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Changes of soil organic carbon, nitrogen and phosphorus concentrations under different land uses in marshes of Sanjiang Plain

Jisong Yang [a,b,*], Jingshuang Liu [b], Xiaojun Hu [a], Xinxin Li [a], Yan Wang [a], Huiying Li [a]

[a] Key Laboratory of Regional Environment and Eco-Remediation (Ministry of Education), Shenyang University, Shenyang 110044, China
[b] Key Laboratory of Wetland Ecology and Environment of Chinese Academy of Sciences, Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun 130012, China

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ABSTRACT

Wetlands provide a large pool of organic matter and nutrients, and are important for maintaining material cycle balances in terrestrial ecosystems, and also help retard climate change. Land use changes in wetlands have greatly disturbed the natural evolution of wetland ecosystems. Wetland drainage and reclamation alters the physical, chemical and biological conditions of the wetland, thus significantly disturbing the material cycles, leading to significant changes in the biogeochemical processes of carbon, nitrogen and phosphorus in the wetland. The wetlands in the Sanjiang Plain are the largest area of fresh wetlands in China. However, the area has experienced major land uses changes since the 1950s; areas of the wetland have been drained and converted to arable land. Some studies have been conducted into the effects of land use change on material cycles in the Sanjiang Plain wetlands but few reports have discussed the C/N and C/P ratios and pH values as indicators of wetland degradation due to land use changes. We selected eight land uses: humus marsh (HM), marshy meadow (MM), drained humus marsh (DHM), drained marshy meadow (DMM), tillage land (TL), abandoned land (AL), natural secondary forest (NSF) and artificial forest (AF), in the Honghe area of the Sanjiang Plain. We studied changes in the total organic carbon (TOC), total nitrogen (TN), total phosphorus (TP), C/N and C/P ratios and pH values in topsoil (0–20 cm) of these eight different land uses. The possible mechanisms underlying the changes, and the significance of the C/N and C/P ratios as indicators of soil quality were also discussed. In the natural wetland, the TOC, TN and TP concentrations in the soil were high, with values of 203.5 g/kg, 20.2 g/kg and 1.44 g/kg, respectively, in HM; and 59.2 g/kg, 5.28 g/kg and 0.83 g/kg, respectively, in MM. Drainage of the HM has led to decreases in the TOC, TN and TP concentrations of about 50%. Significant decreases were also observed in TOC, TN and TP for NSF and AF compared to HM. Drained MM led to decreases in the TOC and TN of about 45%, but had little effect on TP. Marshy meadow that had been drained for more than 10 years experienced an exponential decline in TOC, TN and TP, with decreases of more than 60% for TOC and TN, and 20% for TP. However, after being abandoned for a short time (5 years), the TOC, TN and TP concentrations in soil experienced little change because poor water conditions combined with low productivity led to a large loss of soil organic matter. Land use change in the marsh areas has led to a decrease in C/N and C/P ratios of the soil, which are positively related to TOC and TN with different land uses ($P < 0.05$). Marsh reclamation has led to decreasing C/N and C/P ratios in soil and increasing pH values, which are negatively related to TOC, TN and TP ($P < 0.05$). Changes in carbon, nitrogen and phosphorus in soil with different land uses were mainly regulated by water-heat conditions and microbial activity, while the C/N and C/P ratios were mainly regulated by substrate availability. Our results suggest that C/N and C/P ratios and the pH value could be used as indicators to evaluate the quality and nutrient status of wetland soil under different land uses.

1. Introduction

Wetlands provide a large pool of organic matter and nutrients, and are important for maintaining material cycle balances in terrestrial ecosystems, and also help retard climate change [1]. However, anthropic activities such as the development and utilization of wetlands have led to the land use change of wetlands in approximately 84% of Ramsar sites [2]. The land use change has broken the natural evolvement of wetland ecosystems, e.g., wetland drainage and reclamation alters the physical, chemical and biological conditions of the wetland, thus significantly disturbing the material cycles, leading to significant changes in the biogeochemical processes of carbon, nitrogen and phosphorus

* Corresponding author at: Key Laboratory of Regional Environment and Eco-Remediation (Ministry of Education), Shenyang University, Shenyang 110044, China.
E-mail address: yjswill@126.com (J. Yang).

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in soil [3,4]. Wetland drainage may increase the peat density, change redox conditions and accelerate soil organic matter mineralization [5,6], and wetland reclamation may lead to a fast loss of soil organic matter in cultivated horizon and a decrease of the bioavailability of nitrogen and phosphorus [7,8]. Therefore, the study of the effects of land use change on carbon, nitrogen and phosphorus in wetland soil is vitally important to understand the response of matter cycles of wetland to anthropic activities.

