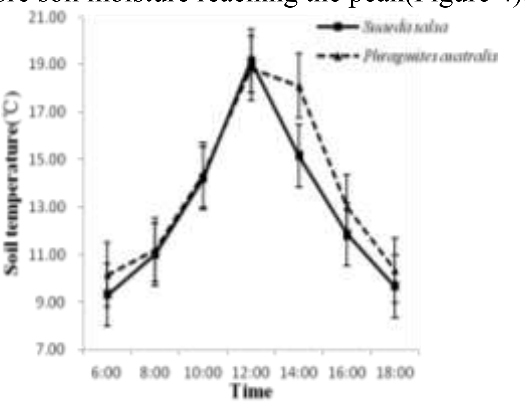

Figure 1. The diurnal variations of soil temperature in two vegetation communities.

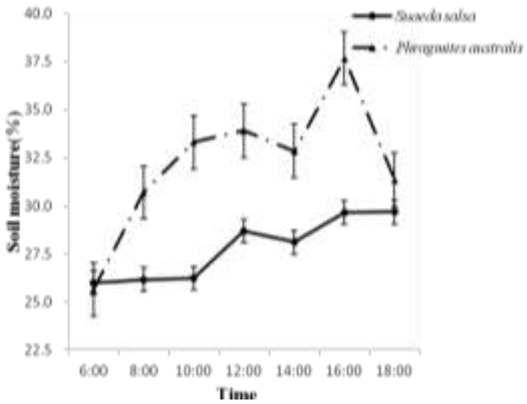

Figure 2. The diurnal variations of soil moisture in two vegetation communities.

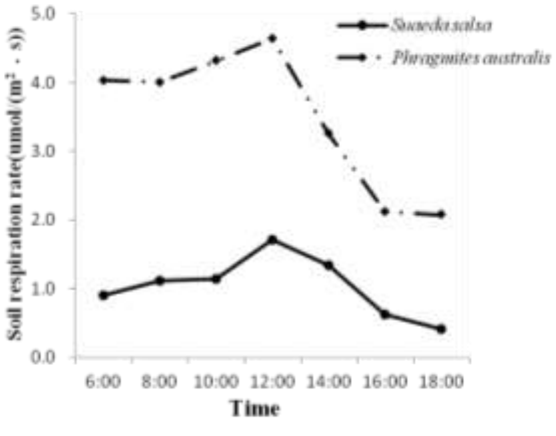

Figure 3. The diurnal variations of soil respiration in two vegetation communities.

3.4. Correlation between soil respiration rate and environmental factors

3.4.1. Effect of soil temperature on soil respiration. Soil temperature and soil moisture were respectively the control factors and limiting factors of soil respiration, and whose combined effect could explain most variations of soil respiration [18]. Different region probably had different sensitivity of soil respiration to soil temperature. The results of regression analysis for soil respiration rate and soil temperature in Suaeda salsa communities indicated that the soil respiration showed significant exponential correlation with soil temperature($R=0.760, R^2=0.577, P<0.05$)(Figure 5).The model was $y = 0.245e^{0.105t}$.

