



**CHEN Xi General Chief Editor**

Series on "Ecosystem Assessment and Management of Arid Region in Central Asia"

# **MODELING DRYLAND ECOSYSTEMS' RESPONSE TO GLOBAL CHANGE IN CENTRAL ASIA**

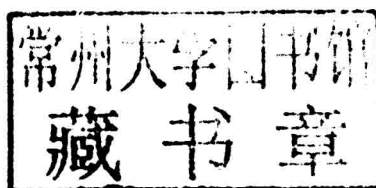
Compiled by CHEN Xi, ZHANG Chi, LUO Geping



**China Meteorological Press**

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## ABSTRACT

The book is a review of the information on climate change, ecosystem carbon cycle and other research areas in arid area of Central Asia.

The book consists of eight chapters, describing the spatial and temporal variation and the internal mechanism of the climate, land use and ecosystem in arid area of Central Asia.

The book is rich in content and informative, and has a rigorous system, and contains a lot of new ideas and contents. We believe that this book will be interesting to the researchers engaged in arid area of Central Asia and teachers and students in related fields in colleges and universities.

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## MODELING DRYLAND ECOSYSTEMS' RESPONSE TO GLOBAL CHANGE IN CENTRAL ASIA

Compiled by CHEN Xi, ZHANG Chi, LUO Geping

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## Preface One

Since industrial revolution, global climate changes such as global warming became serious environmental problems. Central Asia locates in the center of Eurasia Continent, far from oceans, having an arid climate. The interactive effects from the westerly, the arctic high latitude air mass, and the humid airflow from the Indian Oceans result in strong variation in temperature and humidity, frequent outbreak of climate extreme events in the region. The regional ecosystem is fragile and sensitive to global change. Researches showed that the surface temperature in Central Asia increased quickly in the last one hundred years. In average, the regional temperature increased by  $0.74^{\circ}\text{C}/\text{century}$ , much higher than the global mean warming rate. This caused steady shrinkage of the Tianshan and Altai mountain's glaciers, whose area has reduced by about 15%—30% in the recent 40 years, resulting in significant changes in the regional hydrological, agricultural and ecological systems.

Ecological and Environmental problems are the all-time concerns to the governments of Central Asia countries. Ecological disasters in Central Asia—for example, the Aral Sea crisis further draws international attention. The United Nation, the Shanghai Cooperation Organization (SCO), and Chinese government all initiated counteracting projects to solve the problem. In the September of 2011, the SCO published a Joint Communiqué to Promote Ecological Conservation in Central Asia. Studying global change and its effects on Central Asia ecosystem and the solution is especially important for protecting the international ecological/economic security and development in the region of Central Asia and China. It also promotes technological cooperation against climate change among the SCO members.

The “Ecosystem Assessment and Management of Arid Region in Central Asia” book series compiled studying results of more than one hundred scientists from 40 institutes both in China and abroad. It is the product of the first large scale resource and environmental cooperation among the SCO members. The series assesses the fundamental patterns in climate, geography, and ecological changes in Central Asia. Being the first Chinese publications that address the

issue in scientific details, this series has important research and application value for understanding the responses and adaptations of Central Asia ecosystems to global change as well as ecological conservation in the region. It also provides reference value for the development of Silk Road Economic Belt.

A handwritten signature in black ink, reading "Dahe Qin". The signature is written in a cursive, flowing style.

(QIN Dahe)

December 4, 2013

## Preface Two

Xinjiang of China and the Central Asia make the main body of the Eurasia dryland. Being the largest temperate desert ecosystem, it accounts for 90% of global temperate desert. The unique mountain-oasis-desert ecosystem has global importance. Climate of the Eurasia dryland is mainly controlled by the westerly, the arctic high latitude air mass, and the humid airflow from Indian Ocean, showing a heat-water combination distinct from that of the Africa, America, and Australia, resulting in unique and complex ecological responses to global climate change. Meanwhile, evolution of the regional vegetation is influenced by the Central Asia flora system, the Tibet flora system, the Mongolia flora system, and the Tethys flora system, especially sensitive to changes in temperature and moisture.

