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# Soil $CO_2$ Flux from Desert Ecosystems in Western China

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**Abstract:** Soil $CO_2$ fluxes were measured in July 2010 at two sites in a desert ecosystem, southern Dzungaria Basin of Xinjiang, China. One site was located in irrigation fields, although seldom irrigated directly compared with neighboring fields. *Tamarix ramosissima* dominates in this site with fragment patchy distributions of salt accumulation. Soil $CO_2$ fluxes at bare soils, salt-accumulated and litter-covered areas were measured with a closed system, which was constructed from $CO_2$ gas analyzer, chamber and air pump. The other site was located 20 km away from the first site, which was covered by algae-lichen in a patchy fashion with the dominant shrub species of *Haloxylon ammodendron*. Soil $CO_2$ fluxes were measured at algae-lichen and litter-covered areas in this site. The results indicated that soil $CO_2$ flux ranged from -0.8 to 1.4 μmol $m^{-2}$ $s^{-1}$ with higher soil $CO_2$ release at litter-covered areas under canopies in both sites. Soil $CO_2$ release at the litter-covered area in the first site was higher than that of the desert site. Soil $CO_2$ flux was found to be negative at bare soil and salt-accumulated area. Increase in soil $CO_2$ release with the increase in soil temperature was not identified from our results. On the contrary soil $CO_2$ release often decreased with the increase of soil temperature, suggesting the importance of water content at soil surface on soil $CO_2$ flux in desert ecosystems.

**Key Words:** Algae-lichen, Litter, Salt accumulation, Soil $CO_2$ flux

## 1. Introduction

Soil $CO_2$ emission constitutes one of the main sources of $CO_2$ emissions to the atmosphere, accounting for about 25-35% of global annual emission (Bouwmann and German, 1998; Schlesinger and Andrews, 2000). Global soil carbon pool has been estimated at 2500 gigatons (Gt), which includes 1550 Gt of soil organic carbon, and this is 3.3 times the size of the atmospheric pool (760 Gt) (Lal, 2004). Generally, soil $CO_2$ emission and soil respiration increases with the increase in temperature (Epron *et al*., 1999; Conant *et al*., 2004). Therefore, response of soil $CO_2$ flux to warming is important for global carbon balance. On the other hand, some studies have described the soil surface absorbed $CO_2$ in arid and semiarid ecosystems (Wohlfahrt *et al*., 2008; Xie *et al*., 2009), although it is difficult to determine whether these results are representative or anomalous. Since arid and semiarid ecosystems covers more than 30% of the Earth's land surface, the effect of soil $CO_2$ flux in these ecosystems could be of great significance for evaluation of global carbon cycle.

The mechanism of soil $CO_2$ flux has many processes of $CO_2$ emissions and absorptions. Soil $CO_2$ emission and respiration is composed of an autotrophic component by roots, associated rhizosphere and a heterotrophic component by soil micro-organisms that decompose organic materials. Generally, temperature is a major environmental factor on soil respiration (Epron *et al*., 1999; Conant *et al*., 2004; Sponseller, 2007). However, soil water content can also be an important factor particularly during dry season in arid and semiarid lands (Conant *et al*., 2004). Soil $CO_2$ absorption has a biological process via photosynthesis by soil crust and non-biological process at alkaline soils. Soil crust communities such as cyanobacteria, algae, mosses and lichens have considerable photosynthetic potential, although this is limited by the hydration status (Lange *et al*., 1992; Lange *et al*., 1998; Jia *et al*., 2008). Xie *et al*., (2009) has shown that alkaline soils absorbs $CO_2$ with a non-biological and inorganic process, and the rate of $CO_2$ absorption depends on the salinity, alkalinity, temperature and water content of the soil.

Despite existence of numerous studies on soil $CO_2$ flux (Wohlfahrt *et al*., 2008; Xie *et al*., 2009; Conant *et al*., 2004), available data is not sufficient to evaluate whether the results of these studies are a representative of arid and semiarid ecosystems. Soil $CO_2$ flux differs among surface type (Maestre and Cortina, 2003; Zhang *et al*., 2007). Spatial variation in soil $CO_2$ flux is especially important for the estimation of $CO_2$ flux in ecosystems because resource distribution, conditions and organisms are markedly patchy in semiarid ecosystems (Schlesinger and Pilmanis, 1998; Maestre and Cortina, 2002). The main objective of this study was to compare soil $CO_2$ flux among soil surface types in the southern Dzungaria Basin. The results of this study can provide more information on evaluation of carbon cycle in arid and semiarid ecosystems.

