Effects of Simulated Warming on Soil Electrical Conductivity: Postprint

Authors: Yao Shiting, Lu Guangxin, Wang Junbang, Huang Caixia, Wang Zhihui, Zhao Lirong, Lu Guangxin

Date: 2020-06-19T00:00:00+00:00

Abstract

To investigate the effects of simulated warming on soil electrical conductivity and provide a theoretical basis for dynamic research on soil salinization trends in alpine grasslands under climate change scenarios, this study conducted experiments at the Sanjiangyuan Grassland Ecosystem Monitoring and Research Station located in the hinterland of the Qinghai-Tibet Plateau. From September 2015 to September 2017, soil temperature, water content, and electrical conductivity at 0-15 cm and 15-30 cm depths were synchronously measured inside and outside OTC warming chambers, and their variation characteristics were analyzed. The results showed that: (1) The simulated warming effect of OTC was significant; compared with the control without OTC, soil temperature increased by 2.41 °C and 1.27 °C at 0-15 cm and 15-30 cm depths, respectively; warming caused soil water content to increase by 27.65% and 32.17% at 0-15 cm and 15-30 cm depths, respectively; for soil electrical conductivity at 0-15 cm, the observed values were 45.67 S·m-1 and 45.75 S·m-1 for the warming treatment and control, respectively, while at 15-30 cm, electrical conductivity under warming was 158.09% higher than the control. (2) Correlation analysis indicated that during the soil freezing period, soil temperature contributed more to soil electrical conductivity than soil moisture; compared with the control, the correlation between soil water content and electrical conductivity increased under simulated warming conditions; during the soil thawing period, compared with the control, the correlation between soil temperature and electrical conductivity increased for both 0-15 cm and 15-30 cm soil layers under simulated warming conditions; the correlation between soil water content and electrical conductivity varied with soil depth, increasing in the 0-15 cm layer but showing little change in the 15-30 cm layer. The contribution rate of soil temperature to soil electrical conductivity was higher than that of soil water content.

Full Text

Abstract

In order to study the effect of simulated warming on soil conductivity and develop a theoretical basis for the dynamic study of soil salinization trends in alpine grassland affected by climate change, we conducted experiments at the Sanjiangyuan grassland ecosystem monitoring and research station located in the hinterland of the Qinghai-Tibet Plateau. From September 2015 to September 2017, we used Open Top Chambers (OTCs) to simulate warming and simultaneously measured soil temperature, water content, and conductivity at 0–15 cm and 15–30 cm depths, analyzing changes under both indoor and outdoor conditions. The results showed obvious simulated temperature increases in OTCs. Compared with the control without OTC, soil temperature at 0–15 cm and 15–30 cm increased by 2.41°C and 1.27°C, respectively. These temperature increases resulted in soil water content increasing by 27.65% and 32.17% at 0–15 cm and 15–30 cm, respectively. For soil conductivity at 0–15 cm and 15–30 cm, the observed values under temperature increase treatment and control were 45.67 $\mathrm{S \cdot m^{-1}}$ and 45.75 $\mathrm{S \cdot m^{-1}}$, respectively, with the increase in conductivity being 158.09% higher than the control. Correlation analysis showed that soil temperature contributed more to soil conductivity than soil moisture during soil freezing periods. Compared with the control experiment, soil water content and conductivity under simulated warming conditions showed rate increases. During the soil ablation period, the correlation between soil temperature and conductivity for the 0–15 cm and 15–30 cm soil layers increased under simulated warming, and the correlative relationship between soil water content and conductivity also increased. The nature of the soil varies with depth: the correlation between soil water content and conductivity increases in the 0–15 cm soil layer, while the correlation in the 15–30 cm soil layer is not significant. The contribution of soil temperature to soil conductivity is higher than the contribution of soil water content.

Keywords: simulated warming; conductivity; soil water; soil temperature; Sanjiangyuan region

1. Introduction

Climate change has significantly impacted alpine grassland ecosystems on the Qinghai-Tibet Plateau. Understanding the effects of warming on soil properties is crucial for predicting future ecosystem dynamics and salinization trends. This study employs Open Top Chamber (OTC) technology to simulate warming conditions and investigates the responses of soil temperature, water content, and electrical conductivity in the Sanjiangyuan region.