The ecosystem in Central Asia is fragile. Climate change and human disturbances could easily induce significant changes in ecosystem or even cause severe ecological disasters. In addition, there are many cross-country rivers among Xinjiang and Central Asia countries, who share the same ecosystem. Any local ecological changes could readily result in international-level ecological issues. For example, the gradual diminishment of the Aral Sea in Central Asia has evolved into a world famous cross-nation ecological disaster in the region. Changes in temperature and precipitation in the recent years resulted in big uncertainties in the regional ecosystem's responses to global change, and more frequent climate extreme events. Therefore, make serious efforts on ecosystem change and ecological management researches under the context of global change is important to both regional ecosystem protection and socioeconomic sustainability in Central Asia.

In 2012, my team member and I investigated the Balkhash Lake basin and the Aral Sea basin, and were impressed by the eagerness of the Central Asia countries' in ecosystem protection and recovery. Findings from more than three-year's researches by more than one hundred scientists from Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan and from eighteen research institutes in China were agglomerated in the "Ecosystem Assessment



and Management of Arid Region in Central Asia”book series, which is the first systematic research report of the world on ecosystem assessment and management in this region. This series made comprehensive assessments on the changes in climate, flora, fauna, soil, and land cover in Central Asia, and proposed suggestions on ecosystem management in Central Asia. With authentic and detailed data and documents, clear conclusions, this series has important values in both scientific research and applications. It is especially important for biodiversity conservation and ecological security. It also promotes the ecological and environmental cooperation among the Shanghai Cooperation Organization member countries.

A handwritten signature in black ink, reading "Fu Bojie". The signature is stylized with a large, sweeping horizontal stroke underneath the name.

(FU Bojie)

December 5, 2013

## Preface Three

Intensified human activity since industrial revolution has resulted in rapid global changes in climate, atmosphere, and land use. Understanding the impacts of global changes on terrestrial ecosystem is important for the maintenance of global ecosystem and human civilization. Experiments and model simulations have been designed to study the mechanisms of a wide variety of factors on the terrestrial ecosystem. Large uncertainties, however, still exist due to the complex negative or positive feedbacks among different components in earth system. Many environmental factors, like the increases in temperature and alterations in precipitation patterns have both positive and negative impacts on ecosystem carbon sequestration. Furthermore, the ecosystems' responses to realistic combinations of global changes are not necessarily simple interactions of responses induced by individual factors. Another major factor contributing to this complexity is the inherent heterogeneity of the landscape at spatial scales ranging from microns to thousands of kilometers.

It has become clear from experience that no single experimental approach to elucidating ecosystem dynamic is sufficient to predict responses over all time and space scales. Accurate predictions of ecosystem responses to suites of global change factors, therefore, depend on successful integration across a range of processes and time scales. The large number of possible combinations and long period over which they operate, however, make it nearly impossible to investigate the effects of multiple stresses on ecosystem carbon storage through controlled experiments. Integrated process-based ecosystem models, which include the physiological responses of ecosystems to atmospheric and climate changes can be quite useful in such multiple stress studies.

Dryland covers 1/3 of global land surface. Being an important land cover type, it was characterized by dry soil surface, higher albedo, and fragile ecosystems. Central Asia is one of the most fragile and over-exploited land in the world. With massive environmental problems, the ecosystem sustainability of this area has drawn attention from governments and scientists from all over the world. In the context of global changes, Central Asia dryland has experienced significant warming in the last century. It also more experienced more frequent extreme climate events such as prolonged drought or flooding,

which could have important impacts on ecosystem structures and functions in this arid region. Despite a few site level or watershed scale researches, the ecosystems' responses to climate changes and land-use change in Central Asia are still unclear at the regional level. A comprehensive and systematic large-scale study on this dryland is still not available.