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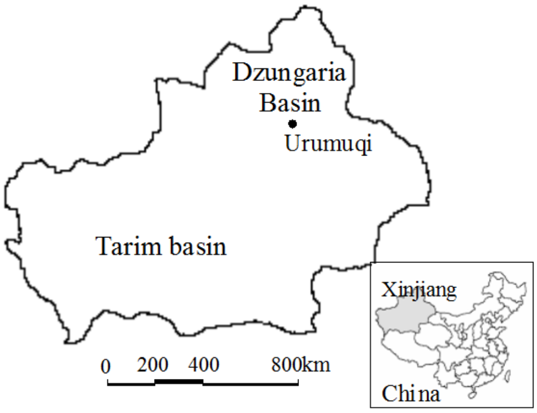


**Fig. 1. Map of study area.**

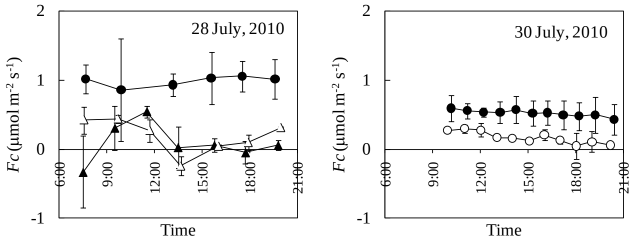


**Fig. 2. Diurnal course of soil $CO_2$ flux in irrigation field site (left) and desert site (right).** Closed circles (●): litter-covered area, closed triangles (▲): bare soil, open triangles (△): salt-accumulated area, open circles (○): algae-lichen area. Data are means ± SD (n=3).

## 2. Materials and methods

Measurements were conducted at two desert ecosystems located in the southern Dzungaria Basin of Xinjiang in China (**Fig. 1**) in July 2010. One location was in irrigation fields (44°17'N, 87°56'E), although seldom irrigated directly compared with neighboring fields. *Tamarix ramosissima* dominates in this site with fragment patchy distributions of salt accumulations. The other site was located about 20 km away from the first site (44°43'N, 87°90'E), which is covered by algae-lichen in a patchy fashion with *Haloxylon ammodendron* as the dominant shrub species. Soil $CO_2$ fluxes were measured at bare soils, salt-accumulated area and litter-covered area at the irrigation field site (from 7:30 - 20:00 Hours, on 28 July) and at algae-lichen area and litter-covered area in the other desert site (from 13:30 - 20:00 Hours on, 29 July and 10:00 - 20:30 Hours, on 30 July). The soil surface at bare soils did not have any litter as well as the salt-accumulated area. Air temperature and relative humidity were measured with a thermo recorder (RS-13, TABAI Espec, Japan) at 15-min intervals. The maximum and minimum temperatures were 36 and 16°C, respectively, with lowest relative humidity at daytime being ~ 20%.

Soil $CO_2$ fluxes were measured with a closed system which was constructed from infrared gas analyzer (IRGA, LI-820, LICOR, USA), chamber (cylingder r=5.25cm, L=15.0cm) and air pump (EAP-01, Asone, Japan). The chamber was made by white vinyl chloride column which didn't allow sunlight to penetrate completely. Data of IRGA were recorded every 5seconds by the data logger (MR2031-MU, CHINO, Japan) with soil temperature (at 5cm in depth) during each measurement. Soil temperature was measured with thermocouple sensor (SCN05-113, CHINO, Japan). Soil $CO_2$ fluxes *Fc* (μmol $m^{-2}$ $s^{-1}$) were calculated by the following formula

$$Fc(t) = \frac{PV}{RTS} \cdot \frac{\Delta C}{\Delta t} \qquad (1)$$

Where *P* is the air pressure (Pa), *V* is the chamber volume ($m^3$), *R* is the molar gas constant (8.314 Pa $m^3$ $K^{-1}$ $mol^{-1}$), *T* is the air temperature (K), *S* is the soil surface area ($m^2$), *C* is $CO_2$ concentration (μmol $mol^{-1}$).

**Table 1. Soil $CO_2$ flux at daytime (12:00-18:00) in irrigation field and desert site.** Data are means ± SD (n=8-22). Different lower case letters indicate significant differences by using Tukey-Kramer test after one-way ANOVA (*P*<0.05).

| site | date | surface | *Fc* (μmol $m^{-2}$ $s^{-1}$) | |
|---|---|---|---|---|
| irrigation field | 28 July | bare soil | 0.01±0.19 | c |
| | | salt accumulation | -0.04±0.19 | c |
| | | litter | 1.01±0.24 | a |
| desert | 29 July | algae-lichen | 0.03±0.35 | c |
| | | litter | 0.40±0.14 | b |
| | 30 July | algae-lichen | 0.16±0.10 | c |
| | | litter | 0.52±0.15 | b |

