Chin. Geogra. Sci. 2010 20(2) 139–143
DOI: 10.1007/s11769-010-0139-4

Changes of Soil Labile Organic Carbon in Different Land Uses in Sanjiang Plain, Heilongjiang Province

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Abstract: In the Sanjiang Plain, Northeast China, the natural wetland is undergoing a rapid conversion into agricultural land, which has resulted in drastic ecological changes in the region. To investigate the effects of different land uses on soil labile organic carbon, soils of *Calamagrostis angustifolia* wetland, *Carex lasiocarpa* wetland, dry farmland, paddy field, forest land and abandoned cultivated land were collected for measuring the contents of soil microbial biomass carbon (MBC), dissolved organic carbon (DOC), readily oxidizable carbon (ROC) and carbohydrate carbon (CHC). The results show that soil organic carbon contents follow the order: *Carex lasiocarpa* wetland>*Calamagrostis angustifolia* wetland>forest land>paddy field>dry farmland. The contents of MBC and DOC in *Calamagrostis angustifolia* and *Carex lasiocarpa* wetlands are significantly higher than those in other land use types. The contents of CHC and ROC are the highest in *Calamagrostis angustifolia* wetland and the lowest in dry farmland. The contents of all the labile organic carbon increase along with the years of abandonment of cultivated land. The ratios of MBC, DOC and ROC to SOC also follow the order: *Carex lasiocarpa* wetland>*Calamagrostis angustifolia* wetland>forest land>paddy field>dry farmland, while the ratio of CHC to SOC is paddy field>forest field>*Carex lasiocarpa* wetland>*Carex lasiocarpa* wetland>dry farmland. When natural wetlands were cultivated, the activity of soil organic carbon tends to reduce in some extent due to the disappearance of heterotrophic environment and the reduction of vegetation residue. Thus, the abandonment of cultivated land is an effective way for restoring soil organic carbon.
Keywords: labile organic carbon; land use; Sanjiang Plain

1 Introduction

Soil organic carbon (SOC) comprises a major pool in the global carbon cycle, and plays an important role in regulating the atmospheric CO_2 concentration. Land use/cover changes and human activities all remarkably influence the contents of SOC (Detwiler, 1986; Guggenberger *et al*., 1995; Tiessen *et al*., 1998), leading to more carbon emission to the atmosphere. Sombroek *et al*. (1993) reported a 20%–50% reduction of soil organic matter (SOM) due to clearing tropical forests and their subsequent conversion into farmland. The content of SOC is a key attribute to soil quality since it has far reaching effect on physical, chemical and biological properties of soil. Among the different forms of SOC, labile organic carbon with turnover time of few days to months can be considered as fine indicator of soil quality, which influences soil function in specific ways and is much more sensitive to the changes in soil management practices (Cambaredlella, 1998). Soil microbial biomass carbon (MBC) and dissolved organic carbon (DOC) have been shown to be sensitive to short-term changes in soil management (Alessandra *et al*., 2002). Some researches have indicated that cultivation can result in the decrease in MBC content, microbial quotient and DOC content (Zhang *et al*., 2005; 2006). Readily oxidizable organic carbon (ROC) and carbohydrate carbon (CHC) also belong to labile organic carbon, and they together contribute hardly 20% of SOC. Moreover, we could expect short to medium-term effect of SOC on soil carbon-sequestration through these pools (Pratap *et al*., 2007).

The Sanjiang Plain is not only the largest wetland distribution region in China, but also the largest area of wetland reclamation in the past 50 years in the world. The area of wetlands in the plain has decreased, how-

Received date: 2009-04-20; accepted date: 2009-11-09
Foundation item: Under the auspices of National Natural Science Foundation of China (No. 30470340)
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ever, the area of cultivated land has increased in the recent decades. With the reclamation of wetlands and the increasing human activities, natural wetland ecosystem has been destroyed and the normal physical, chemical and biological processes were disturbed (Liu and Ma, 2002).

Several researches have been done on land use change in the Sanjiang Plain in recent years. Most of them focused on carbon dynamics when wetlands were cultivated (Zhang and Song, 2004; Wang *et al*., 2009), but few studies paid attention to the carbon dynamics in the conversion from farmland to wetland. The objective of this work is to investigate the changes of SOC content and labile fractions in wetland cultivation and farmland abandonment practices, and to propose the method of wetland recovering in the Sanjiang Plain.

2 Materials and Methods

2.1 Experimental site

The experimental site is located at Honghe Farm (47°35′N, 133°31′E) in the Sanjiang Plain, Northeast China. The average altitude is 55.4–57.9 m. Mean annual temperature is 1.9℃ with an average frost-free period of 125 d. Mean annual precipitation is 550–560 mm, of which more than 65% concentrates in July and August. *Deyeuxia angustifolia*, *Carex lasiocarpa*, *Cares pseudocuraica* and *Carex meyeriana* are typical plants in the area .

