

# Effects of simulated warming on soil respiration to XiaoPo lake

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**Abstract.** The main flux of carbon cycling in terrestrial and atmospheric ecosystems is soil respiration, and soil respiration is one of the main ways of soil carbon output. This is of great significance to explore the dynamic changes of soil respiration rate and its effect on temperature rise, and the correlation between environmental factors and soil respiration. In this study, we used the open soil carbon flux measurement system (LI-8100, LI-COR, NE) in the experimental area of the XiaoPo Lake wetland in the Qinghai Lake Basin, and the Kobresia (Rs) were measured, and the soil respiration was simulated by simulated temperature (OTC) and natural state. The results showed that the temperature of 5 cm soil was 1.37 °C higher than that of the control during the experiment, and the effect of warming was obvious. The respiration rate of soil under warming and natural conditions showed obvious diurnal variation and monthly variation. The effect of warming on soil respiration rate was promoted and the effect of precipitation on soil respiration rate was inhibited. Further studies have shown that the relationship between soil respiration and 5 cm soil temperature under the control and warming treatments can be described by the exponential equation, and the correlation analysis between the two plots shows a very significant exponential relationship ( $p < 0.001$ ). The warming treatment not only increased the  $Q_{10}$  value of soil respiration rate, but also increased the sensitivity of soil respiration rate. The relationship between soil respiration and soil moisture can be explained by the quadratic linear equation ( $p < 0.05$ ). It can be concluded that under the condition of sufficient rainfall, the soil temperature is the main influencing factor of soil respiration in this region.

## 1. Introduction

The increase in greenhouse gas emissions brought about by the problem of global warming has been the world's experts and scholars of common concern. The greenhouse effect caused by the increase of atmospheric CO<sub>2</sub> concentration is one of the important causes of global warming. Soil respiration also has a great influence on atmospheric CO<sub>2</sub> concentration, which is an important link of terrestrial ecosystem carbon budget [1]. In high latitudes, soil respiration is very sensitive to temperature [2], so the study of soil respiration response to temperature changes is even more important. A large number of studies have found that soil respiration rate increases with increasing soil temperature for short-term warming, as in the 2-year warming test in western Ohio, when the temperature rises by 2.5°C, the soil respiration rate increases 26% [3]. Wang [4] summarized the effect of 50 terrestrial ecosystem warming on soil respiration rate by meta-analysis, and increased soil temperature by 2°C and soil respiration rate by 12%. The effect of warming on soil respiration is also different in spatial pattern [5]. The change of soil respiration due to warming will also vary depending on vegetation type, soil structure and background climate characteristics. In temperate forests, The average soil temperature increased by 3.72°C



and the soil respiration rate increased by 12%. In the northern coniferous forest, the average soil temperature increased by 3.42 °C and the soil respiration rate increased by 10%. Liu [6] found that soil respiration rate was greatly affected by soil temperature and increased with the increase of soil temperature, in the study of soil respiration in different communities of Qinghai Lake.

The warming simulation test in the field is one of the main methods to study the relationship between global warming and terrestrial ecosystem. It can not only obtain the direct evidence of the impact of climate warming on ecosystem, Explain the inherent mechanisms of terrestrial ecosystem responses to climate change [7]. The alpine meadows of the Qinghai-Tibet Plateau occupy a special position in the ecosystem type, which can significantly overestimate the changes in the global climate and sound the alarm of the human protection environment. Therefore, in this experiment, the method of simulating temperature increase is used in the XiaoPo Lake wetland of the Qinghai-Tibet Plateau. In order to study the possible effects of climate warming on the respiration of alpine meadows, it also provides scientific basis and basic research data for soil carbon cycling under the background of global warming.

## 2. Materials and methods

### 2.1. Site area

The study area is located in XiaoPo Lake, Gonghe County, Hainan Autonomous Prefecture, Qinghai Province(100°45'00"~100°47'21"E, 36°41'73"~36°42'25"N). It is the Qinghai Lake water level after the decline of the swamp meadow. XiaoPo Lake is a "miniature" of Qinghai Lake ecological landscape, south of Qinghai Lake, north of Qilian Mountain, making the XiaoPo Lake has not only tourism value, but also has a strong ecological value. It is located at about 10 km north of Qinghai Lake, and its topography is about 14.8 km<sup>2</sup> from north to south, with an area of 3212~3221 m [8]. The average annual temperature is -4.6~1°C, the annual precipitation is 291 ~ 575 mm, the annual evaporation is 800 ~ 2000 mm, the soil is watery cryptic soil, mainly in marsh soil and meadow soil [9]. The XiaoPo Lake with unique natural scenery and special geographical location has become one of China's famous scenic spots, but also included in the international wetland resources area.

