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Carbon Cycle in the Changing Arid Land of China

Yanqi Basin and Bosten Lake

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ISSN 2197-9596 ISSN 2197-960X (electronic)
Springer Earth System Sciences
ISBN 978-981-10-7021-1 ISBN 978-981-10-7022-8 (eBook)
https://doi.org/10.1007/978-981-10-7022-8

Library of Congress Control Number: 2018932193

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Foreword

This book, “Carbon cycle in the changing arid land: Yanqi Basin and Bosten Lake,” comes at a time when countries are seriously looking for ways to offset CO_2 emissions. Arid and semiarid regions make up about one-third of the Earth’s land surface, yet these drylands are generally overlooked as places for carbon sequestration because (1) soil organic carbon is low compared to more humid soils and (2) soil inorganic carbon is widely considered to be an inert carbon reservoir rather than an active pool that can be manipulated by land management techniques.

This book provides examples suggesting that soil inorganic carbon is more dynamic and complicated than traditionally thought. In addition, readers of this book will learn about carbon in the interesting geological and climatic setting of northwest China. Perhaps its most important contribution, this book can stimulate carbon research in rangeland and irrigated agricultural settings in other arid land regions of the world.

Las Cruces, USA

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The Carbon Cycle in Yanqi Basin and Bosten Lake: Introduction

Xiujun Wang, Jiaping Wang, Zhitong Yu and Juan Zhang

1 Introduction

The rate of carbon dioxide (CO_2) build-up in the atmosphere depends on the rate of fossil fuel combustion and the rate of CO_2 uptake by the ocean and the land. About half of the anthropogenic CO_2 has been absorbed by the land and the ocean, the so-called sinks for CO_2. The efficiency of the global CO_2 sinks has been observed to change on seasonal to interannual and longer timescales, due to a variety of mechanisms that are not fully understood. Many of the mechanisms are not yet quantitatively defined either at regional or global scales.

The global soil carbon pool is the third largest pool in the Earth system, thus plays an important role in the global carbon cycle and climate system. Soil carbon pool consists of two components, soil organic carbon (SOC) and inorganic carbon (SIC). Soil organic carbon, as a key index for soil fertility and a means for carbon sequestration, has gained recognition. In contrast, much less has been done to determine the magnitude and variability of SIC and to understand SIC dynamics although scientists pointed out its potential for carbon sequestration and climate mitigation (Eshel et al. 2007; Lal and Kimble 2000; Zheng et al. 2011). To date, there is a large discrepancy in the estimated global SIC pool, which ranges from <700 to >1700 Pg (see Eswaran et al. 2000).

The SOC pool is the predominant carbon pool in soils of humid and semi-humid regions, whereas SIC is the most common form of carbon in soils of arid and semiarid zone. More than 35% of Earth's land surface is characterized as either arid or semiarid, where SIC content is 2–10 times as high as SOC content (Scharpenseel et al. 2000).

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X. Wang et al. (eds.), *Carbon Cycle in the Changing Arid Land of China*,
Springer Earth System Sciences, https://doi.org/10.1007/978-981-10-7022-8_1

In this regard, accurately estimating SIC at all scales is essential to evaluate the role of soils in the global carbon cycle (Yang and Li 2011). Moreover, attempts to decrease the atmospheric CO_2 concentration require better understanding of transformation of both SOC and SIC and regulating processes in different soils (Mikhailova and Post 2006; Monger and Gallegos 2000; Zheng et al. 2011).

2 Studies in Yanqi Basin

The arid and semiarid regions have experienced significant climate changes and human activity over the past decades. Climate change (e.g., warming) may have large impacts on the carbon cycle in desert ecosystem (Arnone et al. 2008; Verburg et al. 2005). There has been a significant increase in both temperature (Chen et al. 2009; Liu et al. 2005) and precipitation (Wang and Zhou 2005) in the northwest China over the past 50 years, with implications for the terrestrial ecosystem and carbon cycle (Liu et al. 2009). In addition, there is an increasing trend in growing season for the entire Xinjiang (Jiang et al. 2011). There is also evidence of land use and climate change impacts on SOC and SIC in the northwest China (Wu et al. 2003, 2009). However, there have been limited studies that apply an integrated approach to assess the impacts of climate change and land use changes on the carbon cycling at a regional scale in arid lands.

