The distributions of Glomalin-related soil protein in the coastal wetlands of the Liaohe Delta, Northeast China: Implications for mineral weathering and carbon sequestration

Lixin Pei, Siyuan Ye *, Hongming Yuan, Shaofeng Pei, Shucheng Xie, Jin Wang

Reporter：Lixin Pei

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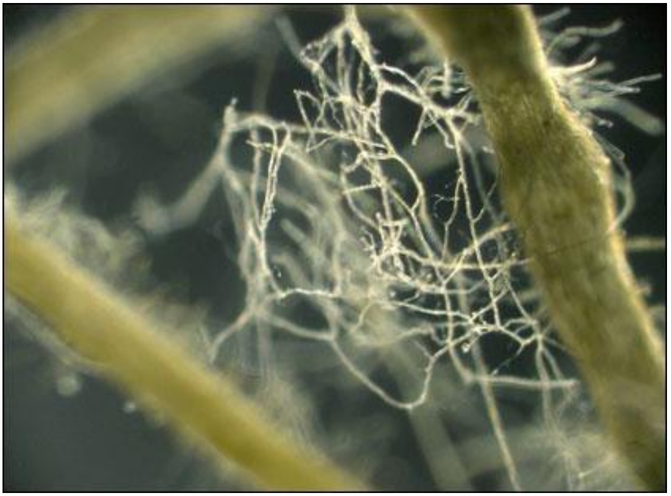
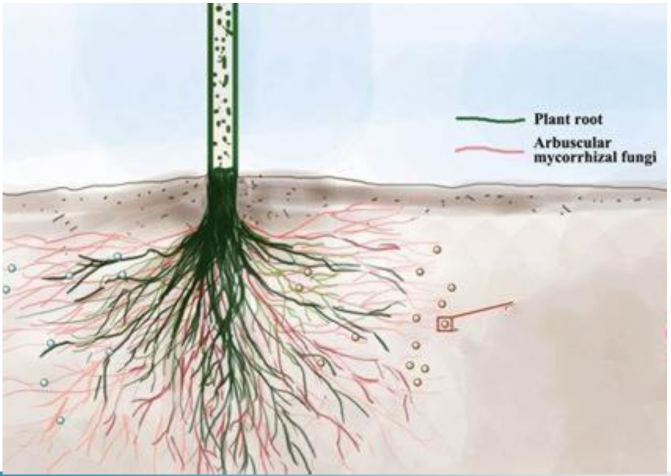
Background



A key contribution to the formation and stabilization of carbon in soil aggregates, and presumably to the acquisition of mineral nutrients via enhanced weathering, is made by arbuscular mycorrhizal fungi (AMF), a plant-associated soil fungus, which may have a symbiotic association with 80% of vascular plant species.



Many functions of AMF in conditioning soils is achieved by its metabolite glomalin. However, glomalin has not been biochemically defined, it has often been quantified in terms of Glomalin-related soil protein (GRSP). Therefore, as a proxy for AMF, GRSP has been widely used to explore the role of AMFs in various ecosystems around the world. However, information on AMF-carbon-weathering interactions is limited, especially in coastal wetlands.

Objectives

We tested the following two hypotheses:

(1) GRSP is widely present in the surface sediments of coastal wetlands and promotes carbon sequestration;

(2) AMF in wetland ecosystems influences mineral weathering and alters nutrient retention.

We then explored factors affecting the distribution of GRSP in wetlands with the expectation that effective measures might be identified to enhance their role in nutrient retention and carbon storage.