### 2.2. Place of the sample

The plot is located in the XiaoPo Lake wetland, 100 m away from the XiaoPo Lake Wetland Protection Station, The tested community is Kobresia Tibetica Meadow. Set up a warming zone in the sample area. Repeat for 3 repetitions. (20 cm in diameter, 14 cm in height) were embedded in the soil, and the polyethylene cylinder was embedded at a depth of 11 cm in the soil. OTC warming principle is: play a blocking role, reduce the flow of its internal air, and reduce the wind speed, so as to ensure that the internal heat is not easy to lose. Second, OTC's main material is glass fiber, it is the sun's infrared radiation penetration, to achieve warming effect. The green plants in the PVC pipe were cleaned up the day before each measurement to minimize disturbance to the soil to maintain the original environment.

### 2.3. Determination of soil respiration rate

In this study, the determination of soil respiration rate was determined using the LI-8100A open soil carbon flux measurement system manufactured by LI-COR. The main hardware in the equipment included soil moisture probe, auxiliary sensor interface, analyzer control unit , Soil temperature probe. The soil respiration rate in the plot was from May to August in the planting season of the petrol growing season, and the soil respiration rate was measured continuously on the 5th and 28th August, respectively. The schedule was from 6:00 to the next day 3:00 am. 6:00 to 24:00 in the morning to two hours for a cycle to determine a group of soil respiration value, 24:00 to 24 am the next morning to three hours for a cycle to determine a group of soil respiration value. In order to obtain the soil surface temperature, insert the soil temperature probe into the ground about 5 cm, in order to get the soil volume water content data, the soil moisture probe into the ground about 5 cm.

### 2.4. Data analysis methods

The simple empirical index model proposed by Lloyd and Taylor (1994) describes the response of soil respiration to temperature changes: The relationship between soil respiration rate and soil temperature is expressed by the exponential model:  $y = ae^{bt}$ , where  $y$  is the soil respiration rate,  $a$  is the soil respiration rate at 0 °C,  $b$  is the reaction coefficient and  $t$  is the temperature.

The  $Q_{10}$  value is given by:  $Q_{10} = e^{10b}$ , where  $b$  is the reaction coefficient [10]. The difference of soil respiration rate under different treatments was analyzed by independent sample T test. The effects of soil temperature on soil respiration rate were tested by pearson correlation analysis. The effects of soil water content on soil respiration rate were tested by partial correlation analysis. The correlation between soil respiration rate and soil water content was analyzed by exponential function. The correlation between soil respiration rate and soil water content was analyzed by quadratic function. The significance level of all the tests was 0.05. All data are calculated by SPSS 21.0, drawing through OriginPro8 to complete.

### 3. Results and analysis

#### 3.1. OTC warming effect evaluation

In order to evaluate the warming effect of the OTC in the XiaoPo Lake wetland, we selected the observed data for 5 days (May 4, June 17, July 23, August 5 and August 28) in the 2016 growth season Differences in soil temperature and moisture at 5 cm depth inside and outside the OTC unit. It can be seen from Table 1 that the average soil temperature after simulated temperature increase is 1.37 °C higher than that of the control, and the warming effect is obvious. The difference of soil temperature between 5 cm and 5 cm in OTC was the highest at 3.64 °C, and the minimum was 0.88 °C on August 5. With the increase of soil temperature, soil water content also changed. The water content of the soil under the warming treatment was 44.64% and the control was 44.57%. The water content of the soil was higher than that of the control. The results showed that the soil moisture under OTC warming was not easily evaporated, of the soil than the natural state of the sample soil moisture content. However, in May and July of 2016, soil moisture content was lower than that of the control by 1.2% and 0.09%, respectively, which was probably due to the increase of soil water evaporation after soil temperature rise caused by.

**Table 1.** Soil temperature at the depth of 5 cm and soil water content at the depth of 5 cm in and out of the chamber.