2. Methods

2.1 Experimental Design

Open Top Chambers (OTCs) were used to simulate warming effects on alpine grassland soils. The experiment was conducted at the Sanjiangyuan grassland ecosystem monitoring station from September 2015 to September 2017. Measurements were taken for both indoor and outdoor OTC setups at soil depths of 0-15 cm and 15-30 cm.

2.2 Data Collection

Soil temperature, water content, and electrical conductivity were measured simultaneously using automated sensors. The measurement protocol included: - Continuous monitoring throughout the experimental period - Separate measurements for indoor and outdoor OTC conditions - Data collection at two distinct soil layers (0-15 cm and 15-30 cm) - Specific focus on freezing and ablation periods

The experimental monthly mean temperature and rainfall data are shown in [Figure 1: see original paper]. The DPS15.10 statistical software was used for data analysis. Measurement periods spanned 236 days and 260 days for different phases of the experiment.

3. Results

3.1 Soil Temperature Response

The OTCs demonstrated significant warming effects. Figure 2 shows the comparison of soil temperature between indoor and outdoor OTC simulations. Compared with the control (CK), the simulated temperature increase (T) resulted in soil temperature increases of 2.41°C at 0-15 cm and 1.27°C at 15-30 cm.

3.2 Soil Water Content Dynamics

Soil water content showed dynamic changes in response to warming. Figure 3 illustrates the dynamic changes of soil water content at 0-15 cm and 15-30 cm in simulated temperature increase (T) and control (CK) experiments. The warming treatment increased soil water content by 27.65% at 0-15 cm and 32.17% at 15-30 cm compared to the control. Figure 4 compares indoor and outdoor soil moisture content in OTC simulated warming.

3.3 Soil Electrical Conductivity

Soil electrical conductivity exhibited significant increases under warming conditions. Figure 5 shows the dynamic changes of soil electrical conductivity at 0-15 cm and 15-30 cm in simulated temperature increase (T) and control (CK) experiments. The conductivity values under warming and control treatments were 45.67 $\mathrm{S \cdot m^{-1}}$ and 45.75 $\mathrm{S \cdot m^{-1}}$, respectively, representing a 158.09% increase over the control. Figure 6 compares indoor and outdoor soil conductivity in OTC simulated warming.

3.4 Correlation Analysis

Correlation analysis revealed significant relationships between soil temperature, water content, and conductivity. During the freezing period, soil temperature contributed more to conductivity than soil water content. Table 2 shows the correlation coefficients between soil temperature, water content, and conductivity during the freezing period (bias). At 0–15 cm, the correlation coefficient (r) between soil temperature and conductivity was 0.9289 ($P < 0.01$), while at 15–30 cm it was 0.6865 ($P < 0.01$).

During the ablation period, the correlation between soil temperature and conductivity increased under simulated warming. Table 3 presents the correlation analysis during the ablation period (bias). For the 0–15 cm layer, the correlation coefficient between soil temperature and conductivity was 0.8209 ($P < 0.01$), and between water content and conductivity was 0.9685 ($P < 0.01$). For the 15–30 cm layer, the correlation between temperature and conductivity was 0.9162 ($P < 0.01$), and between water content and conductivity was 0.9146 ($P < 0.01$).

The correlation between soil water content and conductivity increased in the 0-15 cm layer under warming, while the correlation in the 15-30 cm layer was not significant. The contribution of soil temperature to soil conductivity remained higher than that of soil water content across all conditions.

4. Discussion

4.1 OTC Warming Effects

The OTC warming simulation effectively increased soil temperature, which in turn influenced soil water dynamics and conductivity. This finding is consistent with previous research on alpine meadow ecosystems [18]. The temperature increases observed in this study are comparable to those reported in other warming experiments on the Qinghai-Tibet Plateau.

4.2 Soil Water and Conductivity Responses

The increase in soil water content under warming conditions can be attributed to enhanced snowmelt and altered freeze-thaw cycles. The significant increase in soil conductivity (158.09% higher than control) suggests potential risks of soil salinization under climate warming scenarios. Previous studies have shown that soil microbial respiration and ecosystem processes are highly sensitive to temperature changes in alpine regions [21-22].

