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Short communication

Carbon sequestration potential change after marshlands conversion to croplands in the Northeast China between 1982 and 2010

Xiaohui Liu[a], Guihua Dong[b], Zhenshan Xue[a,*], Xianguo Lu[a], Ming Jiang[a], Yuan Zhang[c]

[a] Key Laboratory of Wetland Ecology and Environment, Northeast Institute of Geography and Agroecology, CAS, Changchun 130102, China
[b] China National Environmental Monitoring Center, Beijing 100012, China
[c] Key Laboratory of Geographical Information Science, Ministry of Education College of Resources & Environmental Science, East China Normal University, Shanghai 200062, China

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ABSTRACT

By the land use change analysis and modeling inputs including the plant biomass and soil organic carbon density for carbon sequestration, and the greenhouse gases emissions fluxes, we estimated the total emissions and carbon sequestration of the marshlands in the Sanjiang Plain of the northeast China before conversion and after their conversion to paddy fields (marshlands-paddy) or to uplands (marshlands-uplands). Between 1982 and 2010, it showed that the converted marshlands area occupied 54.8%. And it indicated that the marshlands before conversion had greater contribution to the global warming mitigation than the marshlands conversion to croplands. This study further demonstrated that the marshlands conversion to croplands in the Sanjiang Plain would lead to 64.80×10^6 t CO_2eq/yr of net sequestration loss and may cause the future climate warming.

1. Introduction

Although natural wetlands occupy only 5–8% of the earth's land area, they store about 20–25% of the global soil organic carbon (Gorham, 1991; Mitsch and Gosselink, 2007). As a result of draining wetlands for agriculture, half of the world's wetlands were converted between 1900 and 1999 (Wang et al., 2011). Meanwhile, the landscape pattern changes have influenced the greenhouse gases emissions from ecosystems (Strack et al., 2014).

CH_4 and N_2O emissions also had the warming effects like CO_2 (IPCC, 2007). Paddy fields occupied 1/3 of the croplands area in the world, so it was of great importance to estimate the greenhouse gases emissions from paddy fields in the global carbon budget (Yang et al., 2003; Cleary et al., 2005). Previous studies paid less attention to the integrated estimation of the greenhouse gases emissions and carbon sequestration at the regional scale by the modeling (Teiter and Mander, 2005; Hao et al., 2007; Adhikari et al., 2012). Therefore, the ultimate objective of this study applies the modeling to estimate the potential change of the regional carbon sequestration with the marshlands loss related to the agricultural reclamation in the Sanjiang Plain of the northeast China.

2. Methods

2.1. Study area

The Sanjiang Plain is located in the northeast Heilongjiang Province, China. The total region is 10.89×10^6 ha. The study area (45°47′17″–48°27′56″ N, 130°14′54″–135°05′26″ E) excludes the Muling-Xingkai Plain at the south of Wanda Mountain and covers 6.49×10^6 ha (Liu et al., 2009). It is in the temperate zone with the continental monsoonal climate. The average annual temperature is about 2.5–3.6 °C and the average annual precipitation is about 500–650 mm.

2.2. Remote sensing data sources

The Albers Equal Area Conic Projection System unified the different spatial data (Liu et al., 2013). Land use information was digitized at the GIS software environment.

* Corresponding author.
E-mail addresses: liuxh2752@126.com (X. Liu), xuezhenshan@iga.ac.cn (Z. Xue).

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Table 1
Greenhouse gases emissions fluxes of the specific ecosystems in the Sanjiang Plain ($g/m^2/yr$).

	CO_2 fluxes	CH_4 fluxes	N_2O fluxes	Observation period
Carex lasiocarpa	1883.017 ± 31.46[a]	144.47 ± 25.63[a]	0.1949 ± 0.0786[a]	Annual mean ± SE, 2002–2005
Calamagrostis angustifolia	3228.50 ± 262.97[a]	5.813 ± 2.387[a]	0.1729 ± 0.1886[a]	Annual mean ± SE, 2002–2005
Paddy fields	849.6[b,c]	13.289[d,e]	0.120[d,e]	Annual mean, 2003–2004
Uplands	4279.680[f]	0.118[d]	0.285[d]	Annual mean, 2003–2004

[a] Song et al. (2009).
[b] Khalil et al. (1990).
[c] Song et al. (1996).
[d] Hao (2005).
[e] Wang et al. (2008).
[f] Lu et al. (2008).