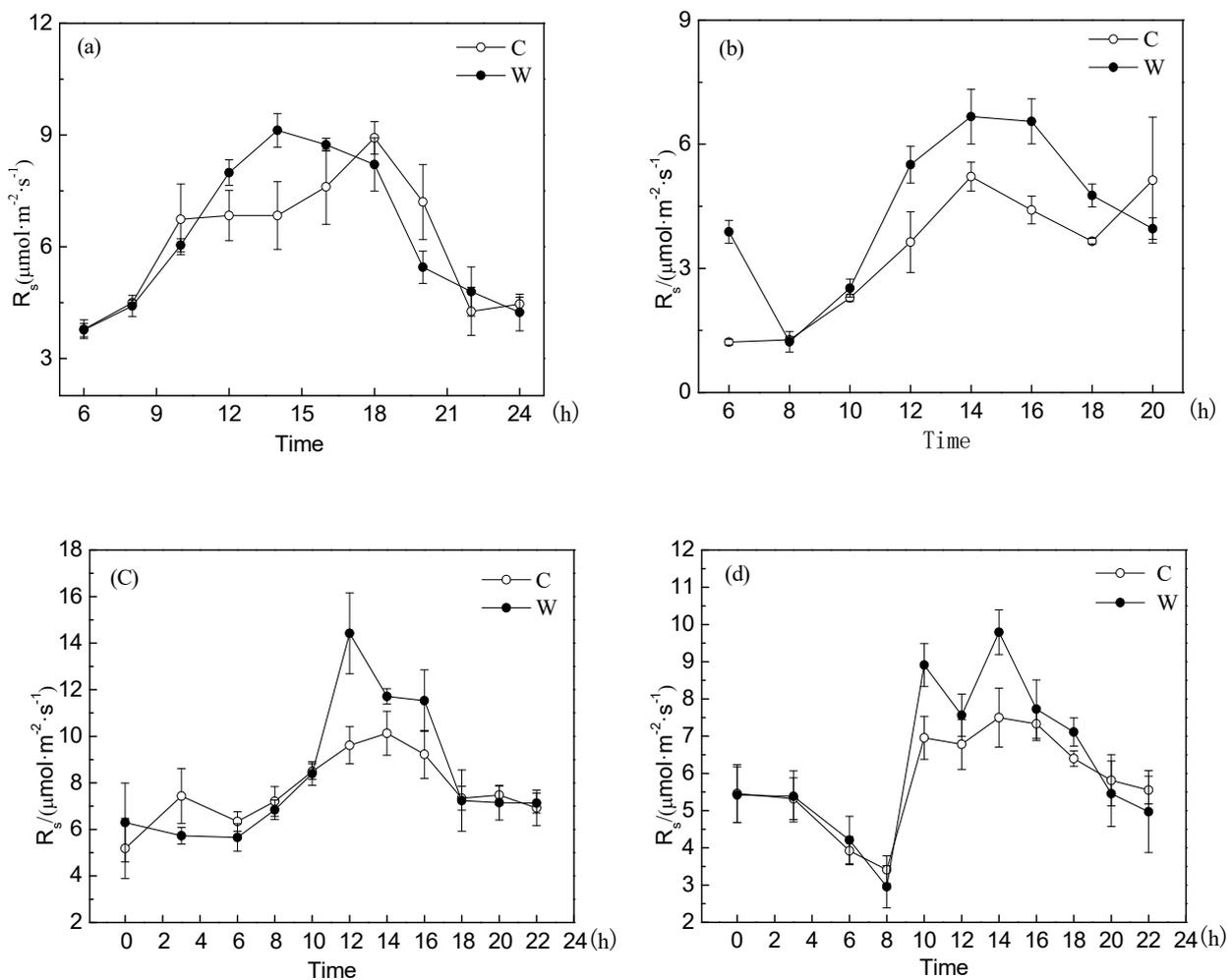
Time	Monthly mean soil temperature at the depth of 5 cm(°C)			Soil water content at the depth of 5 cm (%)	
	Control	Warming	$\Delta$	Control	Warming
<b>May 4, 2016</b>	8.95	12.59	3.64	45.30	44.10
<b>June 17, 2016</b>	16.46	17.03	0.57	43.32	43.75
<b>July 23, 2016</b>	16.57	17.57	1	46.00	45.91
<b>August 5, 2016</b>	18.36	19.24	0.88	43.51	44.23
<b>August 28, 2016</b>	16.69	17.43	0.74	44.70	45.20
<b>Average temperature difference</b>			1.37		

$\Delta$ = Warming- Control

#### 3.2. Effects of simulated warming on soil respiration rate

**3.2.1. Diurnal variation of soil respiration rate.** From Figure 1. (a-d), it can be seen that the peak and the temperature of respiration rate generally appear between 12:00 and 18:00, and the lowest value is generally 24: 00 ~ 3: 00. Visible during the day, due to meteorological conditions (mainly temperature changes), the daytime soil respiration was significantly greater than the night.

