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# Spatial Variation of Dissolved Organic Carbon in Soils of Riparian Wetlands and Responses to Hydro-geomorphologic Changes in Sanjiang Plain, China

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**Abstract:** Spatial variation of dissolved organic carbon (DOC) in soils of riparian wetlands and responses to hydro-geomorphologic changes in the Sanjiang Plain were analyzed through in situ collecting soil samples in the Naoli River and the Bielahong River. The results showed that the average contents of DOC for soil layer of 0–100 cm were 730.6 mg/kg, 250.9 mg/kg, 423.0 mg/kg and 333.1 mg/kg respectively from riverbed to river terrace along the transverse directions of the Naoli watershed. The content of the soil DOC was the highest in the riverbed, lower in the high floodplain and much lower in the river terrace, and it was the lowest in the low floodplain. The difference in the content and vertical distribution of DOC between the riverbed and the three riparian wetlands was significant, while it was not significant among the low floodplain, the high floodplain and the river terrace. The variability of soil DOC was related to the hydrological connectivity between different landscape position of the riparian wetlands and the adjacent stream. Extremely significant correlations were observed between DOC and total organic carbon (TOC), total iron (TFe), ferrous iron (Fe(II)) whose correlation coefficients were 0.819, –0.544 and –0.709 in riparian wetlands of the Naoli River. With the increase of wetland destruction, soil pH increased and soil DOC content changed. The correlation coefficients between soil DOC and TOC, TFe, Fe(II) also changed into 0.759, –0.686 and –0.575 respectively in the Bielahong River. Under the impact of drainage ditches, the correlations between soil DOC and TFe, Fe(II) were not obvious, while the soil pH was weakly alkaline and was negatively correlated with soil DOC in the previous high floodplain. It indicates that riparian hydro-geomorphology is the main factor that could well explain this spatial variability of soil DOC, and the agricultural environmental hydraulic works like ditching also must be considered.

**Keywords:** dissolved organic carbon (DOC); riparian wetlands; spatial variation; hydro-geomorphologic changes; Sanjiang Plain

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## 1 Introduction

In soils, dissolved organic carbon (DOC) is defined as the entire pool of water soluble organic carbon which is either absorbed on soil or sediment particles or dissolved in interstitial pore water (Tao and Lin, 2000), usually it refers to any organic carbon passing through a 0.45-um filter (Xi *et al*., 2007). Although soil DOC content is no more than 2% of total soil organic matter (Wu *et al*., 2013), as the important fraction in the active soil organic carbon pool, it plays a very important role in the global carbon cycle (Liu *et al*., 2014). As a sensitive indicator to environmental change in soils, soil DOC is significantly correlated to $CO_2$ evolution (Agui-

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lar *et al.*, 2012); soil DOC could partly explain $CO_2$ efflux from wetlands (Glatzel *et al.*, 2003). Meanwhile, soil DOC correlates not only with organic carbon mineralization (Li *et al*, 2004), but also with the eutrophication of water body (Li and Qu, 2004). For these reasons, soil DOC has been a hot topic in environmental research, in particular regarding to the distribution of soil DOC.

The distribution of DOC in soil, rainfall magnitude, the soil water content, and the water flow path in catchments determined DOC transport into streams (Xi *et al.*, 2007; Terajima and Moriizumi, 2013). Hence the dynamics of DOC in streams are dominated by both the variation of DOC in the source area and environmental conditions in catchments (topography, geology, vegetation, and climate). However, the increase of DOC in streams leads to the increases in organic acid, acid neutralizing capacity, water color, and so on (Zhang *et al.*, 2009). Furthermore, it also affects freshwater aquaculture, drinking water quality, estuarine and marine ecosystems (Anne-Catherine *et al.*, 2011). Meanwhile, as an important DOC reserve, wetlands, especially riparian wetlands, are the main sources of DOC to streams, and whose production potential of DOC is partially influenced by hydrology, topography and vegetation types (Xi *et al.*, 2007). Hydrology and vegetation are the most direct factors to affect the production of DOC (Coletti *et al*, 2013) among all the factors. While local surface topography affects water table depth and flow situation, it also affects the vegetation type and thus affects DOC amount and composition indirectly (Xi *et al.*, 2007; Kong *et al.*, 2013; Terajima and Moriizumi, 2013). However, until recently, few studies have been focused on the horizontal distribution of soil DOC in different hydro-geomorphologic units and the spatial relationships between these units.

The Sanjiang Plain, a floodplain in the northeastern China includes a large area of natural and artificial wetlands (Xi and Lu, 2007; Song *et al.*, 2011). Wetlands in the Sanjiang Plain store large amounts of organic carbon (Song *et al.*, 2003; Zhang, 2010). The reserves and distribution of soil DOC in wetlands are also affected by the human activities like construction of the man-made ditches, except the hydrology, topography, vegetation and other natural factors (Xi and Lu, 2007; Song *et al.*, 2011). The Naoli River and Bielahong River catchments are the major distribution range of wetlands in the Sanjiang Plain, whose reserves and dynamics of soil DOC in wetlands can affect the DOC exports from the whole wetlands in the Sanjiang Plain, then affect the carbon pools in the Heilong River as the ninth longest river in the world and even Okhotsk Sea in the northwest of North Pacific (Song *et al.*, 2011). Therefore, it is critically important to track the wetland DOC dynamics in the Sanjiang Plain, to reveal the influence of large-scale hydro-geomorphologic factors and the construction of man-made ditches on soil DOC in riparian wetlands.

