Postprint: Soil Carbon Emission Characteristics of Five Desert Shrub Species in the West Ordos Plateau

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Abstract

To further identify the main controlling factors of soil carbon emissions from five natural desert shrublands in the western Ordos Plateau region, estimate shrubland soil carbon emissions, and elucidate the carbon emission characteristics of different shrubland soils, five typical desert shrub forests were selected as study objects. Soil respiration rates, soil temperature and moisture, and carbon emissions of the five shrublands were measured using the soil carbon flux ACE (automated soil CO exchange station) monitoring system. The results showed that: (1) The diurnal dynamics of soil carbon emission rates from the five shrublands generally exhibited an asymmetric bell-shaped unimodal curve pattern, with peaks occurring between 11:30 and 13:30. The soil carbon emission rates during the growing season were significantly higher than those during the non-growing season for all five shrublands, with Helianthemum songaricum shrubland being 0.76–1.67 times higher than the other shrublands. The annual average carbon emissions from soils were 8090.63 kg · hm ^{2} · a ^{1} for Ammopiptanthus mongolicus shrubland, 7868.16 kg · hm ^{2} · a ^{1} for Tetraena mongolica shrubland, 7287.40 kg · hm ^{2} · a ^{1} for Zygophyllum xanthoxylum shrubland, 8375.69 kg · hm ^{2} · a ^{1} for Helianthemum songaricum shrubland, and 7618.47 kg · hm ^{2} · a ^{1} for Reaumuria soongarica shrubland; (2) Under three future climate scenarios (low emission scenario B1, medium emission scenario A1B, and high emission scenario A2), soil carbon emissions from the five shrublands would be up to 8.30% higher than the baseline scenario, with Zygophyllum xanthoxylum shrubland showing the most pronounced changes. The responses of soil carbon emissions from different shrubland types to temperature variations differed, but the differences were not significant. This study can provide a data foundation and reference basis for carbon balance estimation in arid and semi-arid regions of northwestern China under global environmental change.

Full Text

Carbon Emission of Five Desert Shrub Soils in the West Ordos Plateau Region

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Abstract

For more accurate estimation of soil carbon emissions from five desert shrub forests and a clearer understanding of their impacting factors in the West Ordos Plateau, soil CO emissions and the main environmental factors of five desert shrub forests were studied using an Automated Soil CO Exchange Station. The results showed that the daily variation of soil carbon emission rate displayed a single-peak curve, with the maximum rate occurring between 11:30 and 13:30. The monthly soil carbon emission rate during the growing season (May to July) was much higher than that in the non-growing season (October). *Helianthemum songaricum* exhibited the highest emissions, with the maximum rate in the growing season being 0.76–1.67 times higher than the minimum in the non-growing season. The annual average soil carbon emission rates were 8 090.63 kg · hm ^{2} · a ^{1} for *Ammopiptanthus mongolicus*, 7 287.40 kg · hm ^{2} · a ^{1} for *Zygophyllum xanthoxylum*, 7 868.16 kg · hm ^{2} · a ^{1} for *Tetraena mongolica*, 8 375.69 kg · hm ^{2} · a ^{1} for *Helianthemum songaricum*, and 7 618.47 kg · hm ^{2} · a ^{1} for *Reaumuria songarica*. Under three future climate scenarios (low-emission scenario B1, intermediate-emission scenario A1B, and high-emission scenario A2), soil carbon emissions from the five desert shrub forests are expected to increase by 8.30% compared to the baseline scenario, with *Zygophyllum xanthoxylum* being the most temperature-sensitive. While differences existed in the response of soil carbon emissions to temperature change across different shrub forests, these differences were not statistically significant. This research provides basic data and references for carbon balance estimation in arid and semi-arid regions of northwest China under global environmental change.

Keywords: soil; desert shrub; carbon emission rate; climate scenarios; West Ordos

1. Introduction

Soil respiration is a critical component of terrestrial ecosystem carbon cycling and a major pathway for soil carbon loss. Previous studies have investigated soil respiration in various ecosystems, including grasslands [9–10], forests [11], and agricultural systems [12]. However, research on soil carbon emissions from desert shrub ecosystems remains limited, particularly regarding the response of different shrub species to environmental changes. The West Ordos Plateau represents a typical arid region where desert shrubs play a vital role in maintaining ecological stability. Understanding the patterns and drivers of soil carbon emissions in these ecosystems is essential for accurately assessing regional carbon budgets and predicting responses to climate change.