Study area

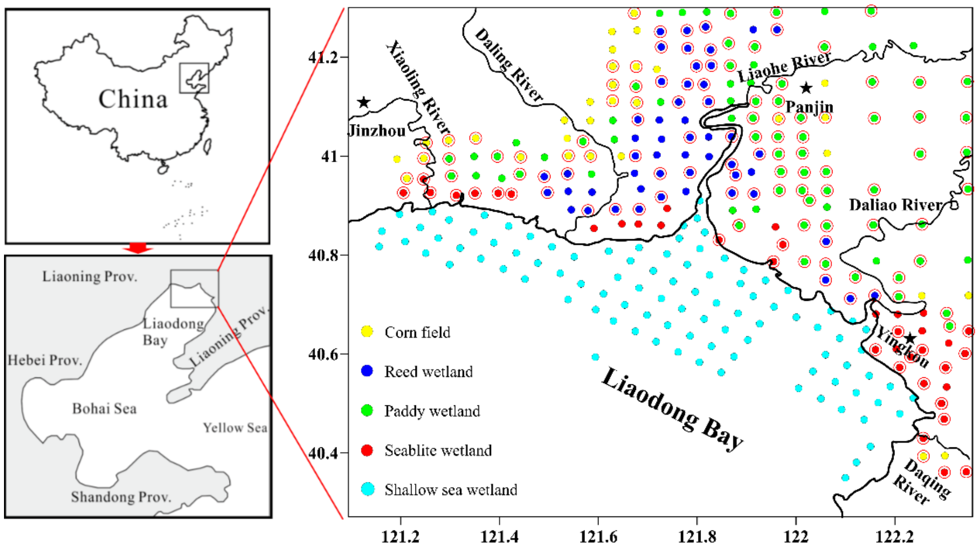


Fig. 1 Location of study area and sampling stations

The stations selected for GRSP analysis are circled in red

The Liaohe Delta is located in the southwest of the Liaoning province, northeast China. This study focused mainly on the upper delta plain wetlands (UDPW) and the shallow sea wetlands (SSW) of the delta. The UDPW of the Liaohe Delta has a total area of 3601 km^2. It includes the world's largest reed field (789 km^2), extensive rice paddies (2465 km^2), an intertidal and seablite wetland (33 km^2), and dry land (314 km^2).

Methods

1. Physicochemical properties of the sediments were measured (pH, grain size, soil organic carbon, total N, total P, major components).
2. The analyses for GRSP were conducted as described by Wright et al. (2006) and the protein concentration was determined by the Bradford assay.
3. The Chemical Index of Alteration (CIA) was used as a proxy for reconstructing chemical weathering.