Then, to investigate the distribution of soil DOC in riparian wetlands, we collected soil samples from river-bed to river terrace in two adjacent catchments with different hydrology and topography. Additionally, for further understanding of the impact of hydrology and topography conditions on the content and distribution of soil DOC in riparian wetlands, we collected soil samples from the bottom of a drainage canal to the top in a high floodplain of catchments. We subsequently measured the concentration of soil DOC and other elements. All results will improve our understanding of soil DOC transport and fate in riparian wetlands, and the functioning and environmental benefits of riparian ecosystems.

## 2 Materials and Methods

### 2.1 Study area

The study sites are in two adjacent catchments. One is in the lower reaches of the Naoli River catchment and another is located in the upper reaches of the Bielahong River catchment. The two catchments are the major distribution range of wetlands in the Sanjiang Plain and wetland ratio is relatively large. The Naoli River belongs to typical mountain-plain river that originates from mountain through plain swamp regions, and the Naoli River is located in the south of the Bielahong River and close to the main canal while the Bielahong River belongs to typical plain river which originates from plain swamp wetlands through plain swamp regions. The Naoli River is partially artificially drained wetlands, and streams are not ditched and cut-off. In comparison, wetland deteriorates seriously and main canal is ditched in the high floodplain of the Bielahong River.

### 2.2 Experimental design and field sampling

Soil samples were collected at two sites in the lower reaches (46°48′34″N, 133°52′54″E) of the Naoli River (site A) and the upper reaches (47°24′03″N, 134°04′57″E) of the Bielahong River (site B) (Fig. 1). At site A, four representative sample plots were selected along a gradient from riverbed to river terrace according to different hydro-geomorphologic conditions (Fig. 2). Within each plot, three sample points were randomly chosen. Soil samples in the lower reaches of the Naoli River were collected in the following soil series: mud marsh soil in the riverbed (A1), humus marsh soil in the low floodplain (A2), meadow marsh soil in the high floodplain (A3), and meadow soil in the river terrace (A4) with a distance of about 200 m among sites.

At site B, soil samples were collected only in the low floodplain (ancient riverbed) and high floodplain, considering the integrality of landscape pattern in the Bielahong River catchment and soil samples in the high floodplain were collected from the bottom to the top of main canal of the Bielahong River. Soil types are all peat soils that include B1 in the low floodplain, B2, B3 and B4 in the high floodplain of the Bielahong River. It is worthwhile to note that B2 is in the bottom of main canal of the Bielahong River with a distance of about 200 m from B1, whereas B3 and B4 are in the bottom and top of the dam. Wetland soil classification was in accordance with marsh classification system in the Sanjiang Plain (Zhang, 1988).

