Yaning Chen *Editor*

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Preface

With the increasing concern of global environmental and ecological degradation, there has been an urgent need to investigate the related water cycle changes. Designed for both academic and business sectors, this book examines the major issues in water resources research in Northwest China, approximately one fourth of the nation's entire land area and one of the world's largest arid regions. The arid region of Northwest China is characterized by its extremely vulnerable water resources and associated ecological environment. The large alpine snow and ice cover has contributed to the development of numerous inland streams, forming a unique landscape characterized by mountain-oasis-desert ecosystems. Water, largely originated from the mountain areas, has been a most critical factor to drive the energy and mass circulation in this region, which responds sensitively to the global climate change. This book focuses on some possible impacts of climate change on hydrology and water resources in the arid region of Northwest China. The contributing authors for this book include Yaning Chen, Weihong Li, Zongxue Xu, Zhongqin Li, Jianhua Xu, Xianwei Wang, Yanjun Shen, Zhi Li and Huaijun Wang, all of whom are active researchers in water resources research in arid and cold environments.

This book comprises 11 chapters discussing various aspects in water resources research. Specifically, the book begins with an introductory chapter (Chap. 1) discussing the physical geography and socioeconomic aspects in Northwest China. Chaps. 2-7 discuss the climate system and hydrologic system changes, some implications of these changes in relation to potential evapotranspiration, the hydrological cycle, and the spatiotemporal variations of the snow cover and glaciers through remote sensing, geographic information systems, and statistical analysis. Chaps. 8 and 9 focus on the model description and experimental design to interpret the hydro-climatic process, emphasizing the integration of water, climate, and land ecosystems through field observations and computer-based simulations. Chaps. 10 examines some extreme hydrological events and presents a study using the historical trend method to investigate the spatial and temporal variability of changing temperature and precipitation extremes in the hyper-arid region of Northwest China. And the Chap. 11 of this book discusses some possible strategies for sustainable watershed management. We believe that the lessons from this study area can be useful for other arid areas in the world.

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Urumqi, Xingjiang, China Yaning Chen
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Chapter 1
Exordium

Yaning Chen

Abstract The arid region of Northwest China is characterized by its extremely vulnerable water resources and associated ecological environment. Water is a critical factor to drive the energy and mass circulation in this region, which responds sensitively to the global climate change. The contradictions between ecology and industrial, agricultural production are very conspicuous in arid region. This chapter discusses the physical geography, climatic characteristics and socioeconomic aspects in Northwest China, the main aspects are as follows: (1) By a waving geomorphic land surface with inter-spacing mountains and depressed basins, the typical landscape comprised vertically with mountain—oasis—desert ecosystems. (2) Situated far from the sea, the relatively secluded Northwest region has a typical continental climate marked by scarce precipitation, high evaporation, wide temperature fluctuations and strong winds. (3) The multicultural population is mainly distributed in the oases, where oasis agriculture is the mainstay. The ecosystems are extremely fragile due mainly to the internal factors of ecological processes and the interference of human activities.

Keywords Northwest China · Landform features · Socio-economic characteristics · Population composition · Ecological degradation

1.1 Natural Geography

The arid region of Northwest China is located in the hinterland of the Eurasian continent, spanning an area from 35° to 50° N and 73° to 106° E. It lies west of the Helan and Wushao Mountains, north of the Kunlun Mountains, and includes the Tarim River Basin, the Qaidam Basin, the Badan Jaran Desert and the Tengger Desert. Geopolitically, the area incorporates the Xinjiang Uyghur Autonomous