Results

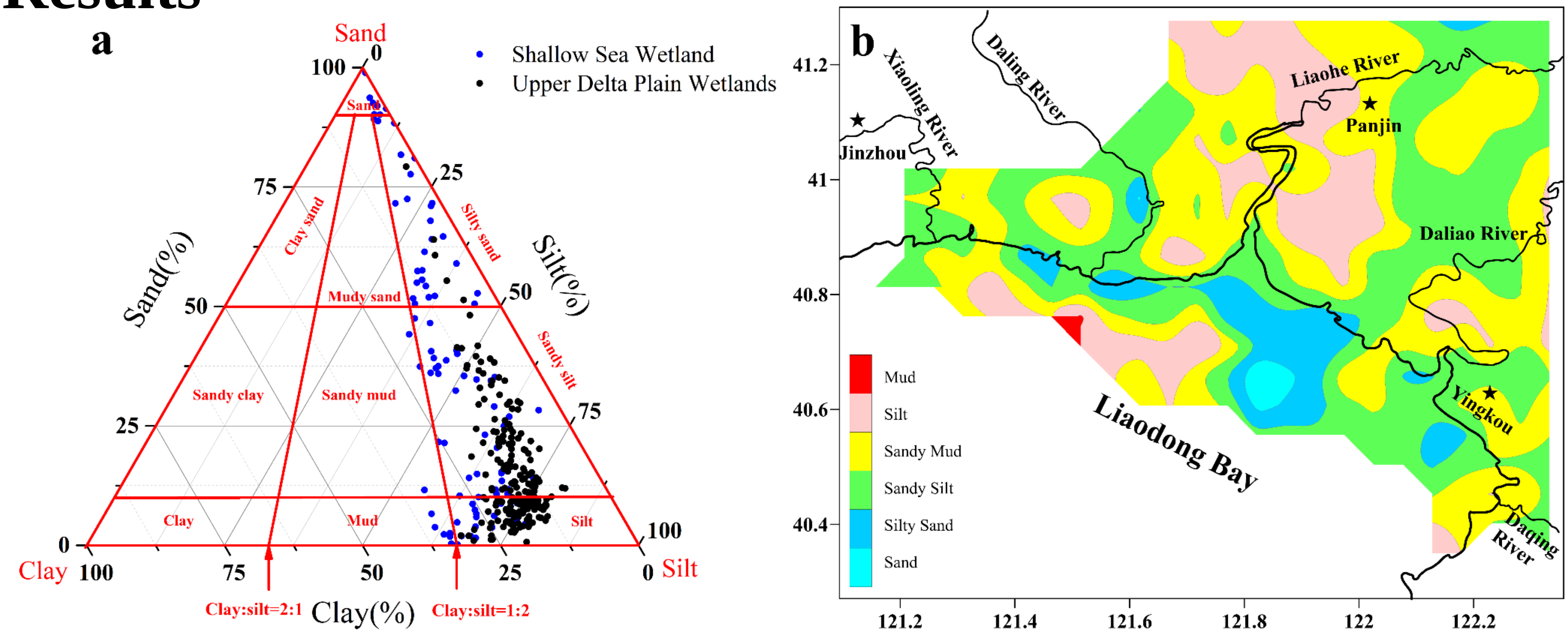


Fig. 2 Ternary map of grain size classification (a) and the spatial variations of sedimentary categories (b)

In the UDPW, the silt and sandy mud were distributed along the Liaohe River and the Daliao River floodplains, which were dominated by reed and paddy wetlands. The sandy silt and silty sand were distributed along the Daling and Xiaoling River floodplains, which were close to the source of the material. In the SSW, the spatial distribution of sediment categories could be divided into three fractions: western fine-grained silt and sandy mud, central coarse-grained silty sand and sand, and eastern middle-sized sandy silt.