2.3. Carbon sequestration and greenhouse gases emissions

2.3.1. Plant biomass and carbon sequestration

Uchijima and Seino (1985) developed the CHIKUGO model for estimating the *NPP* of vegetation from the climatological data. The aboveground biomass is calculated by:

$$NPP = 0.29\exp[-0.216(RDI)^2] \times \left(\frac{0.001 \times R_n}{4.2}\right) \quad (1)$$

where *NPP* is net primary production (t/ha/yr), *RDI* is radiative dryness index, R_n is net radiation ($J/cm^2/yr$) (Jia et al., 2010; Li et al., 2008).

RDI reflects the degree of climatic wetness and dryness in the region which is calculated by:

$$RDI = \frac{R_n}{L \times r} \quad (2)$$

where *L* is latent heat of evaporation (J/g), *r* is annual precipitation (cm/yr).

$$L = 2507.4 - 2.39t \quad (3)$$

where *t* is annual mean temperature (°C).

The carbon sequestration of aboveground biomass was calculated by the photosynthesis equation. The carbon sequestration of belowground biomass was calculated by multiplying the total carbon content of belowground biomass with the belowground plant biomass per unit area, and the total area of the specific ecosystem (Ma et al., 1996).

2.3.2. Soil carbon sequestration

$$M_s = A_s \times c \times d \times \rho \quad (4)$$

where M_s is soil carbon sequestration (t CO_2eq), A_s is soil type area of the specific ecosystem (m^2), *c* is organic carbon content (%), *d* is soil layer thickness (m), ρ is soil bulk density (t/m^3) (Liu and Ma, 2002).

2.3.3. CO_2, CH_4 and N_2O emissions

$$M_i = f_i \times A \quad (5)$$

where M_i is the emission of CO_2, CH_4 or N_2O (t/yr), f_i (i = 1, 2, 3) is CO_2, CH_4 and N_2O fluxes (t/ha/yr) (Table 1), *A* is the total area of the specific ecosystem (ha).

2.3.4. Greenhouse gases emissions in CO_2-C equivalent

$$M_c = \sum_{i=1}^{3} 0.2729 \times \alpha_i \times M_i \quad (6)$$

where M_c is the total emissions (t CO_2-C equivalent (CO_2eq)), α_i (i = 1, 2, 3) is the warming effect coefficient (IPCC, 2007), M_i is the emission of CO_2, CH_4 or N_2O (t/yr).

2.4. Contribution to the global warming mitigation

$$CGWM = F(CO_2\text{-C}) - M_c \quad (7)$$

where *CGWM* is contribution to the global warming mitigation (t CO_2eq/yr), $F(CO_2$-C) is the carbon sequestration, M_c is the total emissions (t CO_2eq/yr).

2.5. Comprehensive carbon sequestration potential

$$CCSP = CGWM_m - CGWM_c \quad (8)$$

where *CCSP* is comprehensive carbon sequestration potential (t CO_2eq/yr), $CGWM_m$ is that of marshlands before conversion, $CGWM_c$ is that of marshlands after conversion (t CO_2eq/yr).

3. Results

3.1. Land use change between 1982 and 2010

The specific area of the land use types could be gained according to Section 2.2. Marshlands area decreased remarkably by 64.4%. However, paddy fields area increased 2.9 times and that of uplands increased by 3.8% between 1982 and 2010. The converted area of marshlands occupied about 54.8% of the original marshlands.

3.2. Carbon sequestration and greenhouse gases emissions

According to Section 2.3, the total carbon sequestration of marshlands before conversion was much greater than that of marshlands-paddy and marshlands-uplands. The CO_2 emission from marshlands before conversion was less than that of marshlands-paddy and marshlands-uplands. Nevertheless, the trend of CH_4 emission of marshlands before conversion was higher than that of marshlands-paddy and marshlands-uplands (Table 2).

3.3. Changes in comprehensive carbon sequestration potential

The total carbon sequestration was always higher than the total emissions whether marshlands before conversion or after conversion (Table 2), which revealed that the marshlands before conversion, marshlands-paddy and marshlands-uplands all served as the carbon sinks. However, the results indicated that the comprehensive carbon sequestration potential decrease by 37.2% after the marshlands converted.

4. Discussion

The restored engineering significantly increased the soil organic carbon of the degraded lands. And the soil organic matter was increased after the damming of river (Zhang et al., 2012; Wu et al., 2013). So the carbon sequestration is highly sensitive to the land use