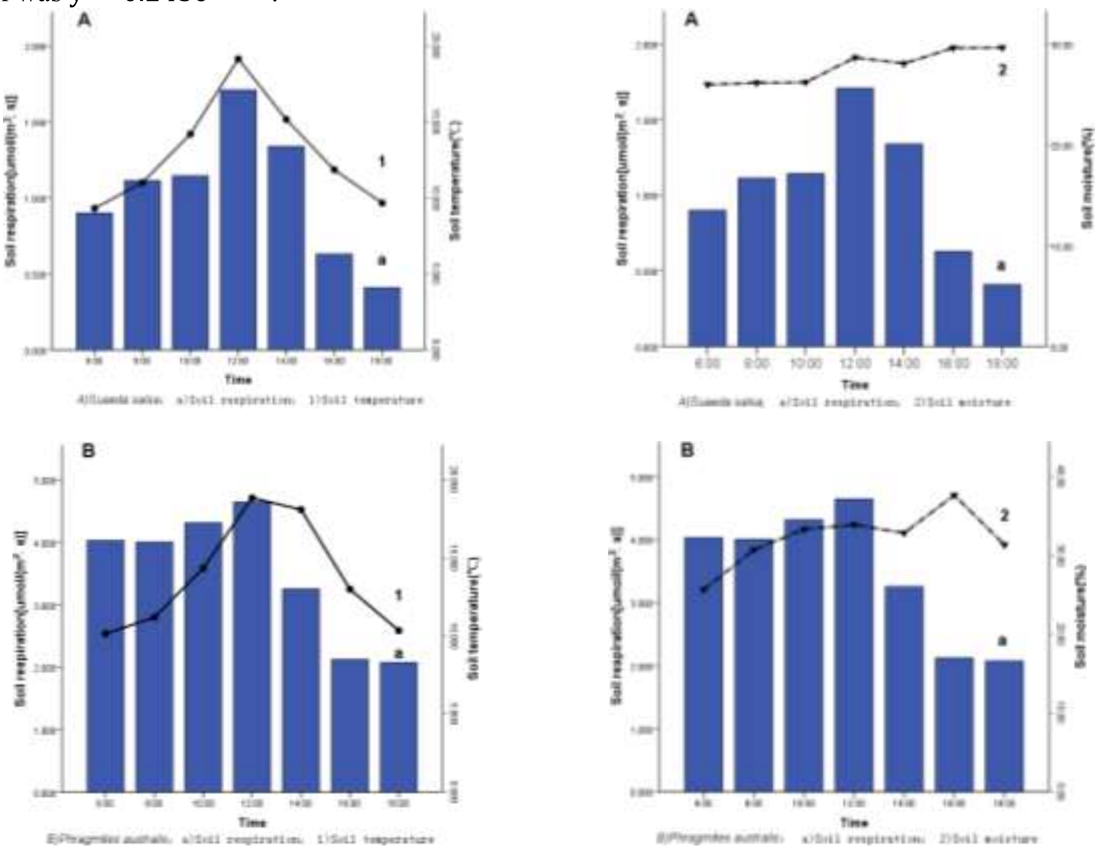

Figure 4. The diurnal variation tendencies of soil respiration and soil temperature and soil moisture in two vegetation communities.

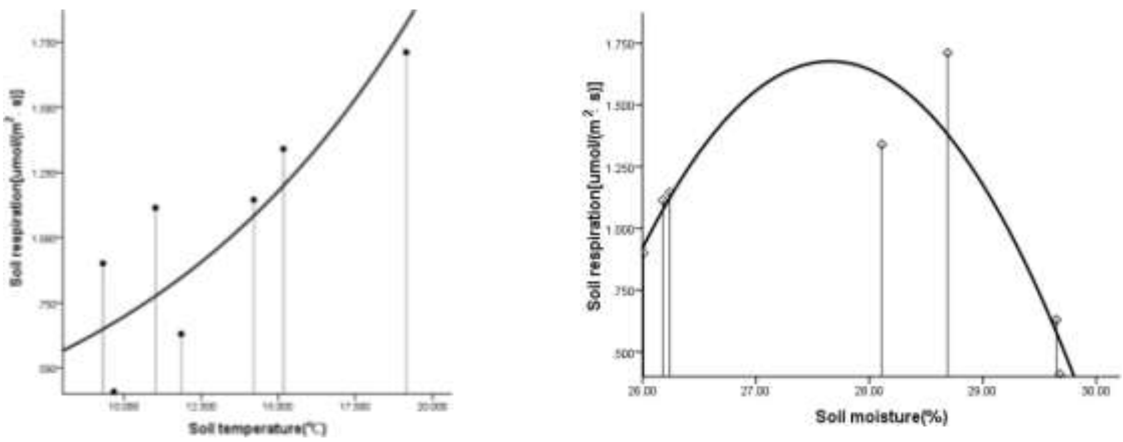

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Figure 5. Relationship between soil respiration and soil temperature in *Suaeda salsa* communities.

Figure 6. Relationship between soil respiration and soil moisture in *Suaeda salsa* communities.

3.4.2. Effect of soil moisture on soil respiration. Soil respiration rate response to soil moisture was more sensitive due to large fluctuations of water content in the topsoil. To discuss the impact of soil moisture on soil respiration rate in Suaeda salsa communities, soil carbon flux and soil moisture were fitted by nonlinear regression analysis. The results showed that there was significant correlation between soil respiration rate and soil moisture described by quadratic models which was $y = -0.276x^2 + 15.277x - 209.566$ (R=0.903, R^2=0.815, P<0.05) (Figure 6).

Likewise, to discuss the impact of soil temperature and soil moisture on soil respiration rate in *Phragmites australis* communities, the soil carbon flux, soil temperature and soil moisture were fitted by linear regression analysis respectively. From the results, the larger significance probability(R=0.691, R^2=0.478, P>0.05) cannot explain there was a significant correlation between soil respiration rate and soil temperature and moisture in *Phragmites australis* communities.