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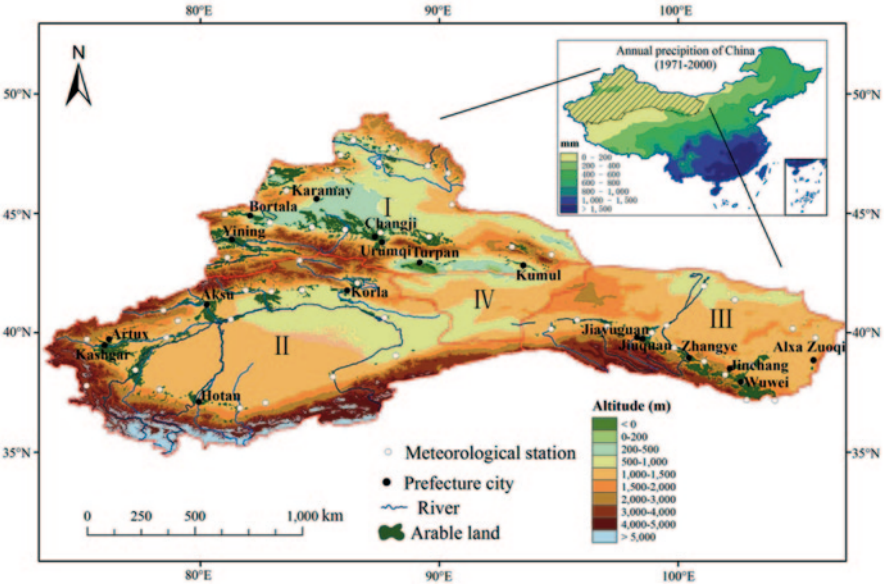

Fig. 1.1 The geomorphologic setting and zoning of the arid region in Northwestern China

Region (Xinjiang for short), the Hexi Corridor in Gansu Province, and the western portion of the Helan Mountains in Inner Mongolia. The land mass comprises approximately 2.5 million km^2 and accounts for one quarter of the total land area of China (Fig. 1.1). It is a major component of the arid region of Central Asia and also the typical region of desert in the world.

The Northwest arid area is bounded to the south by the Kunlun Mountains and and Qilian Mountains, north by the Altai Mountains (Fig. 1.1). These ranges, together with the Tibetan Plateau, effectively block the Indian Ocean moisture from reaching the Northwest. Likewise, the Altai Mountain to the north prevents moisture from the Arctic Ocean from reaching the area.

Xinjiang is divided by the Tianshan Mountains into two parts: north and south. Conventionally, the area south of the Tianshan Mountains is called South Xinjiang and the area to the north is called North Xinjiang. To the east, the Helan Mountains block the moisture from the eastern monsoons. The area north of Qilian Mountain and west of the Helan Mountains are known as the Hexi Corridor.

Northwest China arid zone has diverse and extreme terrain. Its typical topography and geomorphology patterns include towering glaciers, widespread deserts (e.g., the Gobi), vast grasslands, sporadic oases, and numerous mountains and basins. The Tarim River Basin, which is China's largest, spans an area of approximately 530,000 m^2. Additionally, China's largest (and the world's second-largest) mobile desert, the Taklimakan Desert, is in the central portion of the basin. The Turpan Basin, in eastern Xinjiang, has an elevation of −145 m, making it the lowest natural point in the country. The Tarim River and the Heihe River are, respectively, China's longest and second longest inland rivers.

As well as being diverse and made up of extremes, the Northwest arid area is a secluded inland region featuring a continental climate. Being very dry, the region tends to evaporate all precipitation it does receive, the average annual precipitation being only 130 mm (Chen et al. 2009). Because precipitation in the plains area does not produce surface runoff, this is one of the most severely arid areas in the world. The ecological environment is fragile and unstable, and species are extremely poor. Moreover, as the area is situated far from the sea, moisture is unable to reach it (Li 2012). Instead, precipitation mainly occurs in the Yili River Valley (an area strongly influenced by westerlies), north of the Altai Mountains (which is influenced by Arctic Ocean water vapor), or at the edge of the Hexi Corridor region. The highest precipitation levels (up to 800 mm) occur in the eastern mountains of the Yili Valley (Park et al. 2010; Wu et al. 2010; Ye et al. 2000; Yuan et al. 2003; Zhong et al. 2007, 2010).

In light of the area's large geographical span and unique landscape pattern, precipitation and water resources are unevenly distributed (Chen et al. 2009). Some oases with agricultural production activities have annual precipitation of less than 50 mm, with potential evaporation of up to 2,500 or 3,000 mm, which is 50–60 times the average precipitation. Clearly, the arid region of Northwest China can easily be described as one of the world's most arid regions.

