Science Bulletin 65 (2020) 431–433

Contents lists available at ScienceDirect

Science Bulletin

journal homepage: www.elsevier.com/locate/scib

Short Communication

Taklimakan desert carbon-sink decreases under climate change

Fan Yang [a,b], Jianping Huang [a,c,*], Chenglong Zhou [b], Xinghua Yang [b], Mamtimin Ali [b], Chaofan Li [d], Honglin Pan [b], Wen Huo [b], Haipeng Yu [a], Xiaoyue Liu [a], Xinqian Zheng [e], Dongliang Han [a], Qing He [f], Lu Meng [b], Jun Chang [a]

[a] College of Atmospheric Sciences, Lanzhou University, Lanzhou 730000, China
[b] Taklimakan Desert Meteorology Field Experiment Station of CMA, Institute of Desert Meteorology, China Meteorological Administration (CMA), Urumqi 830002, China
[c] Collaborative Innovation Center for Western Ecological Safety, Lanzhou University, Lanzhou 730000, China
[d] Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disaster, School of Geographic Sciences, Nanjing University of Information Science and Technology, Nanjing 210044, China
[e] Xinjiang Agro-Meteorological Observatory, Urumqi 830002, China
[f] Xinjiang Meteorological Bureau, Urumqi 830002, China

A R T I C L E I N F O

Article history:
Received 4 December 2019
Received in revised form 18 December 2019
Accepted 20 December 2019
Available online 31 December 2019

© 2019 Science China Press. Published by Elsevier B.V. and Science China Press. All rights reserved.

The global carbon balance is a core issue in climate change research and a focus of international policy concern [1–3]. The “missing carbon sink” caused by approximately 1.6–2.0 Pg C a^{-1} (1 Pg = 10^{15} g) that is currently unaccounted for, has long plagued researchers [4,5]. Evidence is mounting those seemingly lifeless desert ecosystems, whose roles in the global carbon-cycle have long been neglected, exhibit the unconventional phenomenon of absorption of atmospheric CO_2, sequestering enormous amounts of CO_2 and thereby creating a significant carbon-sink [6–9]. This scenario appears to help narrow the gap in the missing carbon-sink. However, this view has been questioned for the inaccurate carbon sequestration location [10]. The effects of abiotic processes, such as soil temperature gradient, moisture content, parent material, salt/alkali, and pH, on desert CO_2 exchange, have gradually revealed that the phenomenon of a desert carbon-sink is intimately associated with abiotic processes [11]. Thus far, the main processes, whereby, deserts act as carbon-sinks may include the following: (1) variation in the volume of gases caused by changes in pressure and temperature; (2) changes in solubility of CO_2 in soil water films; (3) pH-mediated CO_2 dissolution chemistry; and (4) surface adhesion of CO_2 onto soil minerals [11–13]. In ecosystems with relatively high productivity, the effects of abiotic processes on CO_2 exchange are often neglected because of strong biological respiration. In desert ecosystems, however, the effects of abiotic processes on CO_2 exchange cannot be ignored, although the CO_2 flux is extremely weak. The effects of abiotic processes are even greater than the effects of biological processes [11,14]. The latest research indicates that the absorbed CO_2 gradually, enters the desert groundwater layer by the process of leaching, and eventually converge in the underground saline water layer under the vast desert with the groundwater movement. This process is similar to the inorganic carbon sinks in the ocean [9].

The Taklimakan Desert (TD) is the world’s second-largest shifting desert and plays a vital role in the carbon-sink properties of desert ecosystems. Benefit by the abundant saline-alkali groundwater and extensive salinization, the TD has a huge carbon storage capacity. However, there is uncertainty regarding the magnitude of the contribution made by each internal process towards the TD carbon-sink; and how these processes will respond to climate change.

