SPATIAL DISTRIBUTION CHARACTERISTICS OF SOIL ORGANIC MATTER AND NITROGEN UNDER NATURAL CONDITIONS IN YANCHENG COASTAL WETLANDS

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(Received 31st May 2018; accepted 27th Sep 2018)

Abstract. SOM (soil organic matter) and N (nitrogen) are important ecological factors in coastal wetland ecosystems. A specific area in Yancheng coastal wetlands was chosen and monitored on the spot in April 2012, spatial distribution characteristics of SOM and N and the relationship between them were analysed. The results showed that the content of SOM and N differs significantly in various vegetation types, their content in *Spartina* marshes is the highest, followed by *Reed* marshes, *Suaeda* marshes and the mudflat. The average content of SOM and N in them were 1.138%, 1.103%, 0.851%, 0.399% and the average value of total nitrogen were 489.935 mg/kg, 369.811 mg/kg, 365.491 mg/kg, and 95.542 mg/kg respectively. Furthermore, SOM and TN (total nitrogen), TN and ammonia nitrogen (NH_3-N) in the coastal wetlands are closely related and fit perfectly for linear regression equation, however, the correlation coefficient for OM (organic matter) and NH_3-N is low and fits well for the cubic curve equation. The specific value of carbon and nitrogen are the highest in the mudflat, followed by *Reed* marshes, *Spartina* marshes and *Suaeda* marshes. The specific value of NH_3-N and TN are the highest in the mudflat and in S*partina* marshes, *Reed* marshes and *Suaeda* marshes are close to it. Vegetation coverage conditions and physiological characteristics of plants are important factors affecting spatial distribution of SOM/N in coastal wetlands.
Keywords: *soil ecological elements, spatial differences, relationship, coastal wetlands, Yancheng National Nature Reserve*

Introduction

Coastal wetlands, in the transition zone of the terrestrial ecosystem and marine ecosystem, is an ecologically sensitive area of fragility (Zhang et al., 2005). Nutrient elements such as OM and N, are not only important components of wetland soil, but also extremely important ecological factors in the wetland ecosystem (Mitsch and Gosselin, 1986). Soil is a space-time continuum with high variability and there are obvious variations in the soil properties at the same time in different space positions (Sun et al., 2010). SOM is an important component of the soil. On the one hand, it shows fertility status of the soil; on the other hand, it also reflects the improvement of soil conditions and climate changes (Li and Wang, 2000; Wang et al., 2002). N as an important indicator of wetland soil nutrient levels (Judith and Jeffery, 2001), can not only reflect nutrient supply situation of the wetland soil and, to some extent, its level of availability; but also strongly correlates with the growth of plants.

Yancheng coastal wetland is one of the few typical coastal wetlands in China and the world, but under the bidirectional action of nature and human, the structure and function

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_69176925

of ecosystem changed greatly (Liu et al., 2003) and has raised wide attention of scholars. Real-time monitoring and diagnosis of ecosystem health are scientific preventive measures for maintaining the wealth of coastal wetland ecosystem (Zhu et al., 2010). The study of the biodiversity, accumulation and distribution of SOM, chemical processes of P (phosphorus) and N and soil water characteristics in the coastal wetlands had accumulated a series of achievements. (Gao et al., 2004, 2008; Liu et al., 2005; Shen et al., 2005; Mao et al., 2009; Ren et al., 2010). But study on the relationship between soil OM and N in coastal wetlands needs to deepen and expand. In this paper, one typical case area of Yancheng coastal wetlands is selected to reveal the spatial distribution characteristics of SOM and N in coastal wetlands and further elaborate the relationship of OM and N, NH_3-N and TN. It is of scientific and practical significance for deeply understanding the evolution law of the coastal wetland ecosystem, revealing the environmental change of coastal wetlands and promoting the natural exploitation and utilization of coastal wetlands.

Materials and methods

Study area

Yancheng Nature Reserve lies in the middle of Jiangsu coastal area. It is located between 32°20’ and 34°37’N latitude and 119°29’ and 121°15’E longitude and is bordered by the Yellow Sea to the east. It crosses 6 counties (cities, areas): Dongtai, Dafeng, Tinghu, Binhai, Sheyang and Xiangshui with a coastline of 582 km and a beach wetland area of 45.33 × 104 hm^2, which is the largest western Pacific coast muddy tidal flat wetland. With Xinyanggang River to the north, Doulonggang River to the south, seawall to the west, the core area of Yancheng national natural reserve is the typical long silted wet beach in Jiangsu province and its total land mass is 1.92 × 104 hm^2. The reserve is divided into northern and southern parts by Zhonglugang Road (*Fig. 1*). The northern part, with an area of about 0.52 × 104 hm^2, is a typical artificial management area and is planted a large area of r*eed* marshes. The southern part, with an area of about 1.10 × 104 hm^2, is a typical natural condition control area, whose landscape patterns and ecological processes are mainly affected by the climate, topography, hydrology, soil, vegetation and other natural factors, and it became the typical wetland areas under the control of natural conditions. This paper chose the coastal wetlands under southern natural conditions (Zhonglugang Road to the north, Doulonggang River to the south) as the research area, whose vegetation is from land to sea, in turn is *Reed*, *Suaeda*, *Spartinas* and mudflat.