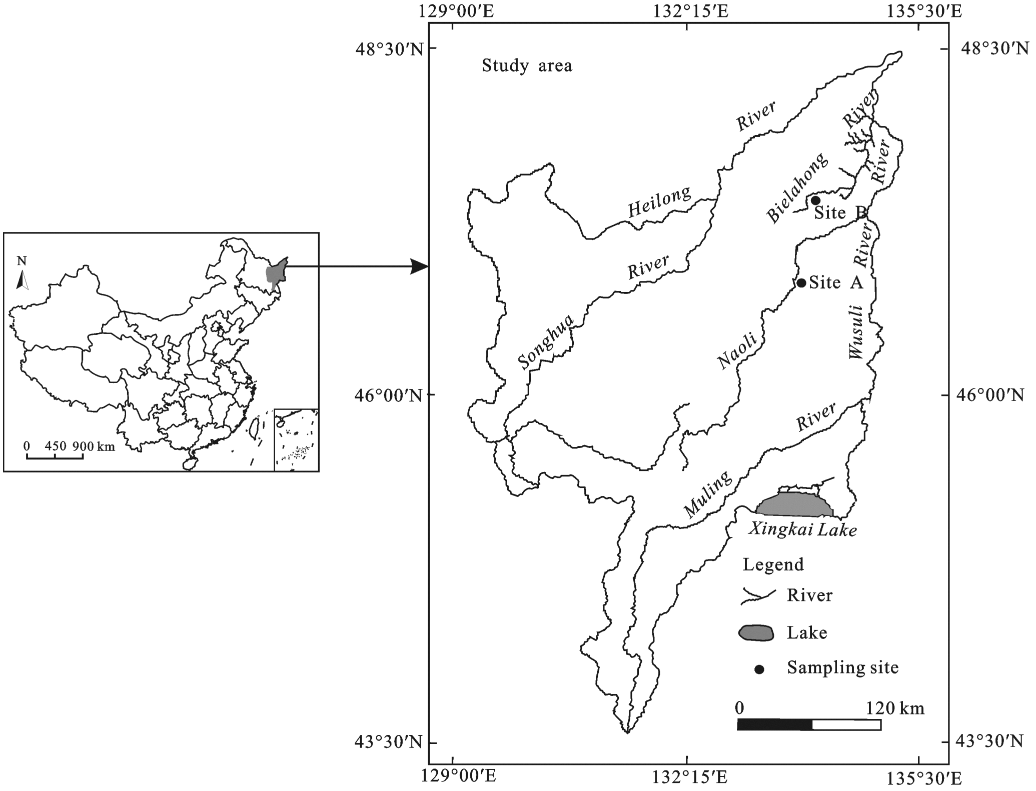

**Fig. 1** Sketch map of study area

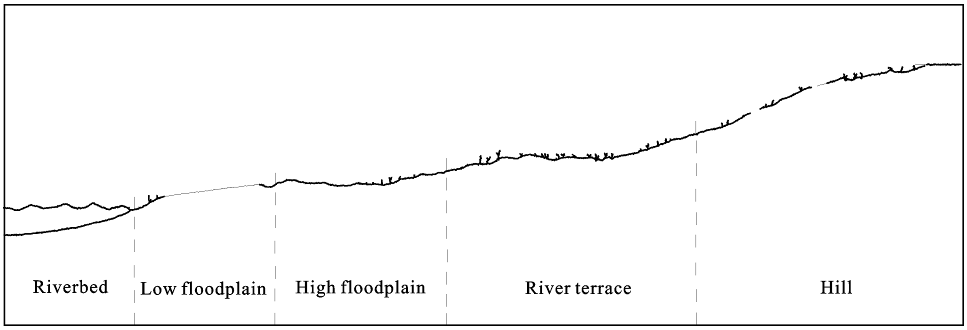

**Fig. 2** Sketch map of hydro-geomorphologic units along transverse directions of Naoli River watershed

According to the soil genetic horizon, soil samples were collected at depths of 0–10 cm, 10–20 cm, 20–40 cm, 40–60 cm, 60–80 cm and 80–100 cm by soil drilling with three replicates. Among them, there is a sampling point collected four layers, thus a total of 138 soil samples in eight sites were collected. All the soil samples were put into the sealed plastic bag. Some of them were stored in refrigerator for the determination of total iron (TFe) and ferrous iron (Fe(II)), and the others were air-dried and ground to pass through a 2-mm mesh sieve (nylon) for measuring DOC, total organic carbon (TOC), total phosphorus (TP) and pH.

### 2.3 Methods

For the measurement of the soil DOC contents, 10 g soil sample was weighed and put in triangular flask with 40 mL distilled water, shocked and leached about 30 min at ordinary temperature. Then after a high-velocity centrifuge for 10 min, the supernatant obtained was filtered through a 0.45-μm filter into separate vials for DOC analysis. The extracts were analyzed for DOC using total organic carbon analyzer (TOCVCPH, Shimadzu, Kyoto, Japan) (Kong *et al.*, 2013). Experiment results were stable, and the addition standard recovery was 97.5%–104.2%.

The TFe was determined with atomic absorption spectrometry (GBC-906 AAS, made in Australia) after digestion by $HNO_3$-HF-$HClO_4$ for 0.5 h (Jiang *et al.*, 2011). The Fe(II) was extracted by chlorohydrin acid solutions and determined with spectrophotometry (Zheng *et al.*, 2010). The other physical and chemical indicators were determined according to national standard.

The data obtained were analyzed for ANOVA using SPSS 14.0 software package. The pictorial diagrams of the distribution variables of DOC in soils of riparian wetlands were performed using OriginPro 8.0.

## 3 Results and Analyses

### 3.1 Distribution variation of soil DOC in riparian wetlands of Naoli River

The vertical variations of soil DOC with different hydro-geomorphologic conditions in riparian wetlands of the Naoli River are shown in Fig. 3. The DOC content was the highest with a mean value of 1055 mg/kg at the depth of 0–10 cm in the soil profiles, and was notably characterized by a decreasing trend with depth. At site A1, A2, A3 and A4, the DOC content decreased with increasing soil depth from 0–10 cm to 10–20 cm，and the declining range of them was 27.0%, 26.3%, 84.9% and 52.1%, respectively. At A1 and A3, the DOC content had been declining with increasing soil depth from 20–40 cm to 80–100 cm. However, at A2 and A4, the DOC content had a slight increase at the depths of 40–60 cm and 20–40 cm, and the rising range of them was 40% and 235%, respectively. The single factor analysis of variance showed that the difference between A1 and A2, A3, A4 was remarkable, while it was not significant among A2, A3 and A4 ($P < 0.05$).