2.2 Sample collection and determination

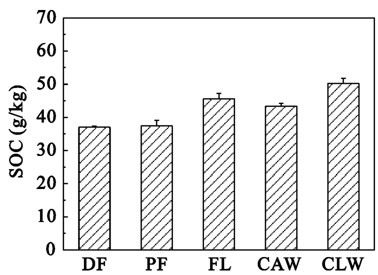
Soil samples were collected from representative types of land uses in the experimental site in August 2008. The land use types included dry farmland (DF), which has been cultivated for 15 years, paddy field (PF), which has been cultivated for 15 years, forest land (FL), *Calamagrostis angustifolia* wetland (CAW), *Carex lasiocarpa* wetland (CLW), and abandoned cultivated land (ACL). The ACLs included 2-year (ACL2), 8-year (ACL8), 10-year (ACL10) and 12-year (ACL12) abandoned cultivated land, all of which once had been cultivated for two or three years before abandonment. For each land use type, three sampling sites were randomly arranged, with a site-interval of more than 10 m. Ten soil samples (0–20 cm) were collected at each sampling site, and then equally mixed them into one soil sample. The mixed samples were sealed to polyethylene bags to prevent contamination.

In laboratory, each soil sample was divided into two parts. Fresh soil sample was preserved at –4℃ for determining MBC and DOC. The other was air-dried for determining ROC, CHC and TOC. MBC was determined by fumigation-extraction method. DOC was determined after extraction of fresh soil (equivalent to 20 g of dry soil) with 100 mL distilled water for 0.5 h and then filtered through 0.45 μm cellulose-acetate filters, after that the concentration of TOC was determined by TOC-V_{CPH}. Air-dried soil samples were used for estimating CHC (Brink *et al*., 1960). ROC was estimated using the method of 0.333 M $KMnO_4$ oxidation (Blair *et al*., 1995).

3 Results and Discussion

3.1 Changes of soil organic carbon

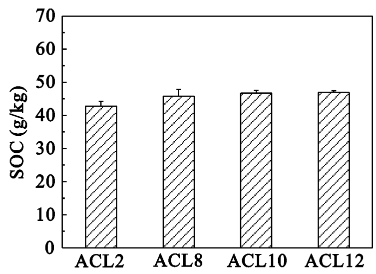
As shown in Fig. 1, the content of soil organic carbon in natural wetland soil is higher than those in other land use types. The contents of SOC in *Carex lasiocarpa* wetland and *Calamagrostis angustifolia* wetland are 50.27 g/kg and 45.62 g/kg, respectively. They are higher than those in forest land (43.38 g/kg), paddy field (37.42 g/kg) and dry farmland (37.05 g/kg). Moreover, soil organic carbon increases along with the years of abandonment of cultivated land (Fig. 2). It is 42.82 g/kg in 2-year abandoned cultivated land and 46.92 g/kg in 12-year abandoned cultivated land, increasing 9.57% in the 10-year abandonment.



DF, PF, FL, CAW and CLW denote dry farmland, paddy field, forest land, *Calamagrostis angustifolia* wetland and *Carex lasiocarpa* wetland, respectively

Fig. 1 Contents of soil organic carbon (SOC) in different land use types

The cultivation of native soils which involves a reduced input of plant residues and a higher soil disturbance caused a substantial reduction of SOM levels



ACL2, ACL8, ACL10 and ACL12 denote abandoned cultivated lands for 2, 8, 10 and 12 years, respectively

Fig. 2 Contents of soil organic carbon (SOC) in abandoned cultivated lands

(Laik *et al*., 2009). These impacts of cultivation on SOM levels are caused by an increased decomposition rate and redistribution of SOM as a result of interactions of physical, chemical and biological soil processes (Turner and Lambert, 2000; Bhattacharyya *et al*., 2009). When cultivated wetland is abandoned, soil organic carbon tends to increase with more vegetation return.