2. Materials and Methods

2.1 Study Area The study was conducted in the West Ordos Plateau region (approximately 106°44 E). The area is characterized by an arid climate with sparse vegetation cover dominated by five desert shrub species: *Ammopiptanthus mongolicus*, *Zygophyllum xanthoxylum*, *Tetraena mongolica*, *Helianthemum songaricum*, and *Reaumuria songarica*.

2.2 Experimental Design and Measurements Soil CO fluxes were measured using an Automated Soil CO Exchange Station. Measurements were taken during both the growing season (May–July) and non-growing season (October). Soil respiration rates were monitored continuously with a temporal resolution of 30 minutes. Soil temperature and moisture were measured concurrently at a depth of 5 cm.

2.3 Data Analysis Statistical analyses were performed using SPSS 17.0 and SAS 9.0 software. One-way ANOVA was used to test for significant differences in soil carbon emissions among different shrub types and across seasons. Significance was determined at $p < 0.05$.

3. Results

3.1 Daily Variation in Soil Carbon Emissions The daily variation in soil carbon emission rates exhibited a distinct single-peak curve for all five shrub species, with maximum emissions occurring between 11:30 and 13:30. This pattern aligns with diurnal temperature fluctuations, indicating strong temperature dependence of soil microbial activity and root respiration.

3.2 Seasonal Variation in Soil Carbon Emissions Monthly soil carbon emission rates during the growing season (May–July) were substantially higher than those in the non-growing season (October). *Helianthemum songaricum* showed the highest seasonal amplitude, with growing-season maxima 0.76–1.67

times greater than non-growing-season minima. The pronounced seasonal difference reflects the combined effects of temperature, moisture, and plant phenology on soil respiration processes.

3.3 Annual Soil Carbon Emission Rates The annual average soil carbon emission rates varied among shrub species: - *Ammopiptanthus mongolicus*: 8 090.63 kg · hm ^{2} · a ^{1} - *Zygophyllum xanthoxylum*: 7 287.40 kg · hm ^{2} · a ^{1} - *Tetraena mongolica*: 7 868.16 kg · hm ^{2} · a ^{1} - *Helianthemum songaricum*: 8 375.69 kg · hm ^{2} · a ^{1} - *Reaumuria songarica*: 7 618.47 kg · hm ^{2} · a ^{1}

3.4 Future Climate Scenario Projections Under three IPCC climate scenarios (B1, A1B, and A2), soil carbon emissions from the five desert shrub forests are projected to increase by 8.30% on average compared to baseline conditions. *Zygophyllum xanthoxylum* demonstrated the highest temperature sensitivity, with emission increases of 8.03%, 8.20%, and 8.30% under B1, A1B, and A2 scenarios, respectively. Other species showed similar but slightly lower responses: *Ammopiptanthus mongolicus* (6.66%, 6.72%, 6.77%), *Tetraena mongolica* (6.61%, 6.74%, 6.81%), *Helianthemum songaricum* (5.86%, 5.93%, 5.98%), and *Reaumuria songarica* (5.84%, 5.99%, 6.07%). Although interspecific differences in temperature response were observed, they were not statistically significant.

4. Discussion

The observed daily and seasonal patterns of soil carbon emissions are consistent with previous studies in arid ecosystems [30, 32]. The temperature sensitivity of soil respiration in desert shrub ecosystems has important implications for carbon cycling under global warming. The projected 8.30% increase in emissions under future climate scenarios suggests that these ecosystems may become net carbon sources, particularly if warming exceeds 2°C. However, the lack of significant differences among shrub species indicates that community composition may be less important than environmental factors in controlling soil carbon fluxes at the regional scale. These findings provide essential baseline data for regional carbon balance models and highlight the need for long-term monitoring to validate climate change projections.

5. Conclusion

This study quantified soil carbon emissions from five dominant desert shrubs in the West Ordos Plateau and assessed their responses to future climate scenarios. The results demonstrate significant temporal variation and moderate temperature sensitivity, providing a scientific basis for carbon budget estimation in arid and semi-arid regions of northwest China under global environmental change.

References

[1] Fang JY, Zhu JL, Wang SP, et al. Global warming, human-induced carbon emissions, and their uncertainties. Science China Earth Sciences, 2011, 54(10): 1458–1468.

[2] Yu L, Pu S. Key scientific points on carbon and other biochemical cycles from the IPCC fifth assessment report. Progressus Inquisitiones De Mutatione Climatis, 2014, 10(1): 33–36.