The TD land surface mainly consists of continuous shifting sand cover, which shows the high homogeneity of this desert. Therefore, the hinterland of the TD can be considered the most representative research area in this desert. In the hinterland of the TD, through a combination of partitioning (dealkalization/desalination, sterilization, and drying) and temperature-controlled experiments, we found that the contribution of various shifting sand components to the total CO_2 flux in the shifting sand is strongly linked to soil temperature. The soil temperature difference between depths of 0 and 10 cm and the rate of soil temperature change at a depth of 10 cm are the two main factors driving CO_2 exchange in the shifting sand. Besides, we obtained the contribution of the CO_2 fluxes of various components in the TD shifting sand (Fig. 1a). Comparing demonstrate that the expansion/contraction of soil air containing CO_2 caused by heat fluctuation in shifting sand provides an unexpectedly strong contribution towards total CO_2 exchange. This long-hidden process in combination with salts/alkali

* Corresponding author.
E-mail address: hjp@lzu.edu.cn (J. Huang).

https://doi.org/10.1016/j.scib.2019.12.022
2095-9273/© 2019 Science China Press. Published by Elsevier B.V. and Science China Press. All rights reserved.

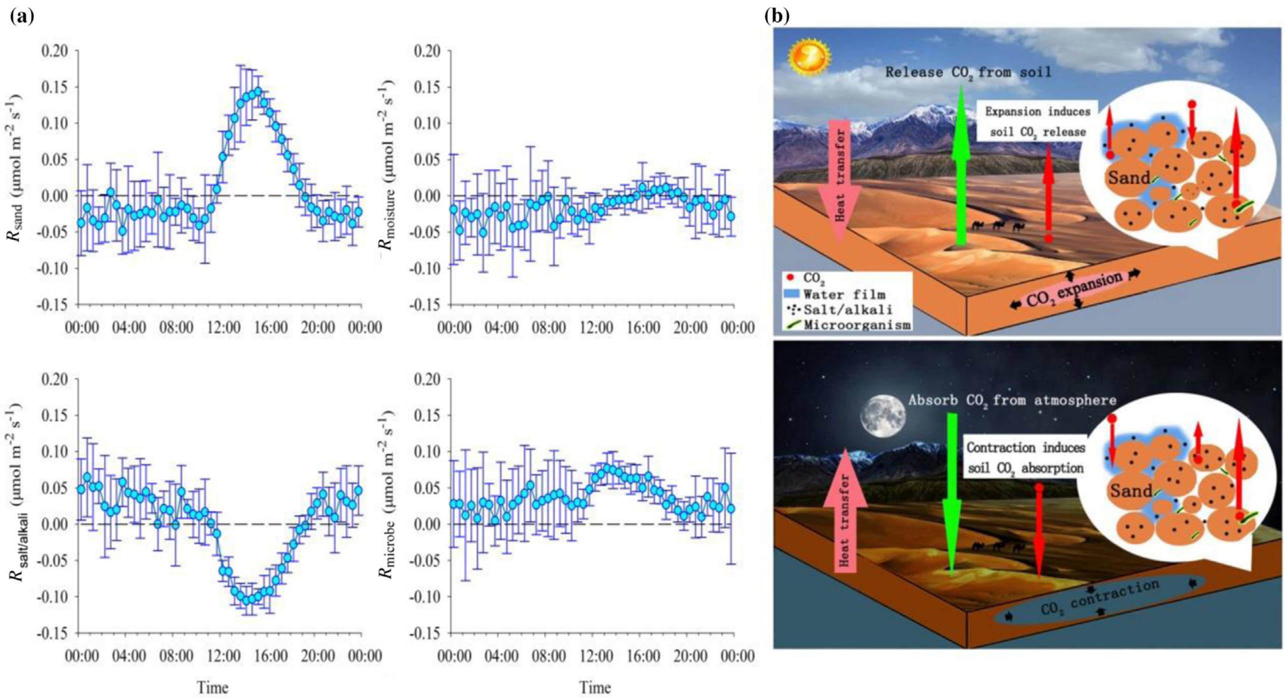

Fig. 1. Contributions of various shifting sand components to the daily dynamic of the total CO_2 flux in Tazhong shifting sand of the TD. (a) The diurnal contributions of various shifting sand components are shown for R_{sand}, $R_{moisture}$, $R_{salt/alkali}$, and $R_{microbe}$, respectively. Error bars represent standard deviations. (b) Overview of various processes of CO_2 exchange in the TD shifting sand. During the day, the surface temperature of shifting sand rapidly increases from sunrise, and heat is gradually transmitted to the lower layers of shifting sand. CO_2 in the pores between the sand particles expands due to this transmitted heat, resulting in CO_2 being released to the atmosphere. As the soil temperature increases and moisture evaporates, CO_2 in the water film of the sand is gradually released into the atmosphere. The chemical action of salts/alkalis promotes atmospheric CO_2 absorption. Microbes cause the release of CO_2 into the atmosphere through decomposition. In the night, the previously heated shifting sand experiences a rapid temperature reduction, and the expanded soil air in shifting sand pores also rapidly contracts. This process causes CO_2 to enter the shifting sand. Increased moisture on the surface of shifting sand causes CO_2 to dissolve in the sand water film. The chemical action of salts/alkalis promotes CO_2 release into the atmosphere. The contribution of microbes is similar to but weaker than that during the day.

