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CARBON CYCLE OF MARSH IN THE SANJIANG PLAIN

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ABSTRACT: The Sanjiang Plain of China is a low plain. Its total area is 10.89×10^4 km^2 and marsh area takes up 10.20%. Marsh is a kind of vegetation type with strong carbon-fixing ability among the terrestrial ecosystem and carbon cycle performing in the form of carbon dioxide. This paper discusses the fixation of atmospheric CO_2 by marsh plant; the transfer of carbon from marsh to atmosphere; the change of CO_2 and vertical transfer of CO_2 near atmosphere of the earth; the carbon flow among marsh plants, soil and atmosphere. Some scientific data about the biological production, carbon content of marsh plants and the capacity for releasing and fixing are used to explain the carbon cycle of marsh in the Sanjiang Plain.
KEY WORDS: carbon cycle, production of plant, soil respiration, vertical transport of carbon dioxide

Peat growth is a process of being helpful for decreasing the increment of CO_2 content in the air, which is caused by combustion of mineral fuels and human activities in terrestrial ecosystem. But, exploiting marsh, especially peat used to be fuels, implies that organic substance accumulated from atmosphere during the past thousands of years is rapidly oxidized. So the marsh plays an important role in the cycle of biogeochemistry.

The Sanjiang Plain is a low plain formed by the common reaction of the Heilong River, Songhua River and Wusuli River. The total area is 10.89×10^4 km^2 and marsh area is 1.12×10^4 km^2, taking up 10.2% of the total area. The Sanjiang Plain is one of the major marsh distribution regions in China.

The cycle of carbon in nature includes the long geological cycle and the short biogeochemical cycle among the terrestrial organism, soil and atmosphere. Through the photosynthesis of green plant, CO_2 in the air is reduced and fixed. As a result, carbon exists in the organic substance in the form of organic carbon. Then when the organic substance is utilized by consumer, carbon is released into atmosphere in the form of carbon dioxide again. From above, we can see that carbon cycle performs in the form of carbon dioxide.

I. FIXATION OF ATMOSPHERIC CO_2 BY MARSH PLANT

The assimilation of green plant, which transforms carbon dioxide into organic carbide, makes carbon flow from the atmosphere to the biosphere. Swamp is a kind of vegetation type with strong carbon-fixing ability in the terrestrial ecosystem. Because of the wide distribution of marsh, the range of net primary productivity is quite great. The Sanjiang Plain, located in the north temperate zone, is mainly comprised of eutrophic marsh. So the biological production is not great, ranging from 465.9 g/(m^2·a) to 1271.9 g/(m^2·a) (Table 1) (Lu *et al.*, 1994; Yi *et al.*, 1988). Carbon content of marsh plant ranges from 39.53% to 44.33% (Table 2). According to Table 3, it is estimated that carbon fixed by marsh plant is 467×10^4 t/a(Lu *et al.*, 1995).

Table 1 Production of marsh plant in the Sanjiang Plain

Dominant species	Area (km^2)	Productivity ($g \cdot m^{-2} \cdot a^{-1}$)		Biomass ($g \cdot m^{-2}$)
		Above ground	Below ground	
Carex lasiocarpa	4493.3	426.8	845.1	1271.9
Glyceria triflora-Carex sp.	591.7	602.2	391.1	993.3
Carex pseudocuraica	793.2	418.5	47.4	465.9
Carex sp. without hummock	57.3	337.7	427.9	765.6
Phragmites communis-Calamagrostis angustifolia	2415.3	450.1	427.9	878.0
Carex sp. with hummock	2841.7	354.0	427.9	781.9

Table 2 Total carbon content in marsh plant in the Sanjiang Plain (dry matter %)

Dominant species	Above ground	Below ground
Carex lasiocarpa	39.53 38.25 – 40.80	44.33 43.35 – 45.30
Glyceria triflora	41.18 39.75 – 42.60	42.45 38.55 – 46.35
Carex pseudocuraica	41.48 40.80 – 42.15	40.80 40.35 – 41.25

Table 3 Estimating value of annual fixation of CO_2 by marsh plant in the Sanjiang Plain

Dominant species	Biomass above ground ($\times 10^4$ t/a)	Fixation of C ($\times 10^4$ t/a)	Biomass below ground ($\times 10^4$ t/a)	Fixation of C ($\times 10^4$ t/a)
Carex lasiocarpa	191.77	76.71	383.77	170.13
Glyceria triflora-Carex sp.	33.59	13.28	3.76	1.59
Carex pseudocuraica	35.63	14.25	23.14	9.82
Carex sp. without hummock	1.93	0.77		
Phragmites communis-Calamagrostis angustifolia	108.72	43.49	227.40*	96.76*
Carex sp. with hummock	100.60	40.24		
Total	471.84	188.74	638.07	278.25

* the figure is the sum of *Carex* sp. without hummock, *Phragmites communis-Calamagrostis angustifolia* and *Carex* sp. with hummock

II. THE TRANSFER OF CARBON FROM MARSH SOIL TO ATMOSPHERE

In the natural marsh ecosystem, the litter is returned to marsh at a time. In the aquatic environment, the remnant piled up on the surface is decomposed and transformed by microorganism. Finally, carbon is released from soil to atmosphere in the form of CO_2. Thus CO_2 is exchanged between soil and atmosphere.

