



Carbon flux in deserts depends on soil cover type: A case study in the Gurbantunggute desert, North China

Y.G. Su, L. Wu, Z.B. Zhou, Y.B. Liu, Y.M. Zhang*

Key Laboratory of Biogeography and Bioresource in Arid Land, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, South Beijing Road 818, Urumqi, Xinjiang 830011, China

ARTICLE INFO

Article history:

Received 22 April 2012

Received in revised form

19 November 2012

Accepted 14 December 2012

Available online 2 January 2013

Keywords:

Arid and semiarid regions

Biological soil crusts

Carbon sink

Rainfall

Vascular plants

ABSTRACT

Carbon flux represents carbon uptake from or release to the atmosphere in desert ecosystems, yet the changing pattern of carbon flux in desert ecosystems and its dependence on soil cover type and rainfall amount are poorly understood. We measured net carbon fluxes (NCF) in soil with four cover types (moss crusted soil, cyanobacteria/lichen crusted soil, bareland and semishrub *Ephedra distachya*-inhabited site) from April to October of 2010 and 2011, and NCF and dark respiration (DR) after four rainfall amounts (0, 2, 5, and 15 mm) in cyanobacteria/lichen crusted soil, bareland and the *E. distachya*-inhabited site. NCF in the *E. distachya*-inhabited site differed significantly from those of the other three soil cover types, while no difference was observed between the moss and cyanobacteria/lichen crusted soils or between the two crusted soils and bareland on most measurement occasions. NCF ranged from -0.28 ± 0.14 to $1.2 \pm 0.07 \mu\text{mol m}^{-2} \text{s}^{-1}$ in the biologically crusted soils, and from -2.2 ± 0.27 to $0.46 \pm 0.03 \mu\text{mol m}^{-2} \text{s}^{-1}$ at the *E. distachya*-inhabited site. Daily NCF in the biologically crusted soils and bareland showed carbon release at most times and total carbon production ranged from $48.8 \pm 5.4 \text{ gC m}^{-2} \text{ yr}^{-1}$ to $50.9 \pm 3.8 \text{ gC m}^{-2} \text{ yr}^{-1}$, while the *E. distachya*-inhabited site showed a total carbon uptake of $-57.0 \pm 9.9 \text{ gC m}^{-2} \text{ yr}^{-1}$. Daily variances in NCF were well-explained by variances in surface soil temperature, and seasonal NCF showed a significant linear relationship with soil moisture in the two biologically crusted soils and bareland when soil volumetric water content was less than 3%. Rainfall elicited intense carbon release in cyanobacteria/lichen crusted soil, bareland and at the *E. distachya*-inhabited site, and both NCF and DR were positive in the first two days after rainfall treatments. Mean NCF and DR were not different between rainfall amounts of 2, 5 and 15 mm in cyanobacteria/lichen crusted soil and bareland, while they were significantly higher after 15 mm rainfall treatment compared with 2 mm and 5 mm treatments at the *E. distachya*-inhabited site. Mean NCF and DR in the first two days increased logarithmically with rainfall amount. Based on our findings, we suggest that *E. distachya*-inhabited sites contribute to carbon uptake in the Gurbantunggute Desert, while biologically crusted soils exhibit carbon release for most of the year. Even though photosynthesis immediately following rainfall can be stimulated, carbon uptake effect in biologically crusted soil is likely intermittent and confined to periods when moisture is available.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Accurate assessment of carbon budget in variable ecosystems is vital to our understanding and accurate estimation of the global carbon balance (Schime et al., 2001; Korner et al., 2003), especially considering the ever-increasing nature of carbon emissions resulting from fossil fuel usage and land use changes (IPCC, 2007). Compared with other ecosystems, deserts have received much less

attention in this regard because of their lower vascular plant biomass (Whittaker, 1975) and soil carbon storage (Ojima et al., 1993; Jobbágy and Jackson, 2000). Indeed, profound variances in the vegetation pattern and large spatial heterogeneity in available resources in desert ecosystems contribute to significant uncertainty in evaluating their roles as carbon sources or sinks (Schlesinger et al., 1996; Jasoni et al., 2005; Wohlfahrt et al., 2008; Xie et al., 2009; Liu et al., 2012). Most studies conducted so far have shown either that deserts are a source of carbon or that they are carbon neutral (Schimel et al., 2001). However, some recent studies have shown evidences of carbon sinks in deserts, and these findings make deserts potentially valuable in efforts to mediate climate

* Corresponding author. Tel./fax: +86 991 7823149.