The book *Modeling Dryland Ecosystem' Response to Global Change in Central Asia* describes in detail the development of several process-based models that were applied to study ecosystem responses to global changes in Central Asia, including a microscale aerodynamic model based on which the eddy covariance technique were developed, a modified biogeochemical model to simulate land use management in Central Asia, an arid ecosystem model (AEM) that emphasizes on the typical ecosystem processes in Central Asia dryland, and a upgraded version of AEM that includes the vegetation dynamic processes and nitrogen cycles. The book is divided by three parts. Part I introduces the background of the study region, ecosystem models, and describes several process models that have been used in ecosystem study in Central Asia; Part II introduces the environmental changes including changes in climate and land use patterns in Central Asia. It also described the geographical, soil, and vegetation constrains on ecosystems in Central Asia. Part III includes several case studies that assess the dryland ecosystems' responses to global changes in Central Asia at both site and regional scales.

Publication of this book is supported by the national & international science and technology cooperation project—"A joint investigation and research for the ecological protection and resource management in Central Asia area in the context of climate change" (2010DFA92720-9 and 2010DFA92720-10), sponsored by the National Ministry of Science and Technology, and the Chinese Academy of Sciences. It cannot be achieved without the cooperation between scientists from China and the Central Asia countries and the unremitting efforts of all involved researchers. Their contributions are acknowledged hereby.

CHEN Xi

September 15, 2014

## Series Foreword

With a typical continental arid climate, Central Asia is located in the hinterland of the Eurasian continent, accounting for 1/3 of the world's dryland area. In a broad sense, Central Asia lies in the Asian hinterland region and stretches from the Caspian Sea in the west, including the five Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan and Turkmenistan) and western China, Mongolia, Russia, Afghanistan, and parts of Iran. More commonly, the term often refers to the five Central Asian countries that cover about 4 million km<sup>2</sup> land area and have a population size of 58.9 million.

Central Asia is sensitive to the global climate change that has strong influence to the region's ecology and environment, which has always been one of the major concerns and hot research topic by Central Asian governments as manifested by the summit of the Shanghai Cooperation Organization. Research shows long-term temperature rise accompanied with steady glaciers retreat in the Tianshan and Altai mountains since the early 20th century in Central Asia. During the past 40 years, the glaciers have shrunk by 15% – 30%, which resulted in changes in the regional hydrological system, agricultural system and ecological system. Meanwhile, several anthropogenic environmental problems such as the Aral Sea ecological crisis caused by large-scaled land reclamation in the early 20th century have drastically worsen ecological conditions and resources in this region. Therefore, researches on the resources and environmental problems in Central Asia in the context of global climate change is important for the environmental protection and improvement as well as sustainable society and economy developments, and will provide scientific support for the ecological protection and resource exploitation of the Shanghai Cooperation Organization member states.

In 2010, the Ministry of Science and Technology, China established a national and international science and technology cooperation project—"A joint investigation and research for the ecological protection and resource management in Central Asia area in the context of climate change(2010DFA92720)"; the State Administration of Foreign Experts Affairs, Chinese Academy of Sciences (CAS), initiate an innovation team project—"Transect Research on Central Asia's Ecosystem (KZCX2-YW-T09)"; the United Nations Development Programme supported a new project "Enhancing Climate Change Adaptive