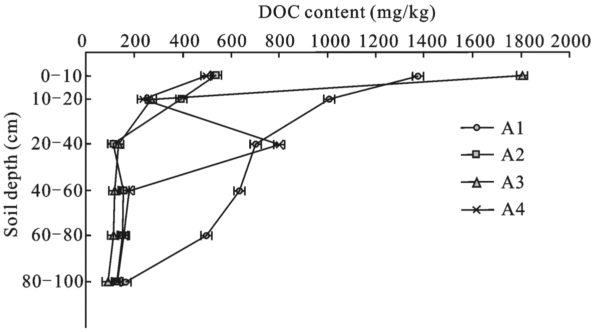

**Fig. 3** Vertical variations of soil dissolved organic carbon (DOC) in riparian wetlands of Naoli River. A1, riverbed; A2, low floodplain; A3, high floodplain; A4, river terrace

Horizontal variations of soil DOC were also analyzed in riparian wetlands of the Naoli River. The results showed that A1 had the highest DOC content with a mean value of 730.6 mg/kg that located on the lowest position. A2, the nearest to A1, had the lowest DOC content with a mean value of 250.9 mg/kg. The A4 located on the highest position that had lower DOC content than A3, and the mean values were 423.0 mg/kg and 333.1 mg/kg, respectively. Further One-way ANOVA analysis showed that significant differences were found between A1 and A2, A3, A4, while there was no significant difference among A2, A3 and A4 ($P < 0.05$).

Soil DOC is the most active carbon component whose variations are intimately associated with other environmental factors. Other environmental factors were listed in Table 1, and a correlation analysis was needed in riparian wetlands of the Naoli River. The results showed that the soil DOC content was significantly correlated with the contents of TOC, TFe and Fe(II) at 0.01 level in riparian wetlands of the Naoli River (Fig. 4). The soil DOC contents are positively

**Table 1** Average value of soil environmental factors in riparian wetlands of Naoli River

| Site | Soil depth (cm) | TOC (g/kg) | TFe (g/kg) | Fe(II) (mg/kg) | TP (mg/kg) | pH |
|---|---|---|---|---|---|---|
| A1 | 0–10 | 28.75 | 9.55 | 10.70 | 1252.72 | 5.93 |
| | 10–20 | 31.43 | 8.37 | 10.40 | 1158.28 | 5.71 |
| | 20–40 | 30.49 | 9.08 | 10.60 | 994.11 | 5.85 |
| | 40–60 | 26.10 | 9.56 | 11.90 | 837.80 | 5.82 |
| | 60–80 | 14.03 | 17.10 | 10.95 | 610.21 | 6.05 |
| | 80–100 | 3.52 | 22.63 | 11.80 | 276.58 | 5.69 |
| A2 | 0–10 | 14.67 | 22.98 | 15.90 | 794.07 | 6.12 |
| | 10–20 | 16.83 | 27.20 | 14.90 | 970.26 | 6.40 |
| | 20–40 | 1.92 | 32.05 | 14.90 | 1308.94 | 6.52 |
| | 40-60 | 1.10 | 31.30 | 17.10 | 1140.92 | 6.65 |
| | 60-80 | 1.31 | 32.11 | 16.40 | 991.40 | 5.98 |
| | 80–100 | 1.20 | 30.37 | 16.70 | 843.12 | 6.26 |
| A3 | 0–10 | 29.37 | 28.60 | 11.50 | 1239.56 | 6.19 |
| | 10–20 | 17.47 | 37.74 | 15.00 | 949.95 | 6.14 |
| | 20–40 | 2.22 | 42.60 | 14.05 | 1549.97 | 6.30 |
| | 40-60 | 1.23 | 32.43 | 16.55 | 1360.36 | 6.35 |
| | 60–80 | 1.06 | 33.32 | 17.10 | 1245.33 | 5.83 |
| | 80–100 | 1.28 | 30.66 | 16.40 | 897.76 | 5.84 |
| A4 | 0–10 | 17.21 | 29.49 | 15.05 | 1252.72 | 5.69 |
| | 10–20 | 2.32 | 22.68 | 15.65 | 1158.28 | 6.63 |
| | 20–40 | 7.35 | 25.80 | 12.80 | 994.11 | 6.78 |
| | 40–60 | 1.31 | 33.60 | 17.00 | 837.80 | 7.03 |

Notes: TOC, total organic carbon; TFe, total iron; Fe(II), ferrous iron; TP, total phosphorus

correlated with TOC contents in riparian wetlands of the Naoli River. That is to say that soil DOC content increased with TOC content. While the magnitude of the ratio of DOC to TOC significantly increased with increasing depth through soil profiles, which was related to the properties of soil DOC mobile, soil DOC content decreased with TFe and Fe(II) contents, which was connected with the organic matter.