E-mail address: zhangym@ms.xjb.ac.cn (Y.M. Zhang).

change compared to temperate forests or grassland ecosystems (Jasoni et al., 2005; Wohlfahrt et al., 2008; Xie et al., 2009). For example, in a sandy desert ecosystem containing deciduous semi-shrubs (*Caragana korshinskii* and *Artemisia ordosica*), slight carbon fixation of $13.87\text{--}23.36\text{ g C m}^{-2}\text{ yr}^{-1}$ has been observed. Moreover, in the Mojave desert, which is dominated by the evergreen shrub (*Larrea tridentata* (DC.) Cov.) and drought–deciduous shrubs (*Lycium andersonii* (A. Gray) and *Ambrosia dumosa* (A. Gray)), carbon uptake of $102 \pm 67\text{--}185 \pm 15\text{ g C m}^{-2}\text{ yr}^{-1}$ has been observed (Jasoni et al., 2005; Wohlfahrt et al., 2008).

The species composition and vegetation cover of desert ecosystems differ greatly (Noy-Meir, 1973). In mobile deserts, vegetation cover is usually around 1% or less, and xeric shrubs or semi-shrubs occur in these areas (Noy-Meir, 1973). By contrast, in fixed and semi-fixed deserts, vegetation cover increases dramatically with precipitation, and can even exceed 40% when ephemeral and ephemeral herbs are present under favorable soil moisture conditions. Moreover, biological soil crusts develop and are widely spread on the soil surface, where no vascular plants develop in these regions (Belnap and Lange, 2003). In recent years, artificial planting in mobile sandy dunes (Li et al., 2003; Zhao et al., 2010) and increasing annual rainfall (Wohlfahrt et al., 2008) have changed vegetation structure, biomass as well as soil properties of deserts. Such changes may potentially alter the magnitude of carbon flux in desert ecosystems. In addition, vegetation structure, which differs profoundly among deserts, interacts with environmental factors that control carbon cycling and affects carbon flux in deserts (Raich and Schlesinger, 1992). For instance, greater vegetation cover usually induces more ecosystem carbon uptake through increased photosynthesis (Wohlfahrt et al., 2008; Gao et al., 2012) and reduced soil respiration, which is induced by lower soil temperature (Luo and Zhou, 2006; Tesar et al., 2008). In addition, since soil properties are always tightly associated with vegetation patterns (Maestre and Cortina, 2002), changes in soil properties may have significant influences on soil respiration, which may indirectly alter carbon flux in desert ecosystems (Luo and Zhou, 2006).

The carbon budget of deserts is largely driven by availability of water to vegetation and soil microbes, as well as biological soil crusts (Noy-Meir, 1973; Smith et al., 1997; Cable and Huxman, 2004). For instance, large carbon release is essentially confined to a very limited period immediately after rainfall (Huxman et al., 2004a, b; Veenendaal et al., 2004; Hastings et al., 2005; Potts et al., 2006a, b; Kurc and Small, 2007), and significant carbon uptake may occur only several days after heavy rainfall events, which increases the rate of photosynthesis in vascular plants (Gao et al., 2012). Rainfall patterns in deserts also determine the trade-off between carbon uptake (photosynthesis by autotrophs) and carbon release (respiration by heterotrophs or dark respiration from photoautotrophs) (Huxman et al., 2004b), specifically, the magnitude and duration of carbon flux are related to rainfall amount (Huxman et al., 2004b) and the interval between consecutive rainfall events (Sponseller, 2007). For instance, biological soil crusts are sensitive to all magnitudes of rainfall, whilst vascular plants are only responsive to heavy rainfall, which can penetrate into deep soil layers and reach the roots. Moreover, biological soil crusts usually initially exhibit carbon release, then take up carbon when moisture is available. Therefore, carbon balance in biologically crusted soil is affected by the duration of rainfall (Huxman et al., 2004b).