Results

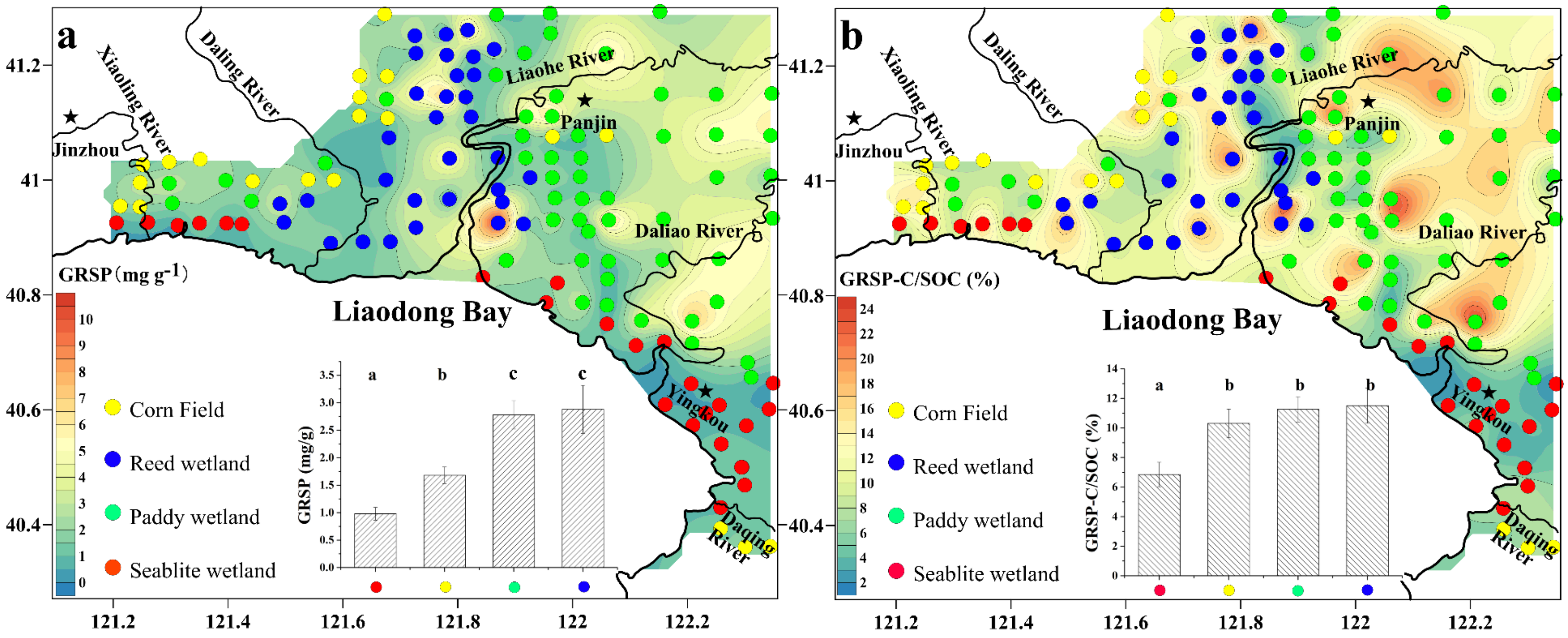


Fig. 3 Spatial variations of GRSP (a) and GRSP-C/SOC (b) in the sediments of the Liaohe Delta

The GRSP concentrations averaged over 133 samples were 2.30 ± 0.17 mg g^{-1}. The highest GRSP concentrations were generally found in the floodplains of the Liaohe and Daliao rivers, where the dominant landscapes were reed and paddy wetlands, followed by corn fields; the lowest concentrations were along the shoreline in the seablite wetlands. The average C concentration of the GRSP (GRSP-C) was 42 ± 1% (range 34–49%), which was within the current literature range of 19–52% (Gillespie et al. 2011; Wang et al. 2014). The GRSP-C/SOC percentages varied from 0.71% to 25%, with an average of 10.4% ± 0.52%. A remarkable finding was that the seablite wetland contained a significantly lower GRSP-C/SOC ratio than the other habitats.