chemistry dominates the release and absorption, respectively, of CO_2 in shifting sand (Fig. 1b).

Through the close relationships between CO_2 flux and soil temperature, combined with historical soil temperature data in the study area at 0 and 10 cm every hour between 2004 and 2017, we estimated the total amount of CO_2 exchange per year in the TD shifting sand (Fig. 2). An average of 6.71×10^6 t of CO_2 per year was released to the atmosphere through the physical process of thermal expansion of soil air containing CO_2 in the TD shifting sand during 2004–2017. Besides, the combined action of the remaining components (salt/alkali + moisture + microbes) led the TD shifting sand to absorb atmospheric CO_2, with an average absorption rate of 8.31×10^6 t a^{-1} during 2004–2017. These release and absorption

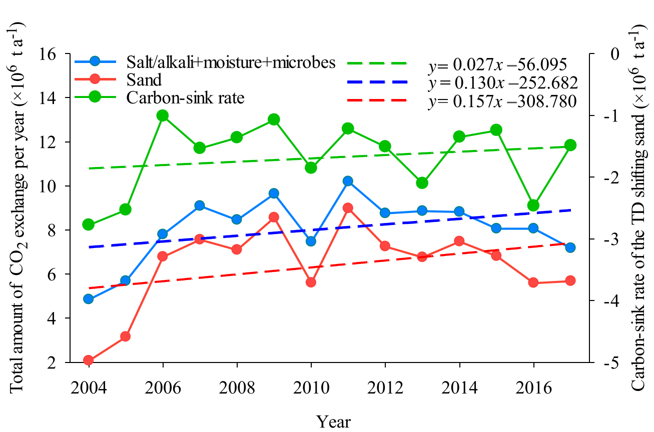

Fig. 2. Temporal variation in the total amount of CO_2 exchange per year for 2004–2017 in the TD shifting sand.

processes together caused the surface of the TD shifting sand to exhibit a clear and stable carbon-sink effect, with an annual carbon-sink rate of 1.60×10^6 t a^{-1} for 2004–2017. The absorbed CO_2 gradually, enters the groundwater layer by the process of leaching, and eventually converge in the underground saline water layer under the vast desert with the groundwater movement. This process is similar to the inorganic carbon sinks in the ocean [7,9]. The TD shifting sand presents huge potential carbon storage capacity, which attributed to the combined effects including about 8 trillion cubic meters of groundwater in the TD and the extensive salinization caused by intense evaporation. The TD shifting sand represents only a small percentage (~0.747%) of global desert areas. If all global deserts are considered, and the Taklimakan readings represent an average uptake state, then the global shifting desert maybe sequesters ~2.125×10^8 t of CO_2 per year. Therefore, the status of desert ecosystems in the global carbon cycle cannot be arbitrarily ignored. Although this cannot completely resolve the problem of the "missing carbon sink", at least it can help to narrow the gap in the "missing carbon sink". However, the total amount of CO_2 released through the thermal expansion of soil air containing CO_2 increased between 2004 and 2017, at a greater rate than that of CO_2 absorption, pumping more CO_2 into the atmosphere. This process eventually, caused an annually weakening trend in the carbon-sink effect of the TD shifting sand.