4. Discussion

Soil carbon fluxes in wetland ecosystem had spatial and temporal variability. Soil respiration heterogeneity was determined by many factors. Different soil environmental factors, vegetation community types and environmental conditions could lead to different soil respiration rates [19]. Mingfeng Li has shown that SOC and TN contents directly or indirectly decided the variation of soil respiration in the relatively stable environmental factors condition [20]. *Phragmites australis* could absorb the nitrogen in soil and water, and its residues and absorbed nitrogen settled into the soil together after a period of time, hence soil total nitrogen content was higher in *Phragmites australis* communities. Xueyang Yu *et al.* have reported that the total carbon accumulation rates of *Suaeda salsa* marsh from the Liaohe Delta was mainly controlled by the accretion rate [13]. The vegetation coverage in situ plants determined organic carbon concentration of soil sediments which were in the sediments surface layer above 10 cm in the coastal wetland. The soil organic carbon was decomposed into CO_2, and microbial activity was relatively high in rich SOC soil to promote the soil respiration. However, the total carbon contents were similar in two communities in this study. Therefore the research concluded that the soil total carbon was not the dominant factor affecting the soil respiration.

Different vegetation types not only affected the soil organic matter content, but also had direct impacts on soil temperature and soil moisture [21]. In this study, as a result of the wide distribution of *Suaeda salsa* communities possibly, the vegetation canopy density was high. In contrast to *Phragmites australis* communities whose lower canopy density made the sunlight pass through branches and leaves to the soil easily, and the tightness was relatively poor. So the diurnal average of soil temperature in *Phragmites australis* communities was higher than that in *Suaeda salsa* communities, and the two variation ranges of soil temperature were larger. At the same time, due to *Phragmites australis* which were aquatic plants and their special habitat conditions, soil moisture was significantly greater than that in *Suaeda salsa* communities.

The behavior in diurnal dynamic of soil respiration was accorded with most research conclusions. Yanbing Xie has demonstrated that the daily pattern of soil respiration rate was obvious in *Phragmites australis* communities wetland in Panjin, Liaoning province, showing a single peak curve which was consistent with the temperature curve [22]. Changchun Song and Yiyong Wang pointed out that CO_2 emissions in marsh wetland plants-soil system were associated with the root layer soil temperature, presented a significant exponential correlation [23]. The relation between soil respiration rate and soil temperature in *Suaeda salsa* communities in the wetland of Yongding River was consistent with distribution models fitted by other wetland ecosystems [24, 25, 26].

In addition to environmental factors, biological factors were also important to affect soil respiration. The temporal dynamic rules of the soil respiration could be divided into diurnal and seasonal variation. Biological factors were smaller change variables on a circadian scale which was the reason why the diurnal variation rules of soil respiration could not be explained by biological factors [27]. Numerous studies have shown that, temperature was the closest environmental factors to carbon exchanged in ecosystems and soil carbon fluxes [28,29].And in this study, there were no significant correlations between soil respiration and soil temperature and soil moisture in *Phragmites australis* communities by the linear regression analysis(P>0.05). Some researchers considered that there were weak correlations between temperature and soil carbon fluxes, which was greatly influenced by light radiation [30]. Zixian Du has shown that, for *Phragmites australis* communities in Minjiang riverside wetlands, soil temperature was not the main impact factors in diurnal respiration, which was consistent with this study [31].

5. Conclusions

(1)Each of the diurnal curves of soil temperature in two communities had a single peak value. Both of the two communities reached a minimum at 6:00, increased gradually between 8:00-10:00, and the maximum at 12:00, then gradually decreased between 14:00-16:00 to about 10℃ at 18:00. And the diurnal variations of soil moisture showed a "two peak-one valley" trend. Soil moisture reached a minimum at 6:00, and the maximum at 16:00 , which in *Phragmites australis* communities was higher.

(2)The diurnal dynamic of soil respiration in two communities had obvious volatility which showed a single peak form with its maximum between 12:00—14:00 and minimum at 18:00. The diurnal average of soil respiration rate in *Phragmites australis* communities was 3.37 times of the *Suaeda salsa* communities.

(3) Significant relationships were found by regression analysis among soil temperature, soil moisture and soil respiration rate in *Suaeda salsa* communities. There could be best described by exponential models which were $y = 0.245e^{0.105t}$ between soil respiration rate and soil temperature, by quadratic models which was $y = -0.276x^2 + 15.277x - 209.566$ between soil respiration rate and soil moisture. But the results of this study showed that there were no significant correlations between soil respiration and soil temperature and soil moisture in *Phragmites australis* communities (P>0.05). Therefore, in the specific wetland environment conditions in Tianjin, soil temperature and moisture were not main factors influencing the diurnal variations of soil respiration rate in *Phragmites australis* communities.

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