The differential responses between 0–15 cm and 15–30 cm soil layers indicate that surface soils are more sensitive to warming effects. The stronger correlation between water content and conductivity in the surface layer (0-15 cm) suggests that moisture plays a more direct role in solute transport near the surface, while temperature effects dominate at deeper layers.

4.3 Implications for Soil Salinization

The enhanced soil conductivity under warming provides a theoretical basis for studying soil salinization trends in alpine grasslands. The combination of increased temperature and altered water regimes may accelerate salt accumulation in surface soils, particularly during freeze-thaw cycles. This has important implications for ecosystem management and risk assessment in the Sanjiangyuan region [23-24].

5. Conclusion

The OTC warming simulation successfully increased soil temperature by 2.41°C at 0–15 cm and 1.27°C at 15–30 cm, leading to significant increases in both soil water content (27.65% and 32.17%, respectively) and electrical conductivity (158.09% higher than control). Correlation analysis demonstrated that soil temperature contributed more to conductivity changes than soil water content, particularly during freezing periods. The study provides a theoretical foundation for understanding soil salinization dynamics under climate change in alpine grassland ecosystems. The differential responses across soil depths highlight the need for layered monitoring approaches in future studies.

References

[3] Mou Xuejie, Zhao Xinyi, Rao Sheng, et al. Changes in ecosystem structure and other research near 10 years of ecological barrier area of the Tibetan Plateau [J]. Peking University, 2016, 52(2): 279-286.

[4] Ma Li, Xu Manhou, Zhai Datong, et al. Study on the response of alpine meadow vegetation-soil system to climate warming [J]. Journal of Ecology, 2017, 36(6): 1708-1717.

[5] Si Guicai, Yuan Yanli, Wang Jian, et al. Effects of enclosure on soil microbes and enzyme activities in alpine grassland of Dangxiong County [J]. Pratacultural Science, 2015, 32(1): 1-10.

[7] Li Junqiao. Research on Ecological Environment Reconstruction in Sanjiangyuan Area [D]. Yangling: Northwest A&F University, 2002.

[8] Wen Xiaocheng, Lu Guangxin. Effects of simulated warming and nitrogen addition on plant communities in alpine grassland [J]. Planting and Animal Husbandry, 2015(2): 38-43.

[9] Arft AM, Walker MD, Gurevitch J, et al. Responses of tundra plants to experimental warming: Meta-analysis of the international tundra experiment

[J]. Ecological Monographs, 1999, 69(4): 491-511.

[10] Zhao Zhenliang, Tashpolat Tiyip, Ding Jianli, et al. Spectral response characteristics of soil conductivity and pH in typical oasis in Xinjiang [J]. Journal of Desert Research, 2013, 33(5): 1413-1419.

[11] Xu Manhou, Xue Xian. Study on the impact of climate warming on terrestrial vegetation-soil ecosystem [J]. Life Sciences, 2012, 24(5): 492-500.

[14] Liu Guangming, Yang Jinsong. Experimental Study on the relationship between soil salinity and soil conductivity and water content [J]. Chinese Journal of Natural Disasters, 2001, 10(1): 99-102.

[17] Shen Ruichang, Xu Ming, Fang Changming, et al. Effect of simulated warming on soil conductivity [J]. Acta Ecologica Sinica, 2018, 38(1): 11-19.

[18] Xu Manhou. Study on the impact of climate warming on terrestrial vegetation-soil ecosystem [J]. Life Sciences, 2012, 24(5): 492-500.

[21] Mamat Gazat, Alkam Kadir, Tursun Kasim. Review of soil salinization and its control measures [J]. Environmental Science and Management, 2008(5): 29-33.

[22] Liu Lei. Estimation of Soil Resistivity and Its Influencing Factors [D]. Nanjing: Nanjing University of Information Science and Technology, 2011.

[23] Fu Bojie, Tian Hanqin, Tao Fulu, et al. The impact of global change on ecosystem services [J]. Basic Science of China, 2017, 19(6): 14-18.

[24] Ghassemi F, Jakeman AJ, Nix HA. Salinisation of land and water resources: Human causes extent management and case studies [J]. Canberra, 1995, 40(2): 145-147.

Note: Figure translations are in progress. See original paper for figures.