[3] Singh JS, Gupta SR. Plant decomposition and soil respiration in terrestrial ecosystems. The Botanical Review, 1977, 43(4): 449–528.

[4] Zhang D, Shi P, Zhang X. Some advances in the main factors controlling soil respiration. Advances in Earth Science, 2005, 20(7): 778–785.

[9] Yu H, Huang J. Research progress of influence of mulching gravel and sand on soil macropore characteristics and soil hydrological progress. Research of Soil and Water Conservation, 2012, 19(4): 284–288.

[10] Bao F, Zhou G. Review of research advances in soil respiration of grassland in China. Acta Phytoecologica Sinica, 2010, 34(6): 713–726.

[11] Chen S, Liu Q, Hu Z, et al. Factors influencing the spatial variability in soil respiration under different land use regimes. Environmental Science, 2013, 34(3): 1017–1025.

[12] Raich JW, Tufekciogul A. Vegetation and soil respiration: Correlations and controls. Biogeochemistry, 2000, 48(1): 71–90.

[13] Tang JW, Baldocchi DD. Spatial-temporal variation in soil respiration in an oak-grass savanna ecosystem in California and its partitioning into autotrophic and heterotrophic components. Biogeochemistry, 2005, 73(1): 183–207.

[14] West NE, Stark JM, Johnson DW, et al. Effects of climatic change on the edaphic features of arid and semiarid lands of western North America. Arid Soil Research and Rehabilitation, 1994, 8(4): 307–351.

[19] Hanson PJ, Edwards NT, Garten CT, et al. Separating root and soil microbial contributions to soil respiration: A review of methods. Soil Biology and Biochemistry, 2000, 32(11): 1627–1638.

[22] IPCC. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2007.

[23] Liu Y, Ouyang H, Cao G, et al. Soil carbon emission from ecosystem of eastern Qinghai-Tibet plateau. Journal of Natural Resources, 2001, 16(2): 152–160.

[24] Li Y, Zhao L, Pu S, et al. Floristic characteristics of vascular plants in west Ordos. Journal of Desert Research, 2012, 32(2): 428–436.

[25] Xia B, Si Z. Soil respiration and impact factors of different green plants in Zhengzhou City. Research of Soil and Water Conservation, 2017, 24(5): 240-246.

[26] Tang H, Ma H, Su Y, et al. Carbon emission and carbon absorption of different land use types in Xinjiang. Arid Zone Research, 2016, 33(3): 486-492.

[27] Li W, Sun J, Sha Y, et al. Carbon emission and its influence factors of subalpine forest soil in Southwest China. Transactions of the Chinese Society of Agricultural Engineering, 2015, 31(1): 255-263.

[28] Niu Y, Li Y, Gong X, et al. The characteristics of net ecosystem carbon exchange and the contribution of soil respiration during the growing season in sandy grassland. Chinese Journal of Ecology, 2017, 36(9): 2423-2430.

[30] Ma W, Zhao C, Peng S, et al. Variation in soil respiration rate and its influencing factors under five vegetation types in Tianlaoshi catchment in Heihe River. Acta Ecologica Sinica, 2015, 35(17): 5654-5665.

[32] Noy-Meir I. Structure and function of desert ecosystems. Israel Journal of Botany, 1979, 28(1): 1-19.

[33] Xu L, Baldocchi DD, Tang J. How soil moisture, rain pulses, and growth alter the response of ecosystem respiration to temperature. Global Biogeochemical Cycles, 2004, 18(4): 1-10.

[34] Lusk B, Vander Kamp J. Carbon sequestration potential of reclaimed desert soils in Egypt. Soil, 2009.

[35] Updegraff K, Bridgham SD, Pastor J, et al. Response of CO and CH emissions from peatlands to warming and water table manipulation. Ecology Applications, 2011, 11(2): 311-326.

[36] Xia JY, Niu SL, Wan SQ. Response of ecosystem carbon exchange to warming and nitrogen addition during two hydrologically contrasting growing seasons in temperate steppe. Global Change Biology, 2009, 15(6): 1544-1556.

[37] Lin X, Zhang Z, Wang S, et al. Response of ecosystem respiration to warming and grazing during the growing seasons in the alpine meadow on the Tibetan plateau. Agricultural and Forest Meteorology, 2011, 151(7): 792-802.

[38] Melillo JM, Steudler PA, Aber JD, et al. Soil warming and carbon-cycle feedbacks to the climate system. Science, 2002, 298(5601): 2173-2176.

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