The diurnal variation of soil respiration rate of *Kobresia humilis* was studied in Figure 1. It can be seen that the diurnal variation of soil respiration rate was  $3.16 \sim 9.12 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$  on June 17, 2016 ;while the control diurnal variation range was between  $3.78 \sim 8.92 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ ; The diurnal variation of soil respiration rate was  $1.22 \sim 6.67 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ , and the diurnal variation of soil respiration rate was between  $1.22 \sim 5.22 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ ; The diurnal variation of soil respiration rate was between  $5.65 \sim 14.42 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$  on the August 5 (August). The diurnal variation of soil respiration was between  $5.18 \sim 10.13 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ . The diurnal variation of soil respiration rate was  $2.96 \sim 9.79 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ , and the diurnal variation of soil respiration was  $3.41 \sim 7.50 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ . As the study area continued to rain on July 23, the soil respiration rate was low, indicating that precipitation increased soil moisture, permeability of soil voids became smaller, soil respiration was inhibited. As the soil has been kept in flooded state, in the anomalous environment, the activity of aerobic microorganisms is inhibited, the decomposition rate of soil organic matter is reduced and the amount of  $\text{CO}_2$  produced in the soil is reduced. Therefore, even under the condition of high temperature in summer, the rate will be at a low level [11]. However, the overall respiration rate of soil respiration was higher than that under the control, indicating that the increase of soil temperature could promote the rate of soil respiration.

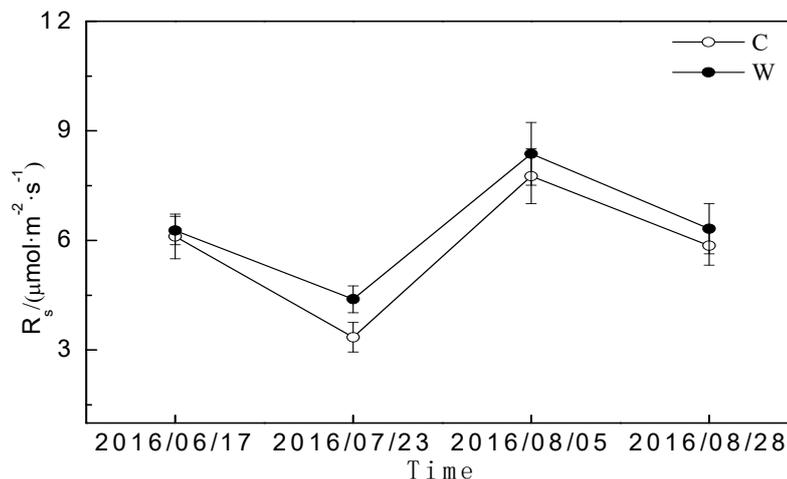


C:control plots; W:experimental warming

**Figure 1.** Diurnal variation of soil respiration ( $R_s$ ) rate of Tibetan Kobayashi in XiaoPo Lake wetland in (a) June 17; (b) July 23; (c) August 6 and (d) August 28 of 2016.

**3.2.2. Monthly changes in soil respiration rate.** Figure 2. shows the monthly variation of soil respiration rate of *Kobresia humilis* in XiaoPo Lake wetland. It can be seen that the change pattern of soil respiration rate in the growing season is similar to that of the control plot, Multi-peak curve form, and in the dynamic trend and soil temperature changes are similar, the maximum soil respiration occurs in the higher temperature in August, In addition to the role of rainfall in July to suppress the role of soil respiration (soil moisture moderate soil respiration rate is the largest, excessive or insufficient soil moisture will inhibit soil respiration [12]), August is at the peak rate, which is due to the increase in temperature, the soil respiration rate has also been a corresponding increase in plant growth during the period of soil respiration was significantly the highest. Figure 2. shows that in August, the higher soil respiration rate is higher because the soil respiration rate decreases with decreasing temperature at the end of the growing season.

