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Contribution of root respiration to spatial-temporal variation of soil respiration in a *Haloxylon ammodendrons* ecosystem in Gurbantunggut Basin

Zhi-min Zhao [a,b,*], Feng-xia Shi [a]

[a] College of Environmental Science and Tourism, NanYang Normal University, Nan Yang 473000, China
[b] State Laboratory of Oasis Ecology and Desert Environment, Xinjiang Institute of Ecology and Geography, CAS, Urumqi 830011, China

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ABSTRACT

On the basis of the sparse distribution of Haloylon ammodendrons, we designed experiment to study the spatial-temporal variation of soil respiration in a Haloxylon ammodendrons ecosystem in Gurbantunggut Basin. A 401 cm transect between two *Haloxylon ammodendrons* was built on 11 April, 2005. We started to measure soil respiration along the built transect in May, 2005. The experiment completed in September, 2007. The result of experiment showed that soil respiration under *Haloxylon ammodendron* crown decreased with distance from stem to the edge of crown. In the open area, shrub roots have no influence on soil respiration. Considering the results of the experiment, the contribution of root and rhizosphere respiration (R_r) to total soil respiration was determined. We deduced that *Haloxylon ammodendrons* root respiration averaged as 0.0768gCO_2 m^{-2} h^{-1}, account for 51.3% of total soil respiration. The seasonal pattern of soil CO_2 efflux under trees, in open areas and estimated root respiration was simulated by temperature-respiration models, moisture-respiration models and bivariable models driven by soil temperature (T_s) and moisture (M_s), respectively. We inferred that bivariable models driven by soil temperature and moisture describe the seasonal variation of soil respiration better than other two kinds of models. The components of soil respiration, R_d and R_r, respond differently to environmental change. R_r is more sensitive to the dynamic of temperature. And combined model of soil temperature and moisture on respiration explain the seasonal variation of R_d better than that of R_r.

1. Introduction

The biogeochemistry of carbon (C) in shrub forest ecosystems is a subject of great interest and importance because of natural and human-accelerated changes in the global atmosphere, especially greenhouse gas accumulation. Climatic variables may affect all components and processes of the global carbon (C) cycle, including soil C contents and dynamics, which in turn have significant feedback effects on the global climate. The global CO_2 flux from soils ranges from 64 to 72 Gt C y^{-1}, which accounts for 20–38% of annual emission of CO_2 from terrestrial and marine sources to the atmosphere [7,31,36]. Therefore, soil CO_2 flux is a key determinant of net ecosystem C balance and thus an important regulator of climate change.

Soil respiration originates from both soil organic matter decomposition (R_d) and root and rhizosphere respiration (R_r). In order to evaluate implications of soil biotic and abiotic variables for soil carbon cycling and sequestration, we need a better understanding how the contributions of these two components to soil respiration [11,15]. In addition, root-associated and bulk soil respiration may responds to increasing temperature differently, and they exhibit different Q_{10} values [2,5,32]. Therefore, they likely alter net C flux from soils as well as the potential for C sequestration, which provides important feedbacks for climate change [9,27]. Increases in *Rr* may reflect increased C inputs to the soil directly from photosynthesis [16], specific root activity, or root biomass [7,13,18,35]. In contrast, increased bulk soil respiration may reduce the potential for C storage in soil [12]. Therefore, quantifying the components of net soil respiration is essential for understanding soil biological processes response to climate change. Moreover, the difference of contribution of components of soil respiration is possible a major reason for the high spatial variation of soil respiration [20].

Several methods have been developed to estimate CO_2 flux from roots and its associated rhizosphere microbial organisms. Hanson et al. [15] classified these methods into three broad categories: component integration, root exclusion, and isotopic approaches. Existing root exclusion techniques may be categorized into three broadly defined areas: root removal, trenching and gap analysis (gap formation).

The gap formation method [4,28] is a procedure that indirectly estimates R_r from the difference in soil respiration rates between the plot under the crown and that in the gap. One of the biggest concerns is

* Corresponding author.
E-mail address: zmz7880@163.com (Z. Zhao).

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the difference of soil physical environment between the two plots. An additional challenge to estimation is the accuracy of soil respiration in the gap, which effected by roots from surrounding vegetation. Shrub system in Gurbantunggut Basin provides an ideal natural laboratory to study spatial variation and partitioning of soil respiration in situ and in a non-destructive manner: there are almost no grasses and residua (wind blowing them away) under the crowns of *Haloxylon ammodendrons*. The sparse distribution of *Haloxylon ammodendrons* provides natural gap for studying the spatial pattern of soil respiration, and for separating the contributions of respiration from roots that support photosynthetically active shrubs and heterotrophic microbes that decompose organic matter in soil.

Most soil CO_2 flux is the result of oxidation of soil organic matter decomposition by heterotrophic microorganisms and respiration by plant roots. Thus, the population dynamics of soil microorganisms (e.g. fungal, bacterial and actinomycetes populations) and the soil abiotic factors (e.g. soil moisture, temperature, pH and organic carbon concentration) are the major factors controlling in the emission of CO_2 by soil. In addition, these abiotic factors affect the gaseous diffusion and metabolic activity of soil microorganism and therefore, control the dynamics of soil microorganisms and their metabolic activities within sites. Then it is significant to quantify the effect factors that controlling R_r and R_d, respectively.