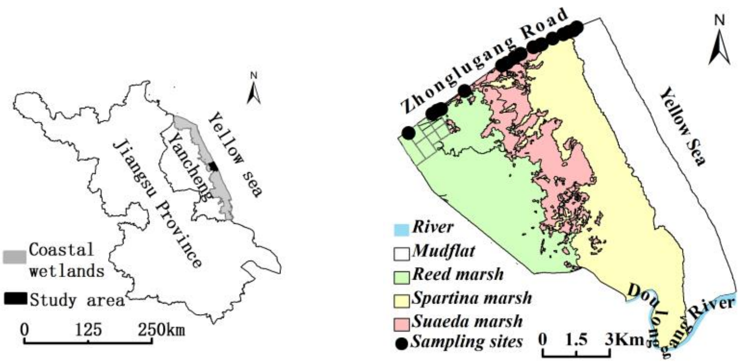

Figure 1. *Location of study area and sample points*

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DOI: http://dx.doi.org/10.15666/aeer/1605_69176925

Data sources and processing

This paper was based on analysis data of research in April 2012. On the south side of Zhonglugang Road in the study area, 17 sample plots are arranged along the direction of land-to-sea. From sea to land were numbered by S1-S17. S1 and S2 are mudflat. S3, S4, S5, S6, S7 are *Spartina* marshes. S8, S9, S10, S11, S12, S13 are *Suaeda* marshes. S14, S15, S16, S17 are *Reed* marshes. The sample is distributed zonally in *Figure 1*. The sample area covered all the vegetation types and the equidistant distribution was basically adopted in each vegetation zone. Each sample plot set three sample points and used the soil collector to collect soil samples of 0-20 cm depth. Each sample column was 10 cm in diameter and 20 cm in height, and three sample columns were taken for mixing. A total of 17 mixed samples were mixed. We brought the samples back for laboratory analysis and recorded the vegetation types of each sample at the same time. After being brought to the laboratory and drying for 7 days, the samples were put into the oven. Under the condition of 50℃ drying to constant weight, further grind the dried sample to make the particle size less than 0.149 mm. The experimental procedures were using the samples to measure the content of organic matter through hydrate thermo - accretion potassium oxidation - colorimetric method. The total content of nitrogen in soil was measured by using concentrated sulfuric acid-indophenol blue colorimetric method. And Ammonia nitrogen in the soil was measured by using indophenol blue colorimetric method. Analyze the field monitoring data with statistic package for social science (SPSS) 19.0 software and single factor variance analysis. Conduct the significant test of difference on the soil OM, TN and NH_3-N. Then, we studied the relationship between OM and TN, OM and NH_3-N, TN and NH_3-N by using the regression analysis method.

Results

The characteristics of SOM\N in the coastal wetland

In the study area, the vegetation zonation is obvious. *Reed* marshes are located above the high tide of spring tide with high vegetation and the average height is above 1.5 m and the coverage is above 90%. *Suaeda* marshes is located in the upper part of the intertidal zone. The plants between the high tide and the average high tide are short, with a height of 0.5-1.2 m and a coverage of about 50%. The *Spartina alterniflora* is located between the mean high tide and the neap tide, with dense vegetation and average height of 2 m, covering degree of 100%. The mudflat is located between the high tide and low tide of the neap tide, almost no vegetation nearly.

The value of the soil OM, TN, NH_3-N is tested by the normal distribution testing in the SPSS 19.0. The data show an approximately normal distribution and are statistically significant. It can be seen from *Table 1:* the content of SOM is between 0.365% and 1.547% and the average level is 0.942%. Its maximum value is in *Spartina* marshes and its minimum value is in the mudflat. There is a moderate degree of variation and the variation coefficient is 36.075%. The content of TN is between 92.316 mg/kg and 908.710 mg/kg, with a mean value of 371.350 mg/kg. Its maximum value is in *Spartina* marshes and its minimum value is in the mudflat. There is a moderate degree of variations and the variation coefficient is 56.314%. The content of NH_3-N is between 3.510 mg/kg and 22.136 mg/kg. Its maximum value is in *Spartina* marshes and its minimum value is in the mudflat as well. Its mean value is 9.101 mg/kg, with a moderate degree of variation and the variation coefficient is 45.872%.