Compared with the control plot, the soil respiration rate under the warming was more fluctuant in the seasonal dynamics, and the average value under the warming condition was  $6.34 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ . The average value of the control was  $5.77 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ . The results showed that there was no significant difference in soil respiration rate between different treatments ( $p > 0.05$ ).



C: control plots; W:experimental warming

**Figure 2.** Monthly variation of soil respiration ( $R_s$ ) rate of Tibetan Kobayashi in XiaoPo Lake wetland

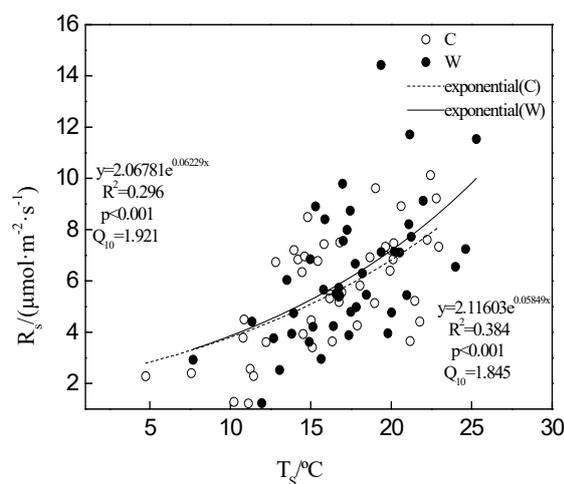
### 3.3. The relationship between soil respiration rate and external environmental factors

**3.3.1. Soil respiration rate and soil temperature correlation.** The relationship between soil respiration rate and soil temperature was fitted using the exponential model  $y = ae^{bt}$  (Figure 3.), and the size of  $Q_{10}$  was calculated by the formula  $Q_{10} = e^{10b}$ . The results showed that the correlation between soil temperature and soil respiration rate was significantly higher ( $p < 0.001$ ); While the correlation between soil temperature and soil respiration rate under warming treatment was also significantly correlated ( $p < 0.001$ ). Therefore, the correlation between soil respiration rate and soil temperature was the best ( $R^2 = 0.384$ ), indicating that the soil temperature under control treatment could explain 38.4% soil respiration. It can be seen from Figure 3. that the fitting effect of the exponential equation in the control is better than that at the time of warming. Because the temperature is high, the soil respiration rate of scattered points gradually diverge, indicating that the temperature is no longer a limiting factor.

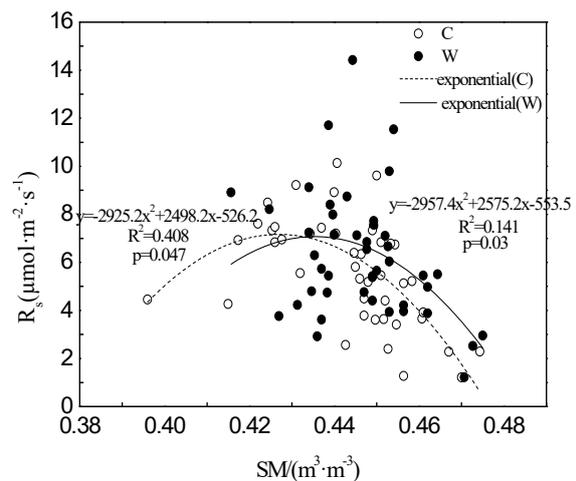
$Q_{10}$  values are commonly used to indicate the degree of sensitivity of soil respiration to temperature changes, that is, the rate of change in soil respiration rate for every  $10^\circ\text{C}$  rise. The soil  $Q_{10}$  value was 1.845, and the soil  $Q_{10}$  value after simulated temperature increase was 1.921. The results show that the change of soil respiration rate to temperature is more sensitive than the soil respiration rate under the

control.

**3.3.2. Soil respiration rate and soil volume water content.** Soil water content is an important factor affecting soil respiration rate, which regulates soil CO<sub>2</sub> emissions. The difference between soil respiration rate and soil water content can be described by linear or quadratic curve equation. In this experiment, the fitting effect of the first quadratic equation  $y = aW^2 + bW + c$  is the best (Fig. 4). The results showed that the soil moisture under the control treatment could explain 40% soil respiration, and the soil moisture under the warming treatment could explain 14% soil respiration.



