Sci. Bull.
DOI 10.1007/s11434-015-0736-9

www.scibull.com
www.springer.com/scp

Article

Earth Sciences

Primary estimation of Chinese terrestrial carbon sequestration during 2001–2010

Qiufeng Wang · Han Zheng · Xianjin Zhu · Guirui Yu

Received: 23 October 2014 / Accepted: 15 December 2014

Abstract Quantifying the carbon budgets of terrestrial ecosystems is the foundation on which to understand the role of these ecosystems as carbon sinks and to mitigate global climate change. Through a re-examination of the conceptual framework of ecosystem productivity and the integration of multi-source data, we assumed that the entire terrestrial ecosystems in China to be a large-scale regional biome-society system. We approximated the carbon fluxes of key natural and anthropogenic processes at a regional scale, including fluxes of emissions from reactive carbon and creature ingestion, and fluxes of emissions from anthropogenic and natural disturbances. The gross primary productivity, ecosystem respiration and net ecosystem productivity (NEP) in China were 7.78, 5.89 and 1.89 PgC a^{-1}, respectively, during the period from 2001 to 2010. After accounting for the consumption of reactive carbon and creature ingestion (0.078 PgC a^{-1}), fires (0.002 PgC a^{-1}), water erosion (0.038 PgC a^{-1}) and agricultural and forestry utilization (0.806 PgC a^{-1}), the final carbon sink in China was about 0.966 PgC a^{-1}; this was considered as the climate-based potential terrestrial ecosystem carbon sink for the current climate conditions in China. The carbon emissions caused by anthropogenic disturbances accounted for more than 42 % of the NEP, which indicated that humans can play an important role in increasing terrestrial carbon sequestration and mitigating global climate change. This role can be fulfilled by reducing the carbon emissions caused by human activities and by prolonging the residence time of fixed organic carbon in the large-scale regional biome-society system through the improvement of ecosystem management.

Keywords Gross primary productivity · Net ecosystem productivity · Ecosystem respiration · Carbon sink · ChinaFLUX

1 Introduction

Terrestrial ecosystems, as sinks of atmospheric CO_2 [1], play an important role in mitigating global climate change [2, 3]. The Intergovernmental Panel on Climate Change (IPCC) identified the objectives and the mechanisms of controlling the global greenhouse gases and provided guidance on the emission reduction targets for countries at different stages of development [4]. Therefore, it is not only an important part of ecosystem and global climate change science [5–7], but also the major scientific and technological outline to fulfill the United Nations Framework Convention on Climate Change and to enhance the management of global and national greenhouse gases [8], to quantify the global and national terrestrial ecosystem productivity and the use and allocation of carbon in a variety of carbon pools or ecological processes, and to

SPECIAL TOPIC: Land-ocean integrated research and development of carbon sink

Q. Wang · H. Zheng · X. Zhu · G. Yu (✉)
Synthesis Research Center of Chinese Ecosystem Research Network, Key Laboratory of Ecosystem Network Observation and Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
e-mail: yugr@igsnrr.ac.cn

H. Zheng
University of Chinese Academy of Sciences, Beijing 100049, China

assess the spatial patterns and dynamics of terrestrial ecosystem carbon source/sink relationships at a regional scale.

The parameters that characterize the ecosystem productivity and carbon budget components include gross primary productivity (GPP), net primary productivity (NPP), net ecosystem productivity (NEP), net biome productivity (NBP), ecosystem respiration (ER), autotrophic respiration of plants (Ra), heterotrophic respiration of microorganisms (Rh) and respiration of biomes (Rb).

Based on the processes of material production, carbon sequestration, and carbon use and consumption in natural ecosystems, Chapin et al. [5] discussed the logical relationships between GPP and its transformations (e.g., NPP, NEP and NBP) after various types of carbon use and consumption (ER, Ra, Rh and Rb) [5, 9], which provided a useful theoretical framework for the quantitative evaluation of ecosystem productivity, carbon budget components, and spatiotemporal patterns of carbon source/sinks at a regional scale [8].

In recent years, on the basis of the conceptual framework of Chapin et al. [5], the observational techniques and assessment methods to determine the productivity (GPP, NPP, NEP, NBP) and respiration (ER, Ra, Rh, Rb) at different spatial and temporal scales have developed and improved rapidly [5, 10]. Currently, the methods used in the determination of ecosystem productivity and the evaluations of the carbon budget at different spatial and temporal scales include eddy covariance [11], resource inventory [12, 13], airborne laser scanning [14], remote sensing evaluation based on resource satellite observations [15], remote sensing inversion of carbon satellites [16, 17], geographical statistical modeling [18, 19], analysis based on process-based models [20–22] and atmospheric inversion [23, 24]. These technologies have improved continually with their own appropriate spatiotemporal scales, and researchers have also performed meta-analyses based on multi-source data from different approaches [25, 26]. Additionally, comprehensive assessments were conducted on the ecosystem productivity or carbon source/sinks at national, continental and global scales by data-model fusion [7, 27, 28].

Results will be different when different methods are used to assess the productivity of the same region or the world [29]. For example, regional NEP measured by eddy covariance [28] was significantly higher than the value estimated by the inventory method [30]. Researchers' understanding on the results obtained from different methods affect their evaluation of the ecological implications of their results. This is associated with the relaxed definitions of related concepts as well, e.g., ecosystem productivity, carbon storage, carbon loss, and carbon leakage, at different spatial and temporal scales [8]. Thus, Yu et al. [8] redefined the ecological meaning and the conceptual framework for terrestrial ecosystem productivity and different carbon fluxes at regional scales, and preliminarily determined the appropriate spatiotemporal scales and boundary conditions for various observational and assessment methods. This provided a more comprehensive conceptual framework and methodology system for quantifying ecosystem productivity, the carbon cycle and terrestrial carbon sinks at regional scales.

Based on the new conceptual framework proposed by Yu et al. [8] and multi-source data at different spatial and temporal scales, we quantified terrestrial ecosystem productivity and the distribution and consumption of carbon in a variety of ecological processes. The magnitude of the carbon source/sink in China was then approximated. The results provided reference information for the evaluation and analysis of the status of the terrestrial ecosystem carbon budget and for the potential increment of a carbon sink in China. The information can also be used as the important basis for decision-making analyses on carbon management in China.

2 Conceptual framework

Steffen et al. [31] and Chapin et al. [5] defined the relationships among GPP, NPP, NEP and NBP by integrating the driving mechanisms in forming productivity of large-scale regional biome-society system with the changes in carbon storage caused by various natural and anthropogenic disturbances, as well as the characteristics of terrestrial ecosystem carbon exchange at different spatial and temporal scales. In this analysis, based on the conceptual framework proposed by Yu et al. [8] and the biologically controlled processes and the spatiotemporal characteristics of carbon cycle in various natural ecosystems, we reconstructed the processes that affect productivity in a large-scale regional biome-society system that was influenced by natural and anthropogenic factors. The relationships of organic carbon distribution and consumption within different carbon pools and ecological processes were refined (Fig. 1), and then, we defined the ecological meaning of carbon source/sinks at different scales using the evaluation and data acquisition methods for the total regional amounts.

On basis of Fig. 1, we assumed that the entire terrestrial ecosystems in China were a large-scale regional biome-society system. By integrating multi-source data, the carbon fluxes of four key processes were quantified, including carbon fluxes of major natural processes in ecosystems, fluxes of emissions from reactive carbon and creature ingestion, carbon emissions caused by anthropogenic disturbances and the carbon losses caused by natural disturbances.