## 3.2 Distribution variation of soil DOC in riparian wetlands of Bielahong River

In addition to the riparian wetlands of the Naoli River, soil DOC variation was also explored in the Bielahong River (Fig. 5). The DOC content was the highest with a mean value of 150.8 mg/kg at the depth of 0–10 cm in the soil profiles, and the differences of soil DOC content in different soil layers were not significant ($P < 0.05$). The B1 had higher DOC content with a mean value of 305.7 mg/kg and a quite different vertical variation from

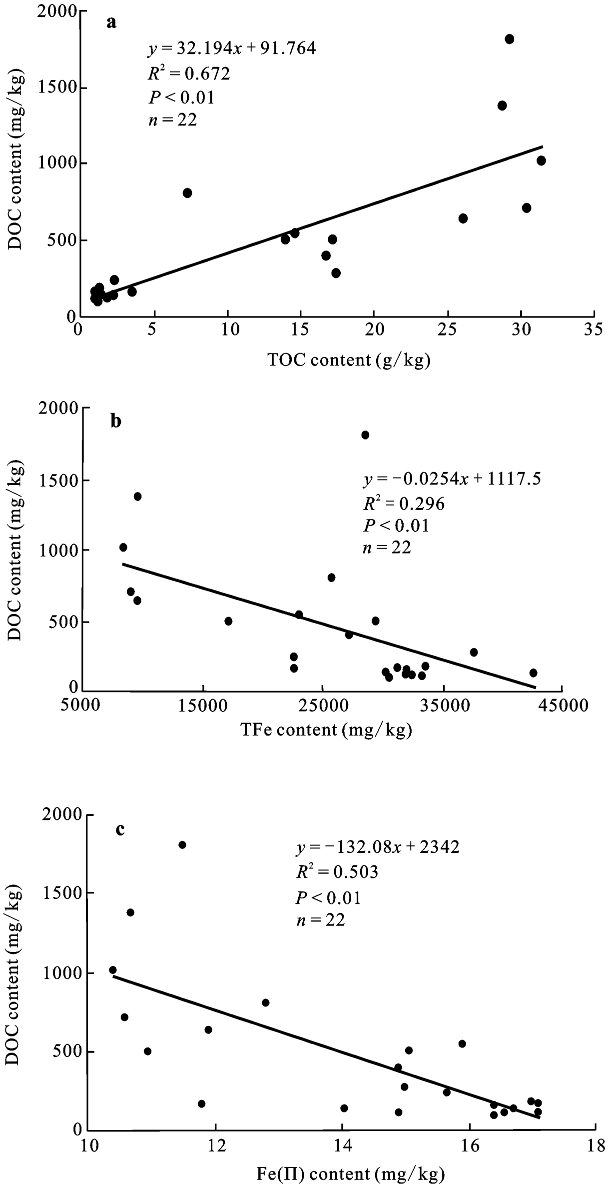

**Fig. 4** Relationship between soil dissolved organic carbon (DOC) and other environmental factors in riparian wetlands of Naoli River. TOC, total organic carbon; TFe, total iron; Fe(II), ferrous iron

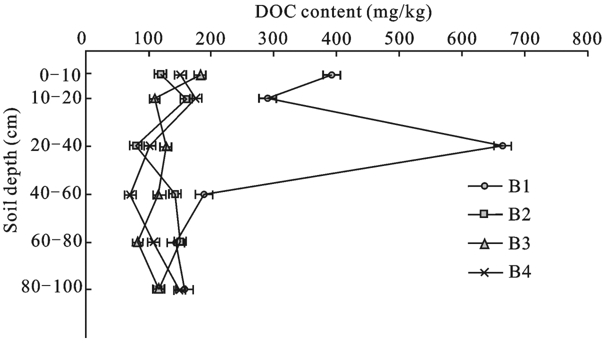

**Fig. 5** Vertical variations of soil dissolved organic carbon (DOC) in riparian wetlands of Bielahong River. B1, low floodplain; B2, bottom of main canal; B3, bottom of the dam; B4, top of the dam

B2, B3 and B4. Nonetheless, similar with B1, B3 had two high points in soil DOC content with increasing depth and the DOC content was the highest at the depth of 0–10 cm in the soil profiles. Through further One-way ANOVA, there was no significant difference in DOC content among B2, B3 and B4 ($P < 0.05$) whose mean values were 128.8 mg/kg, 122.4 mg/kg and 125.6 mg/kg, respectively, and the soil DOC content with different layers was more complex.

Similarly, the soil DOC was significantly correlated with TOC, TFe and Fe(II) in riparian wetlands of the Bielahong River ($P < 0.01$), however, there was a change in the correlation coefficients which were 0.759, –0.686, –0.575 and 0.443, respectively (Fig. 6). In addition, the soil DOC content was negatively correlated with pH ($P < 0.05$), and by calculating, soil pH was high in the Bielahong River than in the Naoli River (Table 2). Thereafter, the environmental hydraulic works like ditching are important factors that must be considered in this variability. To justify the idea, we selected only B2, B3 and B4 to clarify the relationship between soil DOC content and environmental factors in riparian wetlands of the Bielahong River (Table 3), and we found that soil DOC was still significantly correlated with pH, but the correlation coefficients increased. Soil DOC was not correlated with TOC, and this may be the result of soil DOC migration. The correlations between soil DOC and TFe, Fe(II) were not obvious, but soil TOC was negatively correlated with Fe(II).