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DOI: http://dx.doi.org/10.15666/aeer/1605_69176925

Table 1. *Characteristics of SOM, TN, NH_3-N in coastal wetlands*

ITEM	MAX	MIN	AVG	SD	CoV
OM/%	1.547	0.365	0.942	0.340	36.075%
TN/mg/kg	908.710	92.316	371.350	209.123	45.872%
NH_3-N/mg/kg	22.136	3.510	9.101	4.175	56.314%

The distribution pattern of SOM\N in coastal wetlands

It can be concluded from the single factor variance analysis of SOM and N in different vegetation types that: the test results of the three indicators are all F > P (alpha = 0.05), which shows that the content of SOM and N differs greatly between different vegetation. It can be seen from *Figure 2* that the content of coastal wetland SOM and TN is characterized by s-type fluctuation from land to sea. That is to say, it shows the characteristic of “high - low - high – low” from *Reed* marshes, *Suaeda* marshes, *Spartina* marshes to the mudflat. The average content of OM is 1.103%, 0.851%, 1.138% and 0.399% respectively and that of TN is 369.811 mg/kg, 365.491 mg/kg, 489.935 mg/kg and 95.542 mg/kg respectively. In addition, the soil NH_3-N turns out to be of the same characteristic of OM and TN in space after being analyzed and the mean values from *Reed* marshes, *Suaeda* marshes to mudflat is 8.731 mg/kg, 7.635 mg/kg, 12.419 mg/kg, 5.943 mg/kg respectively. Overall, differences in SOM and N in vegetation are reflected: *Spartina* marshes>*Reed* marshes> *Suaeda* marshes > the mudflat.

The content of SOM and N is closely related to vegetation types in coastal wetlands. SOM in coastal wetlands is closely related to the sources of SOM like plankton, benthos and plants. Variations in the content of nutrients like soil nitrogen, in a large degree, is mainly related to the factors such as climate, the soil parent material, etc. While in a small degree, it is mainly affected by the differences of vegetation and terrain without taking the differences of climate and soil plant material into consideration. SOM of the mudflat mainly comes from plankton and humus produced by benthos for lack of vegetation growth and the accumulation of nutrients is inferior to the vegetated areas. Not only *Spartina* marshes are affected by the sea, but also *Spartina* plants are tall in height and rich in density and have developed root system, which makes both the ground and underground biomass larger and the OM and N contribution rate high. In non-growing seasons, a lot of litter accumulates on the surface before large amounts of OM and N return into soil for decomposition. What is more, the good expansion ability of *Spartinas* contributes to the obvious increase in the sedimentary rate on the beach surface, the continuous acceleration of the beach face and accumulation of OM and N. On the other hand, the accumulation of SOM in *Spartina* marshes is affected by sea plankton and benthos. Therefore its capacity of enriching OM is much higher than *Reed*, *Suaeda* and the mudflat. While *Suaeda* marshes have lower content of the OM and N because the alkaline lotus have short plants, small and thin roots with low biomass on both the ground and underground and relatively weak accumulation for the OM and N. *Reed* marshes are less affected by seawater and SOM mainly comes from the metabolism and the litter form of humus of reed roots. Compared to *Spartina* marshes, the biomass and expansion ability of reeds is weaker. Furthermore, *Reed* marshes are located in top area of the coastal wetlands, which results in that their underground water level is lower than that of *Spartina* marshes and *Suaeda* marshes and weak soil peat

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1605_69176925

accumulation ability. So the OM and N content in general is lower than that of *Spartina* marshes.

On the other hand, studies show that the soil particle size is closely related to the content of OM and N. Because *Spartina* marshes and *Suaeda* marshes have smaller particle size, they have greater chance of hummifications product and root secretions and higher content of OM and N. While where is smaller particle size, there is worse ventilation and water permeability, which affect soil respiration and soil in anaerobic condition for a long time and go against the decomposition of OM andNH_3-N. And that does be good to the fixation of C and N. Meanwhile, the particle size of mudflat and *Suaeda* is large, so the content of SOM and NH_3-N is less (Wang et al., 2013; Hou et al., 2011; Oades, 1998).