The objective of the present study was to (1) quantify the spatial variation in soil respiration in shrub forest ecosystem;(2) quantify the contribution of *Rr* and *Rd* to total soil respiration on seasonal time scales.(3)to identify the effects of T_s and M_s on Rs, Rd and Rs, respectively.

2. Materials and methods

2.1. Study site

The present study was conducted in a natural shrub forest (43°20′ 37″ N to 44°29′53″ N and 87°50′24″ E to 88°17′06″ E; at an elevation of 750 and 450 m) in the southern edge of Gurbantunggut Basin in Central Asia. Geographically about 98% of the total area is covered by alluvial plain ranges which are the offshoots of Sangong River with about 4000 km^2 area [24]. The forest was located on the periphery of Sangong Oasis at a distance of 20 km on the south edge of Gurbantunggut Basin. The climate of the area is temperate zone with warm summer and cool winter. The mean minimum and maximum temperature during the study period (May–November, 2005; April—November, 2006; May–September,2007) ranged between 1.54 °C and 31 °C. The total annual rainfall was 250 mm of which about 75% occurred in 4 months of the year from June to September. Soils in the region are gray desert soils and include luvic yermosole and meadow solonchak [37]. The quantity of soil microorganisms was measured by Zhu and Li [25,39].

The forest vegetation was dominated by *Haloxylon ammodendron* (C. A. Mey.) Bung along with other shrubbery like *Tamarix ramosissima Lede, Reaumuria soongorica Maxim, Ceratocarpus arenarius L, Suaeda physophora Pall* and some ephemeral herbaceous vegetation [37].Biological crusts and mosses were common features of soil surface in the area. But unordered graze and human activity disturbed the soil surface stability. Trampling by livestock destroyed the physical texture of soil surface as biological crusts and mosses [38]. All these activities influenced soil CO_2 respiration and the balance of soil carbon in terrestrial ecosystem.

2.2. Experimental design

We established a 401 cm transect between two *Haloxylon ammodendrons* in the Gurbantunggut Basin that traversed an open patch along the east-west direction, start in May 2005.At the east side of the transect was a big *Haloxylon ammodendron* with shrub height of 2.1 m, and an average of crown diameter of 67 cm. The other *Haloxylon ammodendron* at the west side of the transect was smaller, with shrub height of 1.8 m, and an average of crown diameter of 61 cm. A schematic of the transect for the study site is presented in Fig. 1.

We inserted 20 soil collars, each with a height 2.3 cm and an area of 78 cm^2, into the soil along transect for measuring soil respiration. The collars were 20 cm away each other (Fig. 1).

Soil respiration was measured using an infrared gas analysis system (model CIRAS-1 PP Systems, Hitchin, UK) equipped with a flow-through

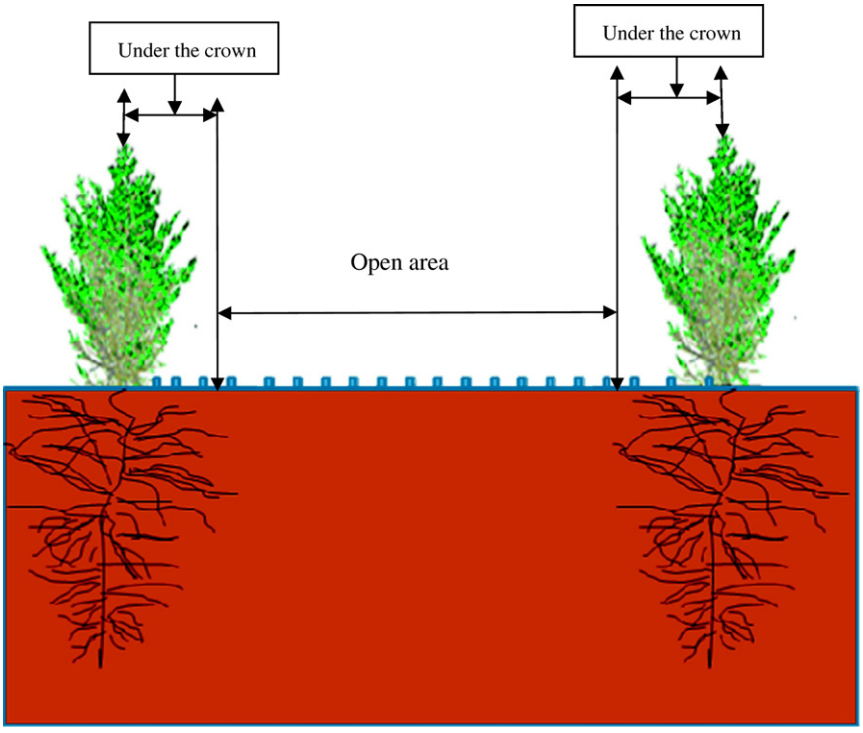

Fig. 1. A schematic of the transect with measured points under the crows and in the open area.