**Table 2** Average value of soil environmental factors in riparian wetlands of Bielahong River

| Site | Soil depth (cm) | TOC (g/kg) | TFe (g/kg) | Fe(II) (mg/kg) | TP (mg/kg) | pH |
|---|---|---|---|---|---|---|
| B1 | 0–10 | 11.78 | 14.86 | 16.05 | 904.31 | 6.32 |
| | 10–20 | 18.77 | 16.48 | 14.70 | 595.95 | 6.12 |
| | 20–40 | 12.30 | 18.58 | 13.70 | 477.91 | 6.03 |
| | 40–60 | 2.79 | 23.52 | 13.35 | 282.77 | 5.51 |
| | 60–80 | 1.33 | 23.39 | 16.40 | 243.96 | 5.74 |
| | 80–100 | 0.98 | 24.70 | 17.25 | 217.43 | 5.50 |
| B2 | 0–10 | 1.47 | 36.89 | 15.65 | 638.42 | 6.62 |
| | 10–20 | 1.18 | 36.20 | 16.50 | 683.07 | 6.75 |
| | 20–40 | 0.94 | 35.80 | 17.25 | 548.25 | 6.83 |
| | 40–60 | 0.98 | 34.67 | 17.15 | 450.36 | 6.94 |
| | 60–80 | 0.87 | 36.32 | 17.50 | 326.10 | 7.10 |
| | 80–100 | 1.02 | 38.07 | 17.00 | 466.81 | 6.99 |
| B3 | 0–10 | 1.63 | 35.34 | 15.25 | 537.37 | 6.24 |
| | 10–20 | 1.01 | 35.99 | 17.15 | 506.61 | 6.64 |
| | 20–40 | 1.49 | 38.78 | 15.70 | 520.28 | 6.96 |
| | 40–60 | 1.09 | 37.98 | 16.90 | 738.68 | 7.00 |
| | 60–80 | 1.30 | 33.06 | 16.20 | 526.85 | 7.10 |
| | 80–100 | 1.18 | 36.26 | 16.80 | 1204.17 | 7.08 |
| B4 | 0–10 | 1.58 | 33.73 | 15.30 | 445.01 | 6.69 |
| | 10–20 | 1.08 | 44.23 | 17.00 | 333.59 | 6.67 |
| | 20–40 | 1.02 | 40.41 | 17.20 | 356.84 | 6.83 |
| | 40–60 | 1.32 | 34.71 | 16.10 | 558.08 | 6.90 |
| | 60–80 | 0.90 | 36.87 | 17.30 | 408.20 | 6.90 |
| | 80–100 | 0.76 | 36.61 | 17.80 | 624.04 | 6.85 |

## 4 Discussion

The DOC content was the highest at the depth of 0–10 cm in the soil profiles, and was notably characterized by a decreasing trend with depth which was consist with previous studies (Huo *et al.*, 2013). It is because that the plant residue in soil top lay is the main sources of soil DOC (Müller *et al.*, 2009), and water is the main driver of DOC leaching and downward mobility along soil profiles (Schulze *et al.*, 2010). However, the DOC was retained in soil profiles of the wetlands in the downward mobility process (Rosenqvist *et al.*, 2010) and the DOC retention effects were not the same in different landscape position, soil type or horizon. So, it can be found that the DOC contents of A1 and A3 had the same

**Table 3** Correlations between soil dissolved organic carbon (DOC) and other environmental factors in main canal of Bielahong River

| | DOC (mg/kg) | TOC (g/kg) | TFe (mg/kg) | Fe(II) (mg/kg) | TP (mg/kg) | pH |
|---|---|---|---|---|---|---|
| DOC (mg/kg) | 1.000 | 0.143 | 0.260 | –0.136 | –0.138 | –0.480* |
| TOC (g/kg) | | 1.000 | –0.234 | –0.993** | 0.139 | –0.453 |
| TFe (mg/kg) | | | 1.000 | 0.288 | –0.221 | –0.075 |
| Fe(II) (mg/kg) | | | | 1.000 | –0.095 | 0.458 |
| TP (mg/kg) | | | | | 1.000 | 0.177 |
| pH | | | | | | 1.000 |