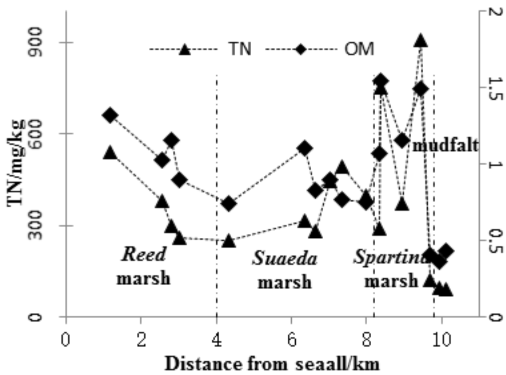

Figure 2. *The OM and TN content of soil in different vegetation*

The relationship between SOM and N in coastal wetlands

By using the SPSS correlation analysis, the conclusion can be drawn that: under the significance level of 0.01, OM and TN, TN and NH_3-N are very close, whose correlation coefficient is 0.825 and 0.858. By using linear regression to analyze the relationship between them, it shows good fitting effect as is shown in *Equations 1* and *2*, while the correlation of SOM and NH_3-N is poorer and its coefficient is 0.688 (the significance level of 0.01). It changes for the reason that NH_3-N in the soil can be directly absorbed by plants in the use of N and easily affected by hydrothermal conditions and biological activities (Deng et al., 2015). So we can use the cubic curve simulation method to express the relationship between them rather than simply using linear regression analysis. The cubic curve simulation method also shows a better fitting effect (*Eq. 3*).

$$OM = 0.444 + 0.001TN \quad \text{(Eq.1)}$$

$$TN = -19.866 + 42.986(\mathrm{NH_3 - N}) \quad \text{(Eq.2)}$$

$$OM = 0.905 - 0.125(\mathrm{NH_3 - N}) + 0.019(\mathrm{NH_3 - N})^2 - 0.01(\mathrm{NH_3 - N})^3 \quad \text{(Eq.3)}$$

where OM = organic matter; TN = total nitrogen; NH3-N = ammonia nitrogen.

The accumulation and decomposition of SOM directly affect the storage and transformation of N in the soil and play a leading role in the nitrogen content (Xu et al.,

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2015). The distribution characteristics of soil carbon (hereafter referred to as C) and N and SOM and N are entirely different in coastal wetland. As can be seen from the C/N value, The C/N value of the mudflat is the highest whose mean value is 24.326. And the C/ N value in *Spartina* marshes and *Suaeda* marshes are highly close and their averages are 15.986 and 14.350 respectively. The C/ N value in *Reed* marshes, whose average value is 18.115, is higher than that of *Spartina* marshes and lower than that of the mudflat. Studies have shown that (Ge et al., 2010), C and N can reveal the conversion relationship between soil C and N in the process of biological decomposition. If the soil C/ N value is higher than 25, it will indicate that the soil N content cannot meet the needs of the bacteria and bring the accumulation of N content. In addition, the rapid propagation of soil spoilage bacteria can accelerate the decomposition of SOM. The C/ N value of all samples of C and N in this study are less than 25 except one point 27.190 in the mudflat. As can be seen from the mean of different vegetation zone average, only the point 24.326 of mudflat is closest to 25. Therefore, the OM and N accumulation of the mudflat is the weakest. The average value of C/N of *Reed* marshes, *Suaeda* marshes and *Spartina* marshes is lower than 20. This indicates that the degree of humification of coastal wetland soil is the highest, which easily causes the decomposition of OM and the mineralization of organic nitrogenous and it leads to the reduction of C and N value.

NH_3-N is one of the main forms of soil inorganic nitrogen and effective N which can be absorbed directly by the plant. By analyzing the ratio of NH_3-N/TN, it can be concluded that the mudflat has the highest ratio and its average value is 6.141. Besides, the content of NH_3-N/TN in the soil of *Spartina* marshes, *Reed* marshes and *Suaeda* marshes are closer. Their average values are 3.052, 2.161 and 2.399 respectively and it has much to do with the absorption of plants. *Spartina* root system is well-developed and may reach several meters deep underground, so the surface of 0~20 cm soil absorb less HN3-N. Therefore, the NH_3-N/TN in *Spartina* marshes is highest; *Reed* marshes take the second place. The root system of *Suaeda* marshes is undeveloped and its roots are short and mainly concentrated in the 15 to 25 cm soil layer. However, it absorbs much more NH_3-N on a scale of 0-20 cm soil layer. So the value of NH_3-N/TN is the lowest. On the other hand, the vegetation coverage and biomass of *Suaeda* marshes are low, which results in more barren soil under the eluviations (*Fig. 3*).