The news of "Have desert researchers discovered a hidden loop in the carbon cycle" (Stone 2008) prompted a focused effort to better understand the carbon cycle in the atmosphere–plant–soil systems in the arid land of northwest China. A few studies have yielded collections of a variety of datasets, including approximately 60 years of climate and hydrological data, nearly 40 profiles of SOC and SIC under various land uses, and seasonal variations of CO_2 efflux and soil CO_2 concentration at different depths in the Yanqi Basin. In addition, a study was carried out to investigate the spatial and temporal variations of OC and IC burials in Bosten Lake. These datasets provide basic information of key hydrological and biogeochemical processes in association with the carbon sequestration in the arid region. On the other hand, these data can also be used for carbon model calibration and validation for the arid region.

This book reports the studies conducted in the Yanqi Basin and Bosten Lake, which aim to better understand the carbon cycle in the arid lands. The first two chapters provide basic information for the region and motivations for the studies. Chapter 3 reports the analyses of climate variables (temperature, precipitation and runoff) over the period of 1960–2014. Chapters 4–9 are the outcomes of core studies on the carbon cycle, which include the distributions of carbon and nitrogen under different vegetation/crops (Chap. 4), the dynamics of soil CO_2 concentration and surface CO_2 efflux in agricultural soil (Chap. 5), the dynamics of SOC and SIC and their isotopes under various land uses (Chap. 6), pedogenic carbonate and its relationship with SOC (Chap. 7), and the spatial and temporal variations in carbon burial in the Bosten Lake (Chaps. 8 and 9). The last chapter is a mini review, which summarizes the main findings from relevant studies, and also discusses the implications and future directions.

3 Significance of These Studies

A comprehensive evaluation of both SOC and SIC stocks in soils/sediments is important to achieve a better understanding of the carbon cycle in the coupled atmosphere–biosphere–pedosphere system. The carbon cycle in the arid and semiarid lands has to deal with the dynamics of inorganic carbon. To date, most studies of the terrestrial carbon cycle have largely focused on SOC pool and atmosphere–land CO_2 fluxes, and our understanding is limited in terms of variability and underlying mechanisms. Apparently, we need data collections of various forms of carbon (e.g., SOC and SIC contents, soil CO_2 concentration and surface CO_2 efflux, and OC and IC in sediments) to understand the variability of carbon fluxes in the atmosphere–biosphere–pedosphere systems in the arid lands.

In summary, the outcomes of these studies will help answer the following important scientific questions: (1) **where does the carbon go if a significant amount of CO_2 is absorbed by surface soils in arid regions?** (2) **how do environmental changes impact the carbon cycle in the arid and semiarid lands?** Answers to these questions will provide insights of the carbon sinks/sources and their variability in the arid and semiarid regions, but also improve our understanding of the carbon cycle at regional to global scales.

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Introduction of the Yanqi Basin and Bosten Lake

Changyan Tian, Lei Zhang and Shuai Zhao

Abstract The Yanqi Basin is formed on the basement of the Kuruktag fold belt and the southern Tianshan fold belt and located in the inland region of the Central Asia and in the transition zone between the Junggar Basin and the Tarim Basin. The Yanqi Basin is a typical arid region with extremely low precipitation (<100 mm/year) but strong evaporation (>2000 mm/year). The main soil types are brown desert soil and alluvial soil, which were developed from limestone parent materials. Land use types/coverages include cropland, shrubland, and desert land. The basin has access to water resources from the Kaidu River and underground waters, which are mainly from melting snows in the Tianshan Mountain. Bosten Lake is the largest freshwater lake in Xinjiang, which is the final converging place for the surface water and groundwater in the Yanqi Basin. Its main inflow water is from the Kaidu River on the west, and outflow is from the Kongque River on the southwest.