Notes: *, the significance level of 0.05; **, the significance level of 0.01

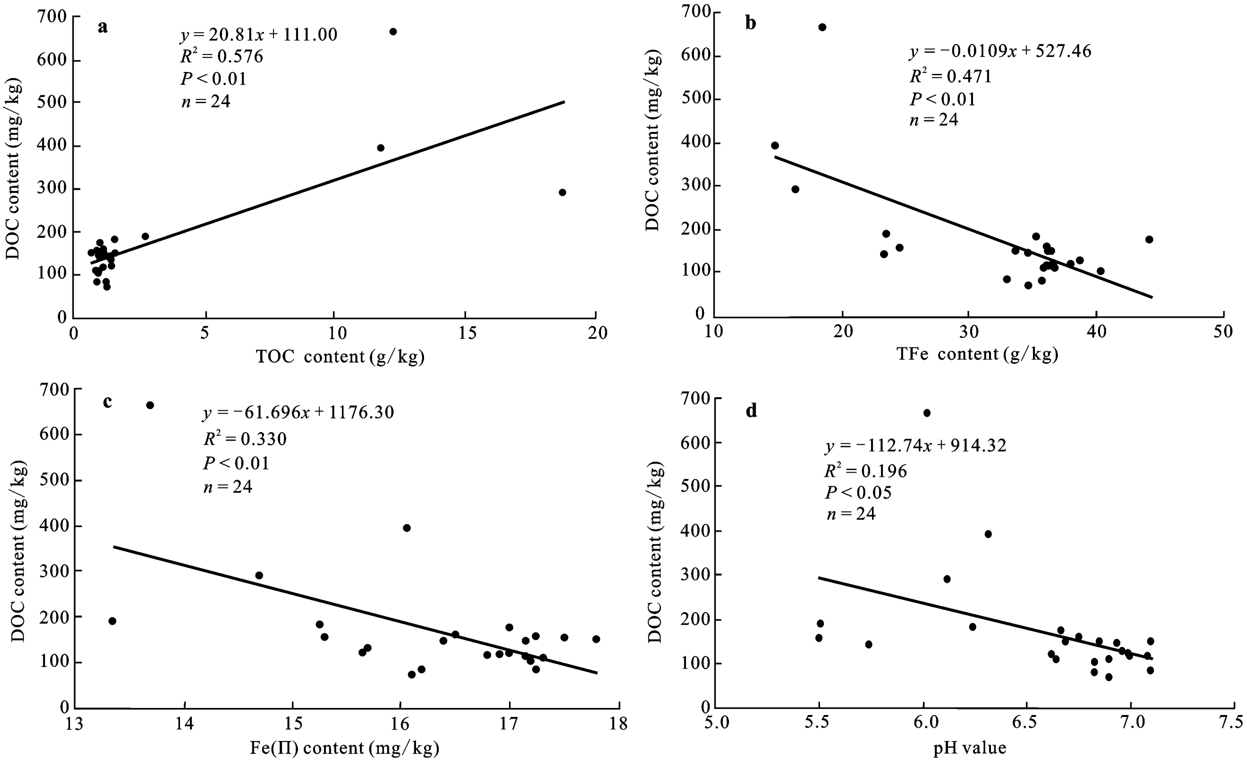

**Fig. 6** Relationship between soil dissolved organic carbon (DOC) and other environmental factors in riparian wetlands of Bielahong River. TOC, total organic carbon; TFe, total iron; Fe(II), ferrous iron

decreasing tendency with depth, but the decreasing range was different from each other. The declining ranges of A1 and A3 were 27.0% and 84.9% at depths of 0–10 cm and 10–20 cm, thus A3 had a better DOC retention effects than A1. In contrast, A2 and A4 had a slight increase at depths of 40–60 cm and 20–40 cm, which may be related to soil adsorption and intercept properties of different horizons.

It is well known that the DOC is a mobile and important carbon source in the subsurface. The loss of dissolved carbon through water has been indicated as one of the most important carbon sources for riverine ecosystems (Wang *et al.*, 2010). We hypothesized that input of the DOC could be an important DOC redistribution mechanism at the catchments (Xi *et al.*, 2007). The variability of soil DOC may be related to geomorphological features and hydrological connectivity between different landscape position of the riparian wetlands and the adjacent hillslope or stream. There were important geomorphological features including the size and slope of riparian wetlands in the Naoli River catchments. The large hillslope supports the permanence of the groundwater supplying for the riparian wetlands, i.e., a long hydrological connectivity of the riparian wetlands with the adjacent hillslope and the stream (Jencso *et al.*, 2009; Montreuil *et al*, 2011). The A1 located on the lowest position of the hydraulic gradients between riparian wetlands and streams, and acted like a DOC sink of the riparian wetlands. Therefore, A1 had the highest DOC content with a mean value of 730.6 mg/kg, and thus significant differences were found between A1 and A2, A3, A4. As the riparian wetlands of the Naoli River, A2 showed a strong hydrological connectivity with A1 due to the near distance from the stream, and thus A2 had lowest DOC content with a mean value of 250.9 mg/kg. The A4 located on the highest position of the hydraulic gradients between riparian wetlands and streams, and the soil DOC was transported through soils from A3 to A2 and then to A1 due to the far distance from the stream. Therefore, A3 had higher DOC content than A4, and the mean values were 423.0 mg/kg and 333.1 mg/kg, respectively. As the DOC source of the stream, riparian wetland soils are able to retain and degrade DOC, and control DOC transport to streams (Jacinthe *et al.*, 2003). So, there was no significant difference among A2, A3 and A4 ($P < 0.05$) through the single factor analysis of variance. That is to say, the source area of soil DOC in riverbed of the

Naoli River, the riparian wetland was affected by lateral flow of the riverbank, thus the soil DOC between low and high floodplain is different but the difference is not significant.