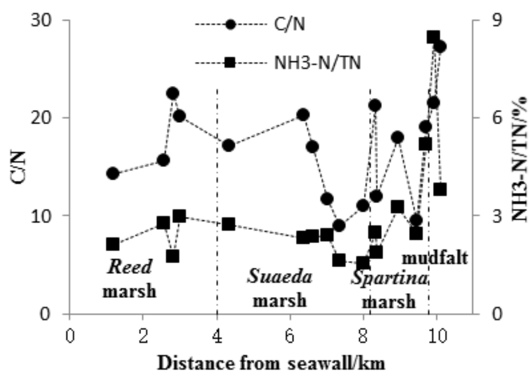

Figure 3. *The NH3-N and C/N of soil in different vegetation*

Discussion

The spatial differences and processes of the soil ecological elements is the basis of exploring the evolution mechanism of in the coastal wetlands. Many studies have

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DOI: http://dx.doi.org/10.15666/aeer/1605_69176925

revealed the response relationship between plant community and environmental factors at the scale of ecosystem (Cui and Yang, 2001; Mao et al., 2009; Yao et al., 2009), which showed that SOM and TN are the main factors that affect the spatial differences of the plant communities in wetlands (Zhang et al., 2009). The spatial differences of the soil ecological factors such as nitrogen, phosphorus, salinity and organic matter were the main content in Yancheng coastal wetlands. There were a series of common achievements, while some were still controversial aspects. Studies on SOM and N are not controversial, the lowest level was in the mudflat, but there were disagreements on whether the highest level was in *Reed* marshes or *Spartina* marshes (Shen et al., 2005; Yao et al., 2009; Zhong et al., 2010). Some studies had showed that the content of OM and N in the surface soil with vegetation distribution is higher than that in the mudflat and the highest value appears in *Spartina* marshes. In the vertical direction, the content decreases gradually from the table down (Mao et al., 2009; Ren et al., 2011). On this basis, the variation of SOM and N in the coastal wetland under natural conditions was further analyzed. The results confirmed that the highest content of the soil OM and N in *Spartina* marshes, and the areas covered by vegetation were higher than the mudflat. The positive correlation between the soil OM and TN was verified, the results showed there was obvious liner relation between them. On the other hand, it was found that the distribution characteristics of the specific value of soil carbon and nitrogen in the coastal wetlands were totally different from them of the soil OM and N. However, some studies showed that the highest C/N ratio appeared in the place where the growth time of *Spartina* was the longest, and the lowest value was the mudflat (Mao et al., 2009). In this paper, the ratio of the soil OM and N in the mudflat was the highest, followed by *Reed* marshes, *Spartina* marshes and *Suaeda* marshes. The ratio of NH_3-N and TN in the mudflat was the highest and the specific value in *Spartina* marshes, *Reed* marshes and *Suaeda* marshes were close. The results indicated that vegetation cover conditions and plant physiological characteristics may be the reasons for the differences of the soil C/N and NH_3-N/TN ratios in the coastal wetlands. However, how SOM, N and vegetation interact and how they are coupled remains to be further studied.

Conclusion

Based on analysis data of research in April 2012, this paper analyzed the spatial distribution features of soil organic matter and nitrogen in Yancheng coastal wetlands under the natural condition and the relationship between soil organic matter, total nitrogen and ammonia nitrogen. The results showed that there were significant differences among different vegetation types. It shows the tendency of decrease from *Spartina* marshes, *Reed* marshes, *Suaeda* marshes to the mudflat. The soil TN and NH_3-N, TN and OM in the coastal wetland were (significance level of 0.01) closely related, the correlation coefficient were 0.825 and 0.858 respectively. The soil OM and NH_3-N correlation was poor, but the fitting effect of the third-order curve equation was good, the curve equation of OM and NH_3-N was as *Equation 3*. The specific value of carbon and nitrogen in the mudflat was the highest and the average value was 24.326. The C/N value in *Spartina* marshes and the *Suaeda* marshes were very close, with the average of 15.986 and 14.350 respectively. The average C/N in *Reed* marshes was only 18.115. The specific value ratio of NH_3-N/TN was the highest in the mudflat, with an average value of 6.141, while the average value of the *Spartina* marshes, *Suaeda* marshes and *Reed* marshes was close, with the average value of 3.052, 2.161 and 2.399 respectively.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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Acknowledgements. This research was supported by National Natural Science Foundation of China (No. 41771199), the Natural Science Foundation of Jiangsu Province, China (Grants No. BK20171277) and the Natural Science Foundation of Jiangsu Higher Education Institutions of China (No.18KJD170001). We gratefully acknowledge Yancheng natural reserve for giving us the opportunity to enter the study area and carry out field works.

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