## 3. Results and Discussion

Diurnal changes of soil $CO_2$ fluxes are shown in **Figure 2**. Soil $CO_2$ flux ranged from -0.8 to 1.4 μmol $m^{-2}$ $s^{-1}$. Soil $CO_2$ releases under canopies at litter covered soil were higher than other surface type in both sites (*P*<0.05). The soil $CO_2$ release at the litter-covered area in the irrigation field site was higher than the desert site (*P*<0.05) and the average $CO_2$ flux during daytime (12:00 to 18:00) was 1.01 μmol $m^{-2}$ $s^{-1}$ (**Table 1**). Zhang *et al*. (2007) had found out that soil respiration rate at *T. ramosissima* community was higher than sites dominated by *H. ammodendron* community throughout the year in western Dzungaria Basin. They also estimated the soil respiration rate to be 2.02 and 0.65 μmol $m^{-2}$ $s^{-1}$ in July at *T. ramosissima* and *H. ammodendron* community, respectively. The higher $CO_2$ release at the litter-covered area during this study in the irrigation field site with *T. ramosissima* as the dominant shrub species was consistent with the results by Zhang *et al*. (2007), although the $CO_2$ release of this study was lower. In addition, soil $CO_2$ fluxes measured in this study were almost consistent with the soil respiration rate measured at the same area by Zhu *et al*. (2008). However, soil $CO_2$ flux was found to be negative at bare soil and salt-accumulated area at specific times. This was evident when the average soil $CO_2$ flux during daytime was -0.04 μmol $m^{-2}$ $s^{-1}$ at salt-accumulated area (Table 1) with the minimum of -0.24 μmol $m^{-2}$ $s^{-1}$ at 13:30. These negative values indicated that soil absorbs $CO_2$ in this ecosystem. Xie *et al*. (2009) reported that the rate of $CO_2$ absorption by alkaline saline desert soils increased with the increase in salinity and the soil $CO_2$ flux measured at saline desert in July ranged from -1 to 1 μmol $m^{-2}$ $s^{-1}$. In the irrigation field site, the salinity of surface soils at salt-accumulated area was assumed to be higher than that at other area based on the surface salt accumulation features. The higher soil $CO_2$ absorption rate at salt-accumulated area was thought to be attributed to the higher salinity of surface soil although there was no significant difference in the rates between bare soil and salt-accumulated area. $CO_2$ absorption via photosynthesis by soil crust may be ruled out in this study since the chamber walls which were not transmissive reduced most of the incident light. The results of soil $CO_2$ flux at algae-lichen area might have been caused by soil respiration including dark respiration of soil crust communities. The lower soil $CO_2$ release at algae-lichen area might be thought to be due to the low amount of organic matter, litter and roots, including soil crust communities.

Generally, soil respiration increases with the increase in soil temperature. Contrary to the notion that soil $CO_2$ release increases with the increase in soil temperature, results from this study indicated that soil $CO_2$ release decreased with the increase of soil temperature (**Fig. 3**). Conant *et al.* (2004) described that soil respiration is related to temperature, but soil moisture can have an overriding influence particularly during dry season in semiarid lands. Soil respiration increases with the increase in soil moisture (Epron *et al*., 1999; Conant *et al*., 2004) and increases immediately after rewetting by precipitation (Sponseller, 2007). Dark respiration on projection area base for soil crust also increases with the increase in thallus water content (Lange *et al*., 1998).

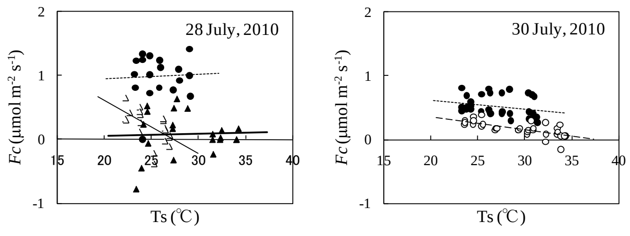


**Fig. 3. Relationship between soil $CO_2$ flux and soil temperature in irrigation field site (left) and desert site (right).** Closed circles (●) and dotted line: litter-covered area, closed triangles (▲) and bold line: bare soil, open triangles (△) and thin line: salt-accumulated area, open circles (○) and dashed line: algae-lichen area.

Therefore, water availability is a major driver of soil $CO_2$ flux in semiarid ecosystems. Although there was no rainfall during the measurement period, we found dew on the twigs of *T. ramosissima* in early morning on 24th July in the site at the irrigation field. Agam and Berliner (2006) described that the amount of dew can exceed that of rainfall for plants and hence adding water to the soil by dew formation and water absorption in arid lands. In addition, soil surface may trap water in the early morning, leading to water content at thin surface layer decreasing gradually from morning to afternoon. Our results suggested that temperature was not a major factor controlling soil $CO_2$ fluxes but water content at soil surface was more important on soil $CO_2$ flux in this ecosystem.


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