1 Geographical Position

Yanqi Basin (85° 50′–87° 50′E, 41° 40′–42° 20′N) is located in the region of Bayingolin Mongol Autonomous Prefecture, Xinjiang, Northwest China (Fig. 1), and this basin belongs to the Kaidu River–Kongque River watershed. It is a Mesozoic rift basin between the main ridge and the branch ridge of the Tianshan Mountain; thus, it is also a kind of semi-enclosed intermontane basin. It lies at an altitude of 1048–1160 m, spanning an area of 5600 km^2 (Kou et al. 2008).

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X. Wang et al. (eds.), *Carbon Cycle in the Changing Arid Land of China*,
Springer Earth System Sciences, https://doi.org/10.1007/978-981-10-7022-8_2

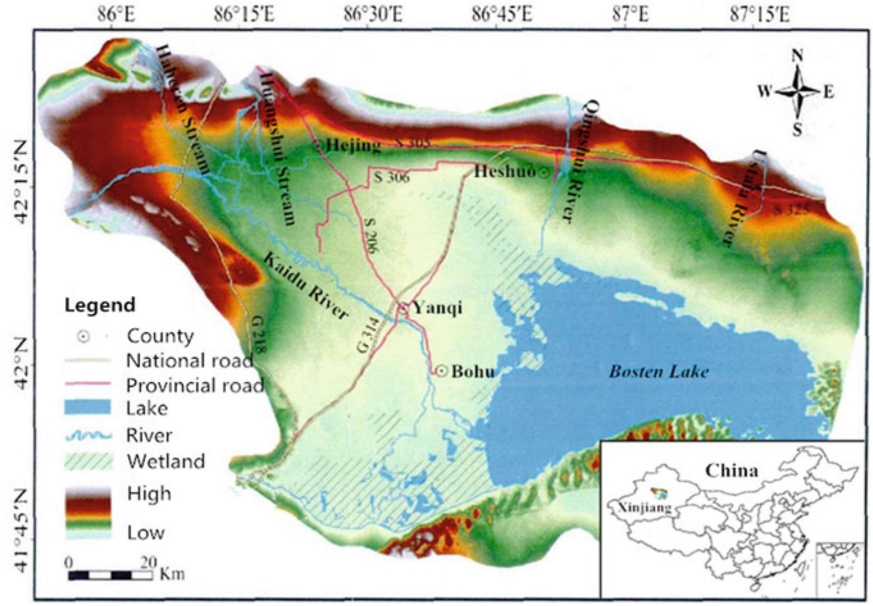

Fig. 1 Geographical position of Yanqi Basin (after Mamat Zulpiya 2014)

2 Geologic Landforms

2.1 Geology

The Yanqi Basin is known as a Mesozoic–Cenozoic basin, which is formed on the basement of the Kuruktag fold belt and the southern Tianshan fold belt. Its southern boundary is the Xingeer fault, borders Kuluketage mountain; its northern boundary is the Sangshuyuanzi fault, borders Saaerming mountain; its western boundary is the Tiemenguan fault, borders Huola mountain; its eastern boundary is the Kezile mountain. According to the distribution of Mesozoic and Cenozoic strata in the basin, its geometric structure can be divided into three tectonic units: Bohu depression in the south, Yanqi uplift in the middle, and Hejing depression in the north.

It has been found that the main sedimentary layers were formed in the middle-lower Jurassic Series, Neogene System, Paleogene System, and Quaternary System. The layers from the middle and middle-low Jurassic System consist of several coal seams and dull mudstone; the layers from the Neogene System consist of thick brick-red mudstone and argillaceous siltstone, which exist as stable areal cap rocks.

In the plain area of central basin, sediments were mainly formed in the Quaternary System and classified as diluvial deposit, alluvial–diluvial deposit, alluvial deposit, and/or alluvial–lacustrine deposit. The lithologic characters of diluvial plain and alluvial–diluvial plain exhibit a single thick layer structure in which only