Desert ecosystems, seemingly lifeless and long-neglected, have quietly played an important role in the global carbon cycle. Our findings will help in accurately identifying the effects and status of the TD on the global carbon cycle. As an example of the role played by deserts, however, a gradual reduction in the carbon-sink properties of the TD shifting sand will place more urgent demands on future responses to climate change.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

This work was jointly supported by the Second Tibetan Plateau Scientific Expedition and Research Program (2019QZKK0602), the National Natural Science Foundation of China (41521004, 41975010 and 41175140) and the China University Research Talents Recruitment Program (B13045).

Author contributions

Jianping Huang, Fan Yang and Chenglong Zhou designed the study and contributed to the ideas, data analysis, interpretation and manuscript writing. All of the authors contributed to the discussion and interpretation of the manuscript. All of the authors reviewed the manuscript.

Appendix A. Supplementary materials

Supplementary materials to this article can be found online at https://doi.org/10.1016/j.scib.2019.12.022.

References

[1] Schlesinger WH, Andrews JA. Soil respiration and the global carbon cycle. Biogeochemistry 2000;48:7–20.
[2] Houghton RA. Balancing the global carbon budget. Annu Rev Earth Planet Sci 2007;35:313–47.
[3] Piao SL, Fang JY, Ciais P, et al. The carbon balance of terrestrial ecosystems in China. Nature 2009;458:1009–13.
[4] Houghton RA, Davidson EA, Woodwell GM. Missing sinks, feedbacks, and understanding the role of terrestrial ecosystems in the global carbon balance. Glob Biogeochem Cycle 1998;12:25–34.
[5] Fang JY, Piao SL, Zhao SQ. The carbon sink: the role of the middle and high latitudes terrestrial ecosystems in the northern hemisphere. Chin J Plant Ecol 2001;25:594–602 (in Chinese).
[6] Stone R. Have desert researchers discovered a hidden loop in the carbon cycle? Science 2008;320:1409–10.
[7] Ma J, Liu R, Tang LS, et al. A downward CO_2 flux seems to have nowhere to go. Biogeosci Discuss 2014;11:6251–62.
[8] Ma J, Wang ZY, Stevenson BA, et al. An inorganic CO_2 diffusion and dissolution process explains negative CO_2 fluxes in saline/alkaline soils. Sci Rep 2013;3:2025.
[9] Li Y, Wang YG, Houghton RA, et al. Hidden carbon sink beneath desert. Geophys Res Lett 2015;42:5880–7.
[10] Schlesinger WH. An evaluation of abiotic carbon sinks in deserts. Glob Change Biol 2017;23:25–7.
[11] Parsons AN, Barrett JE, Wall DH, et al. Soil carbon dioxide flux in Antarctic dry valley ecosystems. Ecosystems 2004;7:286–95.
[12] Fa KY, Liu JB, Zhang YQ, et al. CO_2 absorption of sandy soil induced by rainfall pulses in a desert ecosystem. Hydrol Process 2014;29:2043–51.
[13] Fa KY, Zhang YQ, Wu B, et al. Patterns and possible mechanisms of soil CO_2 uptake in sandy soil. Sci Total Environ 2016;544:587–94.
[14] Shanhun FL, Almond PC, Clough TJ, et al. Abiotic processes dominate CO_2 fluxes in Antarctic soils. Soil Biol Biochem 2012;53:99–111.

Fan Yang is an associate professor in Institute of Desert Meteorology, China Meteorological Administration, Urumqi, and a Ph.D. candidate in College of Atmospheric Sciences, Lanzhou University. His current research interests mainly focus on the formation mechanism of desert carbon-sink and the response of desert carbon-sink to climate change.

Jianping Huang is a professor in College of Atmospheric Sciences and a director of Collaborative Innovation Center for Western Ecological Safety, Lanzhou University. He has long been dedicating to the study of dust-cloud interaction and semi-arid climate change by combining field observations and theoretical study. He and his team established the theoretical framework of semi-arid climate change by accomplishing a series of fundamental and influential original research.