The Gurbantunggute Desert is the biggest fixed and semi-fixed desert in China. Its landscape is characterized by mosaic distribution of shrubs, semi-shrubs, biological soil crusts and bareland (Zhang et al., 2007). As in the case of other dry lands, carbon dynamics in the Gurbantunggute Desert is highly sensitive to

water availability (Xu et al., 2007). In the present study, two hypotheses were proposed to explain the variances in net carbon flux (NCF) in the Gurbantunggute Desert: (1) Photosynthesis in vascular plants is usually higher than that of biological soil crusts (Lange, 2003), in addition, though soil organic matter and soil microbes in biologically crusted soils are higher than those in vegetated sites and bareland (Table S1), soil respiration is usually confined to very low values due to low soil moisture. Moreover, soil moisture and temperature differ between measurement periods, and variances in carbon flux might be linked with soil moisture and temperature. Our first hypothesis is that carbon flux at different soil cover sites follows as the relationship: biologically crusted soil > bareland > vegetated site, carbon flux varies with soil temperature and soil moisture at different soil cover sites; (2) Biological soil crusts can utilize a wide range of rainfall events to initiate their physiological activities (Lange, 2003), and they usually show respiration initially, and then photosynthesis occurs. Vascular plants can only use large rainfall events that penetrate into deeper soil layers and are accessible to roots, and small amounts of rainfall only trigger carbon flux in the surface soil layer. Our second hypothesis is then that rainfall translates into dramatic increases in carbon efflux from biologically crusted soil, bareland and vegetated sites irrespective of rainfall magnitude, and that carbon influx in biologically crusted soil and vegetated sites might occur after relatively intense rainfall, which can trigger photosynthesis in crust organisms and vascular plants.

2. Materials and methods

2.1. Study site description

The Gurbantunggute Desert is located at the center of the Jungger Basin in Xinjiang Uygur Autonomous Region of China. It is the biggest fixed and semi-fixed desert in China with an area of $4.88 \times 10^4\text{ km}^2$. Our experiment was conducted in the southern part of the Gurbantunggute Desert (44.87°N , 87.82°E). Precipitation occurs predominantly during spring, totaling approximately 79.5 mm. The mean annual evaporation is 2606 mm. The average annual temperature is 7.26°C . Wind speeds are strongest during late spring, averaging 11.2 m s^{-1} (Zhang et al., 2007). The well developed soil surface cover contributes to the soil stability of the Gurbantunggute Desert, which also benefits from the native vegetation and biological soil crusts. *Ephedra distachya* Linn. is one of the dominant species in Jungger Basin, and is mainly distributed on the sand slope and lower land between sand dunes. The average canopy volume of an individual *E. distachya* is $44,602 \pm 1,0291\text{ cm}^3$ (Table S1), and its cover can reach 20% at the study site. Biological soil crusts are widely distributed on soils between shrubs, usually with a cover >60% (Table S1). Two types of biological soil crusts dominate in this region: cyanobacteria/lichen and moss crusts (Zhang et al., 2009). The cyanobacteria/lichen crusts usually exist in every location in a sand dune, except at dune tops in some high sand dunes. They are mainly composed of *Microcoleus vaginatus* (Vaucher) Gomont ex Gomont, *Microcoleus paludosus* (Kützing) Gomont, *Anabaena azotica* Ley, *Porphyrosiphon martensianus* (Meneghini ex Gomont) Anagnostidis & Komárek, *Collema tenax* (Sw.) Ach., *Psora decipiens* (Hedw.) Hoffm., *Xanthoparmelia desertorum* (Elenkin) Hale., and *Diploschistes muscorum* (Schreb.) (Wu et al., 2009). Moss crusts are typically located at the bottom of dunes and form a mosaic with cyanobacteria/lichen crusts. They are usually composed of *Syntrichia caninervis* Mitt., *Bryum argenteum* Hedw., and *Tortula muralis* Hedw. The soil organic matter and total nitrogen content, soil bulk density, and soil mechanical composition all differ largely among biologically crusted soil, bareland, and *E. distachya*-inhabited sites (Table S1).

Download English Version:

<https://daneshyari.com/en/article/2024901>

Download Persian Version:

<https://daneshyari.com/article/2024901>

[Daneshyari.com](https://daneshyari.com)