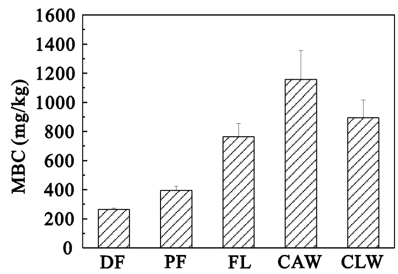


Fig. 3 Contents of microbial biomass carbon (MBC) in different land use types

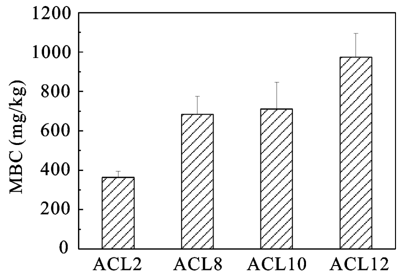


Fig. 4 Contents of microbial biomass carbon (MBC) in abandoned cultivated lands

3.2 Changes of soil labile organic carbon

3.2.1 Microbial biomass carbon

Soil microbial biomass carbon (MBC) shows similar changes with soil organic carbon in different land use types (Fig. 3). With regard to the two types of natural wetland, however, MBC in the *Calamagrostis angustifolia* wetland (1157.9 mg/mg) is higher than that in the *Carex lasiocarpa* wetland (894.74 mg/kg). This maybe relates to soil moisture conditions. Due to perennial or seasonal inundation, excessive moisture in *Carex lasiocarpa* wetland soil may inhibit microbial activity, making MBC decrease. The MBC in dry farmland is only 263.16 mg/kg, which decreases by 77.27% and 70.59% compared with those in *Calamagrostis angustifolia* wetland and *Carex lasiocarpa* wetland. The contents of MBC in abandoned cultivated lands are obviously higher than those in both dry farmland and paddy field, and have an obvious boost along with the increasing years of abandonment (Fig. 4). It increases from 363.16 mg/mg in 2-year abandoned cultivated land to 973.68 mg/kg in 12-year abandoned cultivated land, increasing 168.12% in the 10-year abandonment.

3.2.2 Dissolved organic carbon

Dissolved organic carbon (DOC) is the most important energy to soil microbe, and microbial metabolite also has great contribution to soil water-soluble carbon pool. The contents of DOC in the two natural wetlands are significantly higher than those in other land use types (Fig. 5). The content is 521.23 mg/kg in *Calamagrostis angustifolia* wetland, and 486.82 mg/kg in *Carex lasiocarpa* wetland, increasing 83.47% and 96.43% compared to that in dry farmland, respectively. Soil DOC in farmland declines compared to natural wetlands due to the reduction of photosynthate. The grass roots layer is damaged after wetlands are reclaimed and crops are harvested each year, resulting in sharply reduction of plant returned to the soil. Zhang *et al*. (2005) reported significant changes in soil DOC with different land use types. Gregorich *et al*. (2000) also reported that when the forest land or grassland became cropland, the content of DOC decreased significantly. Along with the increasing years of abandonment of cultivated land, plant restoring quantity increases, and the content of DOC increases significantly (Fig. 6). It reaches 424.57 mg/kg in 12-year abandoned cultivated land, which accounts for 81.46% of that in the *Calamagrostis angustifolia* wetland.

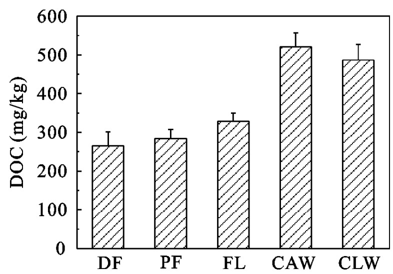


Fig. 5 Contents of dissolved oraganic carbon (DOC) in different land use types

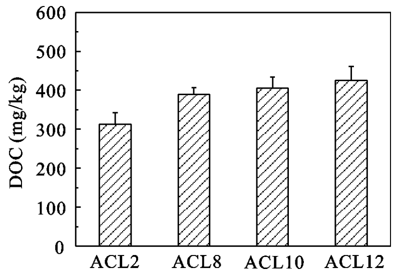


Fig. 6 Contents of dissolved organic carbon (DOC) in abandoned cultivated lands

3.2.3 Carbohydrate carbon

The carbohydrate carbon (CHC) contents follow the order: *Carex lasiocarpa* wetland>forest land>*Calamagrostis angustifolia* wetland>paddy field>dry farmland (Fig. 7). After abandonment for two years, the content of CHC is still relatively low (823.73 mg/kg) (Fig. 8). And after abandonment for ten years, the content increases to 1 129.33 mg/kg, even slightly higher than that in *Carex lasiocarpa* wetland. Carbohydrate carbon mainly comes from root exudation and the decomposition products of root cell wall. The dissolution of root cells has an important contribution to the increase of CHC content. Due to the development of plant roots in natural wetlands, the content of CHC is higher than that in farmland soil. After abandonment of cultivated lands, the content of soil CHC begins to increase along with the restoration of vegetation and growth of root.