Sanjiang Plain, located in Heilongjiang province of Northeast China, in which the marshes are the largest area of fresh wetlands in China. However, the area has experienced major land uses changes since the 1950s; areas of the marsh have been drained and converted to arable land. The percent of area of marshes have decreased from 32.74% to 8.81% and that of tillage land increased from 15.91% to 51.17% from 1954 to 2005 [9]. The dominant landscape of marsh has converted to that of tillage land, which obviously changes the processes of carbon, nitrogen and phosphorus in marsh soil. The previous studies have reported that there were examined decreases of soil carbon, nitrogen and phosphorus after marsh converted into tillage land [10–13], and increases of those after tillage abandoned [14,15]. These studies have been conducted into the effects of land use change on matter cycles in marshes of Sanjiang Plain, but few discussed the C/N and C/P ratios and pH values as indicators of wetland degradation due to land use changes. Our aims of the research are to study the changes of TOC (total organic carbon), TN (total nitrogen) and TP (total phosphorus) in the top-soil of different land uses in marshes of Sanjiang Plain, and also discuss the indicative significance of C/N, C/P ratios and pH value for evaluation the degradation of wetland soil.

2. Material and methods

2.1. General characteristics of study sites

The study area is located in the hinterland of the Sanjiang plain of China, with the elevation of 55.4–57.9 m and the mean temperature of −18 to −21 °C, 21–22 °C and 1.6–1.9 °C during January, July and a year, respectively. The period of freeze is five months and the biggest frozen depth achieve at 1.9 m. The annual mean of precipitation is 565–600 mm, 60% of which occurs June–August, and that of evaporation is 542.4–580 mm. The eight sites for the top-soil sampling were selected at a marsh (47°35′17. 8″ N, 133°37′48. 4″ E) and the surrounding area in Honghe farm, northeast Heilongjiang Province. The types of marsh are humus marsh (HM) and marshy meadow (MM), and the six types of land uses such as drained humus marsh (DHM), drained marshy meadow (DMM), tillage land (TL), abandoned land (AL), natural secondary forest (NSF) and artificial forest (AF) are distributed at the surrounding of marsh. The description for selected sample sites was shown in Table 1.

2.2. Sampling and analysis

Soil sampling was taken in September 2005. Three to five replicated plots were selected at each type of land use for soil sampling. For each plot, three cores (0–20 cm depths) were taken with a stainless steel auger (5 cm diameter) and then mixed into one compositive sample. In laboratory, visible roots and organic residues in samples were removed. A part of subsamples were sieved through 2 mm and determined pH values with a water:soil ratio of 2.5:1. The remaining was air-dried and then ground to pass through a 0.149 mm sieve to analysis the contents of TOC, TN and TP in soil, using potassium dichromate-sulfuric method, the Kjeldahl method after digesting with sulfuric acid and molybdate-ascorbic method after an acid wet oxidation, respectively, referring to the methods by Lu [16].

2.3. Data treatments and analysis

The data of TOC, TN, TP concentrations, C/N, C/P ratios and pH values in TL soil are means of tillage land reclaimed for different years, respectively, which are used to be compared to those in soils of other land uses. The one-way ANOVA ($P < 0.05$) and Pearson ($P < 0.05$) analysis were performed using SPSS 13.0. Graphics and data fitting were performed using OriginPro 8.5.

3. Results

3.1. Changes of organic carbon, nitrogen, phosphorus concentrations, C/N and C/P ratios and pH values in soil under different land uses

3.1.1. Changes of organic carbon, nitrogen, phosphorus concentrations

The concentrations of TOC, TN and TP in top-soil have obviously changed due to land use conversion (Fig. 1). In the natural wetland, the TOC, TN and TP concentrations in the soil were high, with average values of 203.5 g/kg, 20.2 g/kg and 1.44 g/kg, respectively, in HM; and 59.2 g/kg, 5.28 g/kg and 0.83 g/kg, respectively, in MM. Drainage of the HM has led to decreases in the TOC, TN and TP concentrations of 52%, 49% and 54% ($P < 0.05$). Significant decreases were also observed in TOC, TN and TP for NSF and AF compared to HM ($P < 0.05$), respectively, with the decreases of 87–93%, 85–91% and 36–49%. Drained MM led to decreases in the TOC and TN of 45% and 46%, respectively; and reclaimed MM led to decreases by 53% and 54%, respectively; but had little effect on TP ($P > 0.05$). However, after being abandoned for a short time (5 years), the TOC, TN and TP concentrations in top-soil experienced little change ($P > 0.05$).

Table 1
Description for selected sample sites.

Land use	Change history of land use	Main vegetation type
HM (humus marsh)	Humus marsh	*Carex meyeriana* and *Carex lasiocapa*
MM (marshy meadow)	Marshy meadow	*Carex angustifolia*
DHM (drained humus marsh)	Drained humus marsh for about 7 years	*Carex meyeriana* and *Carex appendiculata*
DMM (drained marshy meadow)	Drained marshy meadow for about 7 year	*Deyeuxia angustifolia*
TL (tillage land)	Tillage lands converted from marshy meadow and reclaimed for 1, 3, 4, 7, 12 and 15 years	*Glycine max*
AL (abandoned land)	Tillage land converted from marshy meadow and reclaimed for about 12 years and then abandoned for 5 years	*Deyeuxia angustifolia*
NSF(natural secondary forest)	Humus marsh drained to natural secondary forest for about 10 years	*Quercus mon-golica*, *Populus davidiana* and *Betula fruticosa*
AF (artificial forest)	Tillage land converted from humus marsh and reclaimed for about 12 years and then converted into artificial forest for about 5 years	*Pinus sylvestnis var. mongolica Litv.*