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Effect of the conversion of grassland to spring wheat field on the CO_2 emission characteristics in Inner Mongolia, China

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Abstract

Chinese grasslands have undergone great changes in land use in recent decades. Approximately 18.2% of the present arable land in China originated from the cultivation of grassland, but its impact on the carbon cycle has not been fully understood. This study was conducted in situ for 3 years to assess the comprehensive effects of cultivation of temperate steppe on soil organic carbon (SOC) and soil respiration rates as well as ecosystem respiration. As compared with those in the *Stipa baicalensis* steppe, the SOC concentrations at depths of 0–10 and 10–20 cm in the spring wheat field were found to have decreased by 38.3 and 17.4% respectively from 29.5 and 21.9 g kg^{-1} to 18.2 and 18.1 g kg^{-1} after a cultivation period of 30 years. Accordingly, the total amounts of soil respiration through the growing season (from April to September) in 2002, 2003 and 2004 were 265.2, 282.2 and 237.4 g C m^{-2} respectively in the spring wheat field, which were slightly lower than the values of 342.2, 412.0 and 312.1 g C m^{-2} in the *S. baicalensis* steppe, while ecosystem respiration of 690.9, 991.2 and 569.6 g C m^{-2} respectively in the spring wheat field were markedly higher than those of 447.0, 470.9 and 429.7 g C m^{-2} in the steppe plot. Similar seasonal variations of ecosystem respiration and soil respiration existed in both sample sites. Respiration rates were higher and greater differences existed in both ecosystem respiration and soil respiration during the exuberant growth stage of plants (from mid-June to mid-August). However, in the slower-growth period of the growing season (before late May and after late August), the CO_2 effluxes of the two sample sites were similar and remained at a relatively low level. The results also showed that ecosystem respiration and soil respiration were under similar environmental controls in both sample sites. Soil water content at a depth of 0–10 cm and soil temperatures at 5 and 10 cm were the main factors affecting the variations in ecosystem respiration and soil respiration rates in droughty years of 2002 and 2004 and in the rainy 2003, respectively. This study suggests that the conversion of the grassland to the spring wheat field has increased the carbon loss of the whole ecosystem due to the change of vegetation cover type and significantly reduced the carbon storage of surface soil. In addition, the tillage of grassland had different effects on ecosystem respiration and soil respiration. The effects were also dissimilar in different growth stages, which should be fully considered when assessing and predicting the effects of cultivation on the net CO_2 balance of grassland ecosystems.

Keywords: Inner Mongolia; *Stipa baicalensis* steppe; Cultivation; Soil organic carbon (SOC); CO_2 emission

1. Introduction

Grassland is one of the most important vegetation types in China, covering an area of about 4×10^6 km^2

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or about 40% of the nation's total land area (Chen and Wang, 2000). It is one of the most important carbon pools of the Chinese terrestrial ecosystem. A minor change in carbon storage in the grassland ecosystem will greatly affect the concentration of atmospheric CO_2 and the trend of regional or global climate change (Schimel, 1995; Schlesinger and Andrews, 2000; Prentice et al., 2001).