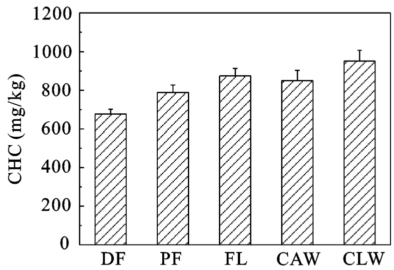


Fig. 7 Contents of carbohydrate carbon (CHC) in different land use types

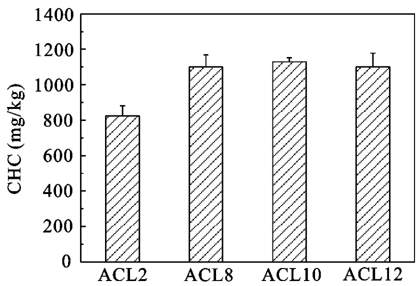


Fig. 8 Contents of carbohydrate carbon (CHC) in abandoned cultivated lands

3.2.4 Readily oxidizable organic carbon

The dynamic of readily oxidizable carbon (ROC) is similar as other labile carbons and the content in natural wetlands is also higher than that in other land use types. Among all kinds of land use types, the content of ROC in *Carex lasiocarpa* wetland is the highest (Fig. 9). Compared with *Carex lasiocarpa* wetland, ROC decreases by 53.51% in dry farmland. Along with the increasing years of abandonment of cultivated land, the content of ROC increases gradually, up to 5602.51 mg/kg after 12-year of abandonment (Fig. 10).

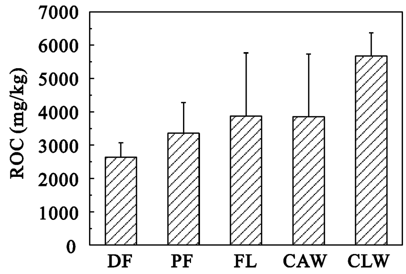


Fig. 9 Contents of readily oxidizable organic carbon (ROC) in different land use types

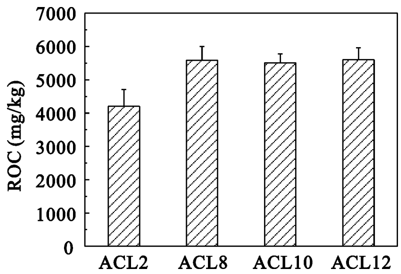


Fig. 10 Contents of readily oxidizable organic carbon (ROC) in abandoned cultivated lands

3.3 Distribution ratio of soil labile organic carbon

The ratio of labile carbon to SOC can reflect the turnover efficiency of soil organic matter. The ratio differs under different land use types (Table 1). Both the ratios of MBC to SOC and DOC to SOC are found to be high in natural wetlands. They decrease when wetlands are reclaimed to farmland. The ratio of CHC to SOC is similar to the ratio of MBC to SOC. Among the abandoned cultivated lands, the highest ratio of ROC to SOC appears in 8-year abandoned cultivated land. The ratios of ROC to SOC in *Carex lasiocarpa* wetland and 8-year abandoned cultivated land are significantly higher than dry farmland and paddy fields. This illustrates that the soil carbon pool activity of those two land use types are higher and easily transformed and lost.

Table 1 Percentages of different labile organic carbon to total soil organic carbon under different land use types (%)

	MBC/SOC	DOC/SOC	CHC/SOC	ROC/SOC
DF	0.71	0.72	1.82	7.12
PF	1.05	0.76	2.11	8.97
FL	1.76	0.76	2.02	8.93
CAW	2.54	1.14	1.86	8.45
CLW	1.78	0.97	1.89	11.30
ACL2	0.85	0.73	1.92	9.82
ACL8	1.49	0.85	2.40	12.20
ACL10	1.52	0.86	2.41	11.80
ACL12	2.08	0.90	2.34	11.94

4 Conclusions

Land use types of the Sanjiang Plain have been significantly changed and large area of natural wetlands have been reclaimed for cultivated land in recent decades. The structure and function of wetland ecosystem including energy balance and material flow are disturbed by the changes of land use types in wetland ecosystem. Clearing of the natural wetland and its conversation into cultivated land have led to a pronounced decline of the soil organic carbon. Soil organic carbon contents follow the order: *Carex lasiocarpa* wetland>*Calamagrostis angustifolia* wetland>forest land>paddy field>dry farmland. Soil labile organic carbon in *Carex lasiocarpa* wetland and *Calamagrostis angustifolia* wetland are also higher than those in other land use types.

Along with wetland cultivated, soil labile organic carbon tends to decrease due to the disappearance of heterotrophic environment and the reduction of plant return. When cultivated wetlands are recovered, the content of labile carbon increases. Accordingly, the abandonment for cultivated wetlands is an effective way for the restoration of soil organic carbon.

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