**Figure 3.** Correlation between soil respiration ( $R_s$ ) rate and soil temperature ( $T_s$ )



**Figure 4.** Relationship between soil respiration ( $R_s$ ) rate and soil moisture (SM)

In this experiment, the relationship between soil water content and soil respiration rate was studied by partial correlation analysis, in order to eliminate the effect of soil temperature, because there was a close relationship between soil temperature and soil respiration rate. The results showed that there was a significant positive correlation between soil water content and soil respiration rate ( $p=0.047$ ), and there was a significant positive correlation between soil water content and soil respiration rate ( $p=0.03$ ). It can be seen from the P value that the relationship between the two treatments is more relevant than that of the control treatment.

## 4. Discussion

### 4.1. OTC warming situation

OTC for field long-term monitoring test, can make the test sample soil conditions are basically not destroyed [13]. The open roof growth chamber, as an ideal heating device, is considered to be an effective tool for simulating global warming [14] and has been widely used in various simulated warming experiments [15]. Beier [16] showed that the minimum temperature of the soil in the warming plot was 0.4 ~ 1.2 °C higher than that of the control plot, and the law of global warming could be simulated. In this study, the total mean value of soil temperature increased by 1.37 °C compared with the control during the simulated experiment in May-August 2016, which was in accordance with the law of global warming.

### 4.2. Temperature sensitivity of soil respiration ( $Q_{10}$ )

Zheng [17] found that the  $Q_{10}$  value of soil respiration ranged from 1.28 to 4.75, and the soil  $Q_{10}$  value

was 1.845 in the study. The soil  $Q_{10}$  value after simulated warming was 1.921. The results of this study were in the range within. Pan [18] studies have shown that soil respiration is very sensitive to the initial soil temperature rise, short-term warming will promote soil respiration. In this study, it was found that the temperature sensitivity of soil respiration at the growth scale was higher than that of the control treatment, but no significant difference was observed. Compared with the control, the soil respiration rate was higher than that of the control, and the  $Q_{10}$  value was higher, which indicated that the soil could release more  $CO_2$  in the atmosphere with the increase of temperature in the future trend of global warming.

#### *4.3. Effects of simulated warming on soil respiration rate*

Soil respiration includes soil animal respiration, soil biological respiration and plant root respiration, which is a relatively complex soil ecology process. Bergner [19] have shown that warming can promote soil respiration. Bai [20] found that warming will increase the alpine meadow soil respiration rate. In this study, the diurnal variation of soil respiration was consistent with the monthly variation trend. Under the warming condition, the soil respiration rate was higher than that in the natural state, and the average temperature was  $6.34 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ , the average of the control was  $5.77 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ . Because the warming can enhance the activity of soil microbes [21]. Due to the high water content in the alpine meadow ecosystem, the temperature during the growing season is also low, so the temperature becomes the main limiting factor [22], so warming will promote alpine meadow soil respiration.

In this experiment, the soil respiration rate increased with the increase of soil temperature under the control and warming treatments, and it had the most significant exponential correlation, which was the same as that of Zhou [23]. There was a strong correlation between soil temperature and soil respiration rate. In this experiment, in order to eliminate the interference of soil temperature on soil respiration rate, the relationship between soil water content and soil respiration rate was studied by partial correlation analysis. The results showed that there was a significant correlation between the control and the warming treatment ( $p < 0.05$ ). The secondary linear equation explained the control, and the soil respiration was 40% and 14% respectively. The correlation between soil water content and soil respiration was significantly lower than that of soil temperature, so the soil water content was lower than that of soil temperature, and the soil temperature was still the main controlling factor. This is due to the abundant rainfall in the XiaoPo Lake area, high soil moisture, and difficult to control the soil respiration. Therefore, the soil temperature is the main limiting factor affecting the soil respiration in this region.

## **5. Conclusion and outlook**

(1) The soil respiration rate was significantly increased under the short-term warming treatment, and the diurnal variation and the monthly variation showed that the soil respiration was significantly larger than that of the night.

(2) Short-term warming treatment will promote soil respiration, and temperature sensitivity under the warming treatment is greater than the control treatment. The change of soil respiration rate to temperature is more sensitive than the soil respiration rate under the control.

(3) Soil temperature may be a major limiting factor affecting soil respiration in the region in areas with adequate rainfall.

In order to increase the reliability of the measurement, we should focus on the soil respiration in different seasons and typical weather in the future. Because the influencing factors of soil respiration are complicated, soil organisms and substrates will affect the respiration in different degrees. Therefore, weather and different seasons combined with soil respiration to strengthen the study.

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