Compared to the Bielahong River, the content of soil DOC was higher in the Naoli River and there was no significant difference between low floodplain and high floodplain. This might be related to the construction of ditches and the lateral flow pathway of groundwater from adjacent hillslope to riparian wetland or stream. Currently, it remains in dispute that the construction of ditches increased or decreased DOC contents in streams. However, the conclusion that the construction of ditches results in decrease of soil DOC in wetland has been confirmed (Billings, 1987; Wallage *et al*., 2006). To minimize DOC losses in drained peatland soils and the pollution of surface water, the impact of drain-blocking on soil DOC content, release and export in peatland are carried out (Worrall *et al*., 2007; Turner *et al*., 2013), and these results imply that the construction or blocking of ditches would cause disturbing influence to the production and transform process of DOC in wetland. In the Bielahong River, the main canal is ditched in high floodplain, thus changed the size and direction of the lateral flow from adjacent hillslope to riparian wetland or stream. The DOC flux from adjacent hillslope flowed into the main canal of the Bielahong River instead of riparian wetlands or steam. As a result, the content of soil DOC in riparian wetlands of the Bielahong River was low, and there was a significant difference between low floodplain and high floodplain.

Soil DOC was mostly concentrated in the top of the soil (0–20 cm) and decreased with decreasing TOC in riparian wetlands of the Naoli River, which indicates the soil organic matter itself played a crucial role in the distribution of soil DOC. While the content of DOC in riparian wetlands of the Bielahong River was the highest at depth of 0–20 cm in the soil profiles, the differences of soil DOC content in different soil layers were not significant. Moreover, the soil DOC content with different layers change was more complex, and this complex was probably related to the disruption of soil development sequence in strong artificial interference (Tao *et al*., 2011). Previous study has confirmed the environmental hydraulic works like ditching are important factors that must be considered in this variability (Montreuil *et al*, 2011). Besides above conclusions, the results of this study shows that soil DOC was not correlated with TOC in the high floodplain which maybe the result of soil DOC migration (Lan *et al*., 2011) and also indicated DOC fluxes ultimately determined the distribution of soil DOC.

At the two sites, the correlations between soil DOC and TFe, Fe(II) were similar. However, the correlations between soil DOC and TFe, Fe(II) were not obvious in the high floodplain because of the main canal for conducting water in the Bielahong River. Soil TOC was negatively correlated with Fe(II), which was consisted with the results of previous study (Jiang, 2007). The results of previous study has confirmed that organic matter donates electron, effective agent for iron reducing-bacteria and fermentation bacteria, and further promotes iron reduction process (Jiang *et al*., 2011). In addition, the correlations between soil DOC and pH were significant in the riparian wetlands of the Bielahong River. A further comparison showed that the value of soil pH in riparian wetlands of the Naoli River was 6.17 and the range was large. In the riparian wetlands of the Bielahong River, however, the value of soil pH increased up to 6.60 and its range reduced. The highest value of soil pH around 7.10 appeared in the bottom of the main canal in the Bielahong River, and the soil here was slightly alkaline, which was related with drainaging water aroused by ditches. So hydro-geomorphologic conditions controlled the hydrological and hydrochemical behavior of riparian wetlands (Montreuil *et al*., 2011), and thus influenced the correlations between soil DOC and environmental factors.

## 5 Conclusions

The different hydro-geomorphologic conditions determined unique spatial variation of soil DOC in the riparian wetlands. The soil DOC content was the highest in riverbed, lower in the high floodplain and much lower in the river terrace, and it was the lowest in the low floodplain. The difference on the content and vertical distribution between the riverbed and the three riparian wetlands was remarkable, while it was not significant among the low floodplain, the high floodplain and the river terrace.

Hydro-geomorphologic conditions influenced the correlations between soil DOC and environmental factors. In riparian wetlands of the Naoli River, the soil

DOC content increased with TOC content, and decreases with TFe and Fe(II) contents with the least disturbance. In riparian wetlands of the Bielahong River, soil DOC content was negatively correlated with pH value and the correlation coefficients between DOC content and TOC, TFe, Fe(II) contents changed under the impact of drainage ditches. In the main canal of the Bielahong River, the correlations between soil DOC content and TFe, Fe(II) contents were not obvious, while the soil pH was weakly alkaline and was negatively correlated with soil DOC content. This proves that riparian hydro-geomorphology is the main factor explaining this spatial variability of soil DOC, and the agricultural environmental hydraulic works like ditching also must be considered.

The spatial variation of DOC contents in water and soils of riparian wetlands is relevant with the hydro-geomorphologic conditions in different landscape positions. Hydro-geomorphology not only directly impacts the transportation and transformation of soil DOC through hydrochemistry process, but also indirectly impacts the production of soil DOC through the growth and decomposition of the plants. Therefore, the recommendations to research the pattern and process of soil DOC in different hydro-geomorphologic conditions of riparian wetlands based on the combination of macrocosm and microcosm were proposed, which will provide scientific evidence for the management of watershed wetland.

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