Results

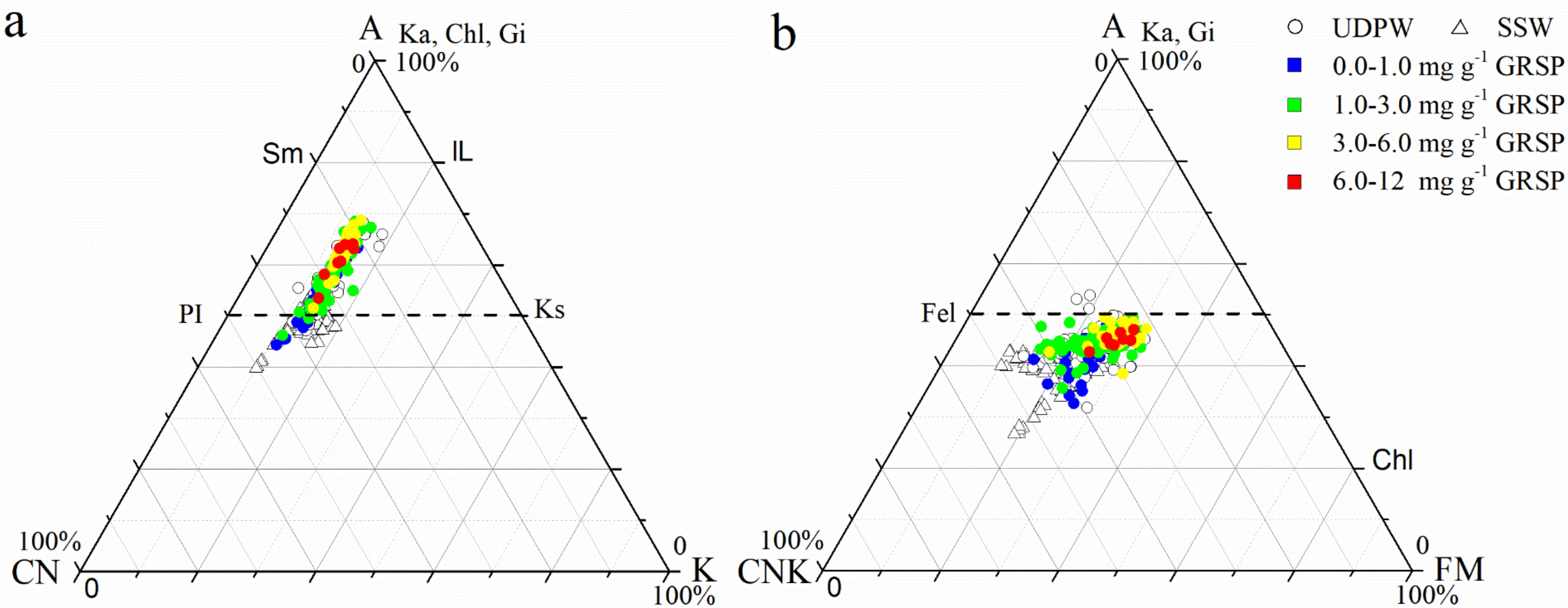


Fig. 4 The A-CN-K (a) and A-CNK-FM (b) chemical weathering trend chart
(Ka = kaolinite; Chl = chlorite; Gi = gibbsite; Sm = smectite; IL= Illite; Pl = plagioclase; Ks = K-feldspar; Fel = feldspar; A-Al2O3; CN = CaO* + Na2O; K = K2O; CNK = CaO* + Na2O + K2O; FM = FeO(T) + MgO)

The trend chart of A-CN-K chemical weathering (Fig. 4a) showed that the weathering trend of the sediments followed a line parallel to the A-CN boundary and close to plagioclase (Pl). The highest GRSP concentrations (>3 mg g^{-1}) were close to the A apex. Meanwhile, the pattern of chemical weathering on the A-CNK-FM diagram (Fig. 4b) revealed that the CNK values were highly differentiated. The bulk sediment compositions with high GRSP concentrations were close to the composition of feldspar (Fel) join.