Capacity via Strengthening Ecological System Management in Central Asian Arid Area(0076478)". All of these projects were organized by the Technology Department of Xinjiang Uygur Autonomous Region, led by Xinjiang Institute of Ecology and Geography Chinese Academy of Sciences, and leagued 17 domestic scientific research institutions, including Xinjiang University, Xinjiang Agricultural University, Xinjiang Normal University, Xinjiang Academy of Agricultural Sciences, Xinjiang Academy of Forestry Science, Animal Science Academy of Xinjiang Uygur Autonomous Region, Xinjiang Academy of Social Sciences, Central Asia Technology Economic Information Center, Xinjiang Institute of Desert, Xinjiang Remote Sensing Center, Science and Technology Information Center of Central Asia, Institute of Geographic Sciences and Natural Resources Research, CAS, Nanjing Institute of Geography Limnology, CAS, Cold and Arid Regions Environmental and Engineering Research Institute, CAS, Shenzhen Institute of Advanced Technology, CAS, The Institute of Remote Sensing and Digital Earth, CAS, Zhejiang University, and Lanzhou University. There are 26 institutions from the Central Asia countries participated in the project, including Kazakhstan Institute of Soil and Agricultural Chemistry, Kazakhstan Institute of Botany, Kazakhstan Institute of Zoology, Kazakhstan Institute of Geography, Kazakhstan Research Institute of Forestry, The National University of Kazakhstan, Kazakh National Agrarian University, Kyrgyzstan Institute of Geology, Kyrgyzstan Institute of Water Problems, Kyrgyzstan Osh State University, Kyrgyzstan National Agrarian University, The National University of Kyrgyzstan, Uzbekistan Institute of Genetics, Uzbekistan Institute of Soil Research, Uzbekistan Institute of Irrigation and Water Research, Uzbekistan Institute of Plant and Animal Research, National University of Uzbekistan, Tajikistan Institute of Geology, Tajikistan Institute of Botany, Tajikistan Animal Research Institute, National University of Tajikistan, Tajikistan Kasetart University, Tajikistan Academy of Agricultural Sciences, Tajikistan Institute of Water Problems, Turkmenistan Institute of Desert Flora and Fauna, and the National University of Turkmenistan.

After more than three years of cooperative research, with a responsibility system of general chief-editor, volume-editor, and chapter-writer, supervised by the principal investigator of the project, scientists from China and Central Asian countries worked together to complete 18 monographs (in Chinese, English, and Russian languages), each with hundreds of thousands words: *Physical Geography of Central Asia*, *Geology and Geomorphology of Central*

*Asia, Soil Geography of Central Asia, An Introduction to Environment of Central Asia, Plant Resources and Utilization in Central Asia, Ecological Status and Conservation of Wildlife in Central Asia* (in English), *Ecosystem Dynamics in Central Asia — Investigation and Data Mining* (in English), *Modeling Dryland Ecosystems' Response to Global Change in Central Asia* (in English), *An Outline of Economic Geography of Central Asia, Land Use and Land Cover Changes in Central Asia, Effects of Climate Change on Mountain Ecosystems* (in Chinese and Russian languages), *Physical Geography of Kirgizstan* (in Chinese and Russian languages), *Soil and Land Resources of Kazakhstan* (in Chinese and Russian languages), *Water Resources and Utilization in Uzbekistan* (in Chinese and Russian languages). This series of monographs reveals the changes in climate, plants, animals, soils and ecosystems in Central Asia, predicts the trend of ecosystem dynamics under different future scenarios, proposes solutions for ecosystem and natural resource managements in Central Asia in the context of climate change. While the research on resources and ecosystem of Central Asia arid region is a long-term work, the publication of this scientific research series provides the first systematical insights on ecological protection and resource management in Central Asia in the context of climate change. This effort provides scientific and technological support for sustainable development in Central Asia. This research received strong support from the National Ministry of Science and Technology, Chinese Academy of Sciences, and Xinjiang government. The project was well organized by the Xinjiang Science and Technology Department. It was the product from the cooperation between scientists from China and the Central Asia countries and the unremitting efforts of all involved researchers. The achievement is the fruit of group work from the above teams, acknowledged hereby. As the first systematic study on the resources and environmental problems in Central Asia, mistakes and limitations are unavoidable, and criticisms and advices are welcomed.



(CHEN Xi)

November 28, 2013



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Series Foreword

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