The snow and glaciers coating the Northwest mountains give birth to more than 600 rivers. Other than for the Irtysh River in northern Xinjiang (which is part of the Arctic Ocean water system), all are inland rivers. Due to scant river runoff and closed terrain conditions, no tributaries pour into the main stream and the waters flow mainly through deserts until finally evaporating. The major rivers in this area are the Tarim River, the Yili River, the Irtysh River, the Heihe River, and the Shiyang River.

The Yili River originates in the Tianshan Mountains and is fed by high levels of precipitation due to the effect of the prevailing westerlies. The annual runoff of the Yili is 17 billion m^3, making it the largest in the region (Ye et al. 1996). The Tarim River Basin is composed of the Aksu River, the Hotan River, the Yarkand River and the Kaidu-Kongque River. Measuring 2,179 km in length, the Tarim River is China's longest inland river, and flows from west to east through the northern basin. All of these rivers, along with numerous streams, are products of glacier snowmelt water. They wind through the arid region's oases and serve as the main source of irrigation water for local farmland.

The Northwest features a large diurnal temperature range with adequate heat and light sources, making it suitable for thermophilic plants and crops. However, because of the large geographic span from north to south and the uneven spatial distribution of heat resources, there are significant differences in the cropping systems and crop varieties. In southern Xinjiang, and where heat resources permit, cotton is grown and there are both summer and winter wheat crops. In contrast, the cooler climes of northern Xinjiang and the Hexi Corridor yield only one annual growing season, the main crops being wheat and spring corn. The uneven spatial distribution of heat resources directly impacts inter-regional differences in crop growth periods.

Currently, Northwest China is the main gathering point for ethnic minorities. Despite harboring a vast and rich supply of minerals, oil, gas and other natural resources, the area remains underdeveloped but is slated to become an important

resource replacement for China in the twenty-first century. Indeed, with the focus of national economic construction moving ever westward, the arid zone has become the fulcrum for China's economic growth. However, the resources presently in place to support the development of the ecological environment are inadequate, and the conflict of water utilization is very conspicuous. How to achieve sustainable use of resources in the Northwest, along with ecologically sustainable management and sustainable economic and social development, has become the focus of attention of all levels of government as well as the affected communities.

1.1.1 Landform Features

As outlined above, the arid area of Northwest China is a vast territory of complex topography that includes mountains, plateaus, deserts and basins, with mountain runoff supplying most of the water resources. From a macroeconomic viewpoint, the region is mainly composed of large basins (the Tarim, Junggar and Turpan-Hami Basins and the Hexi Corridor) and continuous mountain ranges (the Tianshan, Karakoram, Kunlun, Qilian and Altai Mountains).

1.1.1.1 Terrain

Generally speaking, the terrain in the Northwest arid zone is high in the west and low in the east. In the mountainous western area, which features the Qilian, Kunlun, Tianshan and Altai Mountains, some peaks reach as high as 7,000 m. The foot of the Qilian Mountain is connected to the Alashan Plateau and the Hexi Corridor, the latter which forms part of the depression zone at the edge of the Qilian Mountains and is about 1,000 km long. The piedmont sloping plains, composed of numerous alluvial fans of the Qilian Mountains. These plains, situated among the Heli Hill and the Longshou and Qilian Mountains, are between 1,000 and 1,500 m above sea level.

Being located west of the Yellow River, the Hexi Corridor terrain tilts from southeast to northwest and is an important road leading to the Western Regions from eastern China. Historically, the famous ancient "Silk Road" passed through there and it is still the main road connecting eastern China with Xinjiang. Although the annual precipitation is less than 200 mm, the abundant snowmelt from the Qilian Mountains enables irrigation, thereby creating the mainstay agricultural base of the Northwest territories (Zhao et al. 1995).

The Alashan region is high and flat. It belongs to the temperate dry desert region, which is 1,000–1,500 m above sea level. In winter, this area is strongly influenced by high pressure centered on Mongolia, and so the climate is more arid than in the Junggar Basin. However, in summer, the southeast is impacted by Pacific monsoons, bringing sudden and thunderous showers. Annual precipitation in the region hovers around 200 mm, while the lower reaches of the Heihe River receive only about 50 mm. The main desert vegetation is made up of extremely sparse shrubs and semi-shrub desert (Zhao et al. 1995).