Results

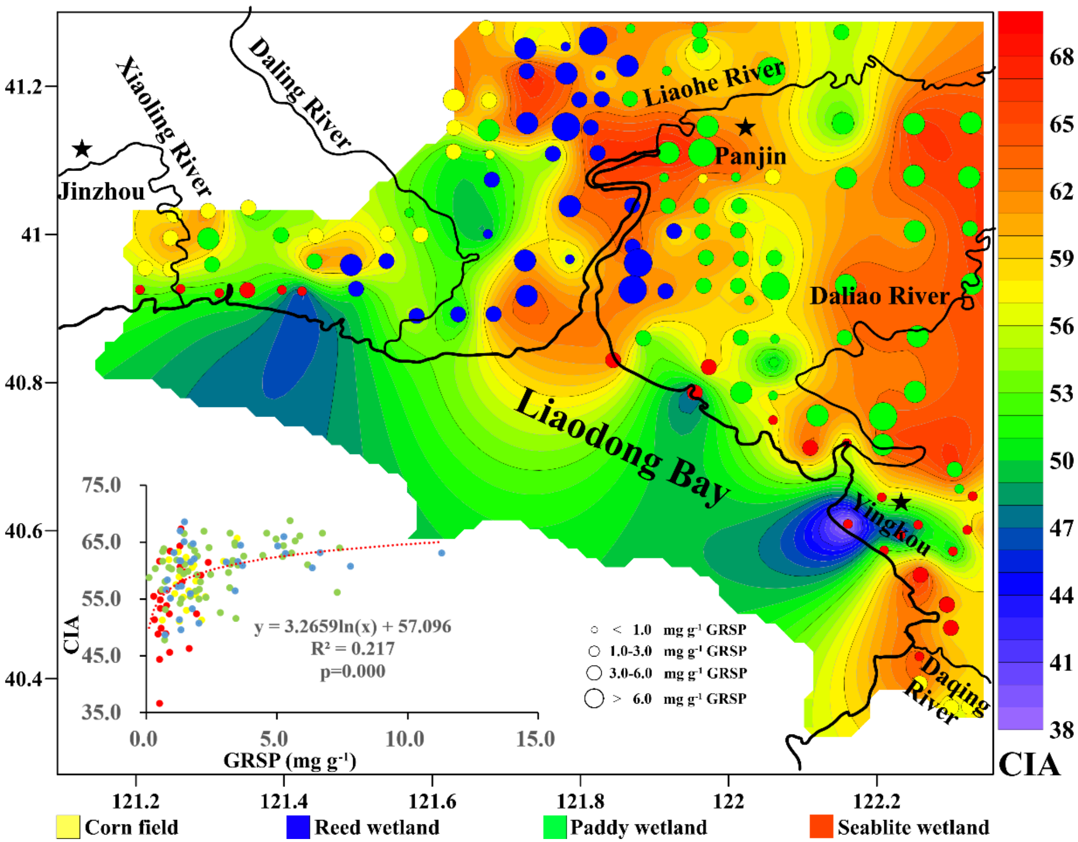


Fig. 5 Spatial variations of CIA in the sediments of the Liaohe Delta

The CIA value averaged over 204 samples in the UDPW was 59, with a range of 37–69. About 84% of the surface sediments in the UPDW were assigned to the primary weathering category; 10% (in the floodplain of the Liaohe River and Daliao River) were classified as moderately weathered; and 6% (right on the coastlines or near the mountain area) were classified as unweathered. In the SSW, the CIA ranged from 19 to 58 and averaged 47, and 56% and 44% of the samples were assigned to the unweathered and primary weathering categories, respectively. No samples were assigned to the moderate or intense weathering categories (Fig.5). The CIA was significantly correlated with GRSP concentrations (r2=0.22, p<0.01) (Fig. 5).

Results

Table 1. Pearson correlation coefficients (r) and goodness of fit (r2) between GRSP (CIA) and sediment physicochemical properties in the LHD (n=133 samples for GRSP correlations; n=204 samples for CIA correlations).

Variables	GRSP	CIA	SOC	WC	BD	Sand	Silt	Clay	pH
GRSP	1**	0.43**	0.56**	0.55**	-0.57**	-0.26**	0.22*	0.25**	-0.12
	(1)	(0.22)	(0.31)	(0.30)	(0.32)	(0.07)	(0.05)	(0.06)	(0.02)
CIA	0.43**	1**	0.59**	0.45**	-0.58**	-0.45**	0.41**	0.37**	-0.20*
	(0.22)	(1)	(0.35)	(0.20)	(0.33)	(0.20)	(0.17)	(0.14)	(0.04)
Variables	Na	K	Ca	Mg	N	P	S	Cl	Fe
GRSP	-0.36**	-0.16	-0.02	0.17**	0.45**	0.32**	-0.07	-0.21*	0.41**
	(0.13)	(0.02)	(0.00)	(0.03)	(0.21)	(0.10)	(0.00)	(0.04)	(0.17)
CIA	-0.87**	-0.14	-0.12	0.39**	0.62**	0.28**	-0.38**	-0.59**	0.74**
	(0.76)	(0.02)	(0.01)	(0.15)	(0.38)	(0.08)	(0.15)	(0.35)	(0.55)

Note: SOC = sediment organic carbon; WC = water content; BD = bulk density.* $p < 0.05$.** $p< 0.01$.

Both the CIA and GRSP were significantly correlated with nutrient concentrations (SOC, N, P, and Fe), sediment structure (moisture, BD, and grain size), and environmental stressors (Na, Cl) ($p<0.01$)

Conclusion

- GRSP is widely present in the surface sediments of coastal wetlands and the remarkably high GRSP-C/SOC ratios confirmed that GRSP was an important part of the sediment carbon pool in the LHD (Fig.3). However, the implications of high GRSP-C/SOC ratios for carbon sequestration are not good in our study, due to the GRSP concentrations were not significantly higher than the analogous concentrations in many other ecosystems. That means a large amount of carbon may have been returned to the atmosphere or otherwise lost from these ecosystems.
- The results of triangle maps (Fig. 4) indicated that biologically AMF-mediated weathering in this area leads to the formation of clay minerals. Moreover, The CIA was significantly correlated with GRSP concentrations, and both the CIA and GRSP were significantly correlated with nutrient concentrations. These results indicate that AMF excursions in wetland ecosystems enhance carbon sequestration and mineral weathering, and in turn they alter retention of at least some nutrients.
- Through the analysis of environmental factors affecting accumulation of GRSP, effective management can improve the acquisition of mineral nutrients and in turn enhance soil carbon sequestration in wetland ecosystems

More detailed information is available in the following article:

Pei, L., S. Ye, H. Yuan, S. Pei, S. Xie and J. Wang. 2019. Glomalin-related soil protein distributions in the wetlands of the Liaohe Delta, Northeast China: Implications for carbon sequestration and mineral weathering of coastal wetlands. Limnology and Oceanography.

Thank You