Cultivation is one of the most significant human activities affecting the grassland ecosystem besides grazing. Some previous studies have already shown that the conversion of grassland to crop field will significantly reduce C input, owing to the decrease of litter and the removal of aboveground part of crops after harvest. The results obtained by Huggins et al. (1998) indicated that conversion of native tallgrass prairie to annual crops of wheat (*Triticum aestivum* L.), oats (*Avena sativa* L.) and corn (*Zea mays* L.) would reduce the annual return of plant biomass C by 80% or more. In addition, long-term cultivation practices such as plowing, harrowing and fertilization will destroy the macroaggregate (Elliott, 1986; Singh and Singh, 1996) and accelerate the mineralization of organic carbon, promoting soil respiration accordingly (Buyanovsky et al., 1987; Huggins et al., 1998; Li and Chen, 1998). It was estimated by Houghton (1995) that carbon loss amounted to about 10 Pg C (1 Pg = 10^{15} g) of the global grassland ecosystem from 1850 to 1980 caused by land use change and 40% came from a temperate grassland ecosystem. In total, cultivation of grassland and corresponding agricultural management practices such as fertilization, irrigation and tillage will change soil structure, physiochemical properties and composition of soil microorganism population to a certain extent (Aguilar et al., 1988; Cambardella and Elliott, 1993; Davidson and Ackerman, 1993; Huggins et al., 1998; Six et al., 2000; Conant et al., 2001; Steenwerth et al., 2002; Jaiyeoba, 2003), affecting carbon storage and carbon exchange rate between soil and atmosphere significantly. Globally, the influence of land use change on carbon cycle processes of terrestrial ecosystems has been studied extensively (Six et al., 1998; Wagai et al., 1998; Ellert and Janzen, 1999; Houghton et al., 1999; Aslam et al., 2000; Post and Kwon, 2000; Brye et al., 2002; Lal, 2004; Franzluebbers, 2005; Malo et al., 2005; Puget and Lal, 2005; Tan and Lal, 2005). Until now, reports from China have rarely been seen. Even rarer are reports about the comprehensive effects of land use change of grassland on soil organic carbon (SOC) and soil respiration as well as ecosystem respiration.

Objective of the present study was to probe into the potential changes of the soil carbon sequestration and all the separate fluxes comprising ecosystem carbon emission after the conversion of native grassland to cultivated agroecosystem in Inner Mongolia, China. The questions addressed were: (i) to compare soil organic carbon concentration between a temperate steppe and a wheat agroecosystem, (ii) to find the differences in the effluxes of CO_2 and their seasonal variation between the two ecosystems and (iii) to determine the key environmental factors influencing the seasonal fluctuation of ecosystem respiration and soil respiration. This is done to provide basic data in order to scientifically evaluate the effect of land use conversion on the role of China's grasslands in greenhouse gas emissions and potential C sequestration.

2. Site and methods

2.1. Site description

The experimental sites were in the Xilin River Basin of Inner Mongolia, China (43°26′–44°39′N, 115°32′–117°12′E) and in the vicinity of the Inner Mongolian Grassland Ecosystem Research Station (IMGERS), which was situated in the core area of the Northeast China Transect (NECT) for the International Geosphere-Biosphere Program (IGBP) on global change study and belonged to the Chinese Terrestrial Ecosystem Flux Observational Network (ChinaFlux). There was practically no human activity in this area before the 1950s. Cultivation started in 1953 and the amount of arable land reached 3.32×10^4 ha in 2000 (Chen et al., 2003), all of which originated from the cultivation of grassland, particularly of the *Stipa baicalensis* steppe. Two study sites, a *S. baicalensis* steppe and a spring wheat field, were selected. The *S. baicalensis* steppe site lies at 43°33′N and 116°49′E, 1340–1350 m above sea level. It is utilized as a mowing pasture and the frequency of mowing is once a year, always in mid- or late August. There are abundant species characterized by mesophytes, xeromesophytes and mesoxerophytes, including *S. baicalensis*, *Filifolium sibiricum*, *Carex pediformis*, *Festuca dahurica*, *Aneurolepidium chinense*, *Achnatherum sibiricum*, etc. The edificator of the steppe is *S. baicalensis*, the density of plant is 29–39 species m^{-2}, with coverage of about 50–90%. Chernozem soil dominates the steppe, with a 50 cm humus layer. The calcic horizon of soil is insignificant or with only slight $CaCO_3$ pseudomycelium deposition. Annual precipitation is about 450 mm, annual mean temperature is -1.4 °C and the $\geq$10 °C accumulated temperatures are 1600–1800 °C. The sample plot of the spring wheat field was adjacent to the *S. baicalensis*