The soil respiration ranges from 1.081 to 1.781 kg/(m^2·a). The rate of soil respiration observed is as follows: peat soil is 1.781 kg/(m^2·a); peat marsh soil and humus soil are 1.431 kg/(m^2·a); meadow marsh soil is 1.081 kg/(m^2·a). All types of marsh release 1463.4×10^4 t of CO_2, containing 395.1×10^4 t of carbon each year (Table 4).

Table 4 Carbon released from marsh soil in the Sanjiang Plain

Soil type	Area (km^2)	Annual soil respiratory rate (kg/m^2)	Release of CO_2 ($\times10^4$ t/a)	Release of carbon ($\times10^4$ t/a)
Peat soil	326	1.781	58.1	15.7
Meadow marsh soil	4262	1.081	460.7	124.4
Peat marsh soil and humus soil	6601	1.431	944.6	255.0
Total	11189		1463.4	395.1

III. CO_2 DENSITY AND CO_2 FLUXES ON MARSH SURFACE LAYER

1. Changes of CO_2 Density on Marsh Surface Layer

In the course of growth of marsh plant, CO_2 exchanges between plant and atmosphere through photosynthesis and respiration of green plant. The daily and seasonal changes of CO_2 density are notable in plant canopy and marsh (Table 5).

2. Vertical Transfer of CO_2 on the Surface Layer

Marsh obtains CO_2 through turbulent flow between soil and air. So the CO_2 flux is expressed by this formula:

$$F_c = f \cdot K_c \cdot \frac{\partial C}{\partial Z}$$

where: f——the converting coefficient from mg/kg to g/cm^3, $f=1.67\times10^{-9}$

K_c——the turbulent exchange coefficient

$\frac{\partial C}{\partial Z}$——vertical density of CO_2

According to this formula and observations of wind and temperature, we can figure out the daily changes of CO_2 fluxes in different growing periods of *Carex lasiocarpa*. The results indi-

cate that CO_2 fluxes present relatively large positive value during June and August, which means CO_2 flows from atmosphere to marsh. On the contrary, during the other months CO_2 fluxes present relatively small negative value, which means CO_2 flows from marsh to atmosphere (Table 6). As far as the whole year is concerned, the positive value is greater than the negative value.

Table 5 Characteristic value of CO_2 density on surface layer of *Carex* (mg/kg)

Date	Altitude (cm)	Plant phenophase and plant height (cm)	Min (Appear time (h))	Max (Appear time (h))	Daily average / Daily range
Jan. 13	100	no plant growth	340 / 12:00	390 / 03:00	370 / 50
Feb. 28	100	no plant growth	350 / 10:00 - 12:00	390 / 18:00 - 07:00	377 / 40
Apr. 28	100	flower bud stage 5 - 18	360 / 16:00	610 / 22:00	440 / 250
May 18 - 19	50	flowering stage 15 - 20	370 / 13:00	540 / 07:00	460 / 170
	150		380 / 13:00	530 / 07:00	456 / 150
Jun. 22 - 23	50	fruit stage 50	314 / 16:00	464 / 22:00	342 / 150
	150		318 / 16:00	462 / 22:00	375 / 144
Jul. 20 - 21	50	maturing stage	314 / 10:00 - 13:00	438 / 04:00	372 / 114
	150		324 / 13:00	416 / 01:00	371 / 92
Aug. 25 - 26	50	yellow-maturity stage 55	340 / 16:00	430 / 22:00 - 04:00	380 / 90
	150		330 / 13:00	435 / 04:00	374 / 105
Sept. 5 - 6	50	yellow-maturing stage 55	340 / 16:00	400 / 19:00 - 01:00	386 / 60
	150		340 / 13:00	410 / 22:00 - 01:00	383 / 70

Table 6 CO_2 flux of *Carex lasiocarpa* in different growing periods

Date	Growing period	Daily average flux of CO_2 ($\times 10^{-8}$ kg·m^{-2}·s^{-1})	Wind speed at height of 1.5 m (m/s)	Daily average temperature at height of 1.5 m (℃)
May 18 - 19, 1993	flowering stage	-0.35	1.07	15.25
June 20 - 21, 1994	fruit stage	1.71	0.48	21.18
July 20 - 21, 1994	maturing stage	1.20	1.21	24.63
Aug. 25 - 27, 1992	maturing stage	0.47	1.63	19.49
Sept. 5 - 6, 1992	yellow-maturity stage	-0.22	1.00	17.80
Oct. 17 - 18, 1994	withering stage	-0.15	2.54	7.28

IV. THE CARBON FLOWS AMONG MARSH PLANT, SOIL AND ATMOSPHERE

In the marsh ecosystem in the Sanjiang Plain, the total annual plant biomass is 11.1×10^6 t/a, the fixation amount of C is 4.67×10^6 t/a. The organic matter containing C is transferred into soil system, then returned to air in the form of CO_2, the release amount of carbon from soil to atmosphere is 3.95×10^6 t/a. From those figures, we can see that the accumulation of carbon is larger than decomposition of carbon. So peat would be accumulated on the surface to some extent, including mineral marsh. The peat accumulation becomes a increasing carbon pool. When hydrothermal condition is steady enough, peat in marsh is isolated from the atmosphere cycle of carbon. To sum up, it is clear that the accumulation of peat is helpful for decreasing CO_2 content in the air. However, when we drain off the water from marsh and utilize the dried marsh in different ways, the marsh will be CO_2 source instead of CO_2 sink, the pattern of carbon cycle will be changed. The results research show that if the water is drained off from every mire on the earth, a great amount of carbon will be released, which equals to 35% to 50% of the amount of carbon caused by chopping the forest and burning chemical fuels.

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