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Biological soil crusts are the main contributor to winter soil respiration in a temperate desert ecosystem of China

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Aims

Biological soil crusts (BSCs) are a key biotic component of desert ecosystems worldwide. However, most studies carried out to date on carbon (fluxes) in these ecosystems, such as soil respiration (RS), have neglected them. Also, winter RS is reported to be a significant component of annual carbon budget in other ecosystems, however, we have less knowledge about winter RS of BSCs in winter and its contribution to carbon cycle in desert regions. Therefore, the specific objectives of this study were to: (i) quantify the effects of different BSCs types (moss crust, algae crust, physical crust) on the winter RS; (ii) explore relationships of RS against soil temperature and water content for different BSCs, and (iii) assess the relative contribution of BSCs to the annual amount of C released by RS at desert ecosystem level.

Methods

Site Description

The study sites are located at the southeast fringe of the Tengger Desert in the Shapotou region of the Ningxia Hui Autonomous Region [37°32′N and 105°02′E, at 1340 m above mean sea level (a.m.s.l.)], western China. The mean daily temperature in January is -6.9°C , while it is 24.3°C in July. The mean annual precipitation is 186 mm, approximately 80% of which falls between May and September. The annual potential evaporation is 2800 mm. The landscape of the Shapotou region is characterized by large and dense reticulate barchans chains of sand dunes that migrate south-eastward at a velocity of 3–6 m per year. The soil is loose, infertile and mobile and can thus be classified as orthic sierozem and Aeolian sandy soil. Additionally, the soil has a consistent gravimetric water content that ranges from 3 to 4%. The groundwater in the study area is too deep (>60 m) to support large areas of the native vegetation cover; therefore, precipitation is usually the only source of freshwater. The predominant native plants are Hedysarum scoparium Fisch. and Agriophyllum squarrosum Moq., Psammochloa cillosa Bor, which scattered distribute with cover about 1% of the entire study area.

Prior to revegetation, straw-checkerboards approximately 1×1 m2 in area were constructed using wheat or rice straw to stabilize the dune surface and allow time for the planted xerophytic shrubs to adapt to the new environment. In 1956, the following 2-year-old xerophytic shrub seedlings were planted within the checkerboard at a density of 16 individuals per 100 m2 and grown without irrigation: Artemisia ordosica Krasch, H. scoparium Fisch, Calligonum mongolicum Turc'z, Caragana microphylla Lam., Caragana korshinskii Kom, Salix gordejevii and Atraphaxis bracteata A.Los. The stabilized area was then expanded to parallel areas in 1964 and 1982 using the same method and species. As a result, the initial stages of change that have occurred at these sites were similar. After more than fifties years succession, the predominant plants are semi-shrubs, shrubs, forbs, and grasses at present and BSCs formed. The common BSCs in the region may be dominated by cyanobacteria, algae, lichens and mosses, or any combination of these organisms. Cyanobacteria species include Microcolous vaginatus Gom., Hydrocoleus violacens Gom., Lyngbya crytoraginatus Schk., Phormidium amblgum Gom., P. autumnale (Ag.) Gom., P. foveolarum (Mont.) Gom. and Phormidium luridum (Kutz) Gom. etc; algal species mainly include Anabaena azotica Ley, Euglena sp., Hantzschia amphioxys var capitata Grum, Oscillatoria obscura Gom., O. pseudogeminate G. Schm. And Scytonema javanicum (Kutz) Bornet Flash etc; lichen species include Collema tenax (Sw.) Ach., Endocarpon pusillum Hedw.; and moss species are dominated by Bryum argenteum Hedw., Didymodon constrictus (Mitt.) Saito., Tortula bidentata Bai Xue Liang and T. desertorum Broth..

Experimental Design and Rs measurements

On October 2010, We selected the moss-dominated BSCs at four revegetation sites and natural vegetation sites, in which 3 replicated plots were selected randomly. In each plot, olyvinyl chloride (PVC) collar (lenth 10 cm, internal diameter 10cm) were inserted 7 cm into the soil. During the establishment of PVC collars, each plot falling within distances less than 2.0 m of an existing replicate was discarded and reallocated to ensure a minimum distance between replicates of 2.0 m.

Soil respiration was measured with a LI-6400 and a soil CO_2 flux chamber (LI-6400-09). The target value was set close to the ambient CO_2 concentration ($\sim 380\mu$molmol_1), and the ΔCO_2 value was set as the factory default value (10μmolmol-1) (LiCor 1997). Thin-walled PVC collars were inserted at least one night (12h) before measurement so as to avert CO_2 flushing, as recommended by LiCor (1997). Measurements were performed monthly between November 2010 (1months after the collars were inserted to avoid any bias promoted by soil alteration during the placement of collars) and March 2010. Diurnal Rs were measured every two hours from 8:00 to 6:00 of the next day. In parallel to the measurements of soil respiration, Measurements of soil respiration, soil moisture, and soil temperature were taken according to a stratified random design.
Important findings
(1) The RS was positively correlated to soil temperature in all BSCs, and was significantly influenced by the interactions of soil temperature and water content in moss, lichen and mixed BSCs.
(2) The sensitivity of RS to soil temperature at 10cm depth (Q10) ranged from 1.25 in moss-dominated BSCs to 1.63 lichen-dominated BSCs. The Q10 tended to increase with soil temperature until reaching a threshold, and then decline.
(3) Soil respiration rates remained low at night time and exhibited as single-peak curve at day time from April to October, and compare to the shifting sand area, a remarkable monthly variation occured in the BSCs dominated area.
(4) The winter RS for the moss, lichen, and mixed BSCs averaged 102, 56 and 85 gCm-2 winter time_1, respectively. The winter RS was positively correlated to soil organic carbon (SOC) concentration at O horizon.
Our results indicate that winter Rs of BSCs-dominated areas are the main contributor to the total carbon released by soil respiration and, therefore, which we should considered when estimating carbon budgets in desert ecosystems.

Key words: Winter Soil Respiration; Biological Soil Crust (BSCs); Q10