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The Social Impacts of Climate Change in China over the Past 2000 Years

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Preface

As the most active element in the natural environment, climate change has had wide and profound impacts on human society at multiple temporal and spatial scales, although it might not be a determinant driving force. A growing number of cases from all around the world have proven that there is a close and complex relationship between human history and climate change. How climate change has affected the human history is a key issue of the study of impacts of past climate change, which is also an important research topic of man-land relations in the time dimension, in Geography. As early as the beginning of the twentieth century, Huntington (1907), a famous American geographer, pointed out that climate change was indeed one of the driving forces in the development of human society in his famous book, *The Pulse of Asia*. His theory of climate cycle became a milestone in understanding the impact of natural environment from the perspective of environment change instead of an unchangeable environment. However, in Huntington's time and for a long period afterward, both his viewpoints and the evidence supporting his views had been questioned, because in the early twentieth century, the climate was generally believed to be stable with less change over the historical period, except in the distant geological period; and the evidence of climate change used by Huntington was not as reasonable as that we use today for the scientific study on climate change. The study on the impact of historical climate change was less developed for many years.

Today, more than 100 years later, the situation has become quite different. It has already become an important theme of past global change research, seeking to understand the processes and mechanisms of past human-climate-ecosystem interactions at multiple, spatial and temporal scales, so as to enhance our understanding of contemporary climate change impacts and human social adaptation. Thanks to significant advances in the study of past climate change and historical social development, it is increasingly recognized that climate change as one of basic driving forces had strongly, both positively and negatively, impacted the course of human civilization. Many historical events such as population fluctuations and migrations, economic fluctuations, social instabilities and even dynastic changes were closely and complexly connected with climate change. But, more than seeking to find the connections between climate change and specific historical events by direct comparisons of historical climate change events and related social phenomena occurring during the same period, there is now a lot of studies focusing on the impact mechanism of climate change aimed at learning from History as a key for a better understanding of the impacts of global climate change at the present and in the future times. Although today it is difficult to simply repeat the impacts of climate changes that occurred in the past, the facts of past climate change impacts can at least serve as an analogy to provide an early warning scenario for dealing with ongoing challenges of global climate change. In particular, the processes and mechanisms of human response to the impacts of climate change revealed by historical events have not changed significantly over time and location and thus represent an important value for human society to cope with the great challenges of global climate change in the future.

Instead of learning *about* the historic aspects, the main purpose of the studies on the impact of past climate change is to learn *from* History, revealing the general processes and mechanisms valuable for understanding the impact of climate change. The focus of current studies on the impact of historical climate change is no longer to provide more proof that climate change is able to affect history, but to indicate how climate change affects human society throughout history. The social impacts of climate change are not a simply cause-and-effect relationship but are a coupled result of the multiple factors in the natural and social systems at multiple spatial and temporal scales. So, we must, of necessity, get rid of the paradigm of geographic environmental determinism, thereby avoiding simply attributing climate change as a civilization-related determinant. More importantly, it is urgent that we develop a new research paradigm on the base of man-environment interactions. However, such a study is hard to implement and is still undergoing exploration, due to the difficulty of obtaining proxy of interpreting the interaction process between the impacts of past climate change and human responses, the multi-cause nature of the social events in historical periods, the complexity of the social responses process to climate change, in addition to the uncertainty of the results of past climate change reconstructions.

China is a country that has great potential for the research of impacts of past climate change. As an agriculture-intensive society bathing in the Asian monsoon climate regime, the History of China has been strongly impacted by climate change. Although historical China saw its borders vary from dynasty to dynasty, its core social-economics closely aligned with the major agricultural area throughout History. This geographic and temporal overlap allows for continuous comparison across the Chinese core areas. There are abundant historical records spanning thousands of years that relate the impacts of (and adaption to) climate change in China. These records provide the opportunity for studying the process and mechanism of the social impacts of past climate change and human adaptation.

In this book, we attribute the impacts of historical climate change on social development of China to the issue of food security. Taking long-term climate change and climate extremes as external forcing and adopting the core concepts of resilience, vulnerability and adaptation of human systems, we have analyzed the process and mechanism of historical climate change affecting China's socio-economic development over the past 2000 years by reconstructing the proxy series of various socio-economic subsystems and case studies. The key topics include: the relationship between historical climate change impacts and the vulnerability of Society, how socio-ecological resilience has mitigated the impacts of climate change and maintained the continuity of Chinese civilization and how learning and innovation in the adaptation process have enhanced the capacity to copy with climate change by increasing China's resilience. The book contains 9 chapters covering the natural and historical background of China (Chap. 1), a summary of climate change in China over the past 2000 years (Chap. 2), conceptual models and reconstruction methods for studying historical impacts of climate change in China (Chap. 3), the relationship between changes of production, economy, population and social subsystems and climate change over historical periods (Chaps. 4–8) and processes and mechanisms of the impacts and adaptation to historical climate change in China (Chap. 9). As a cooperative work, all the authors, Xiuqi Fang, Yun Su, Jingyun Zheng, Lingbo Xiao, Zhudeng Wei, Jun Yin, Xudong Chen, and Xianshuai Zhai, involved have contributed their wisdom to the task. The book as a whole is coordinated by Xiuqi Fang and Yun Su.

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Beijing, China Xiuqi Fang

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Chapter 1
Introduction

1.1 The Natural Environment of China

China lies in Southeast Eurasia, with a large span from 73° 40′E to 134° 46′E and 3° 52′N to 53° 31′N. Most of the country is located in the middle latitudes.

China has a vast territory including both land and sea. The land area is about 9.6 million square kilometres. China's mainland coastline measures approximately 18,000 km. It is flanked to the east and south by the Bohai, Yellow, East China and South China Seas, with a total maritime area of 3 million square kilometres under Chinese jurisdiction. The Bohai Sea is the continental sea, while the Yellow, East China and South China Seas are marginal seas of the Pacific Ocean (Fig. 1.1).

1.1.1 The Three Topographic Steps

The main characteristic of the Chinese landform is that the land surface decreases in a stepped pattern from west to east, which is known as the topographic steps of China.

The first step is formed by the Qinghai-Tibet Plateau in the west. It is the highest plateau in the world, with an average elevation of more than 4000 m. At 8848.86 m above sea level, Mount Qomolangma[1] is the world's highest peak. The boundary line between the first and second steps of the topographical staircase is formed by Kunlun Mountains, Qilian Mountains and Hengduan Mountains on the edge of the Qinghai-Tibet Plateau. To the east and north of the boundary is the second topographic step, with an average elevation of 1000–2000 m. It consists of vast plateaus (the Inner Mongolia, Loess and Yunnan-Guizhou Plateaus) and basins (the Junggar Basin, Tarim Basin and Sichuan Basin), separated from each other by high

[1] Mount Qomolangma, known in the West as Mount Everest, comes from Tibetan of China for "Goddess of the Universe".

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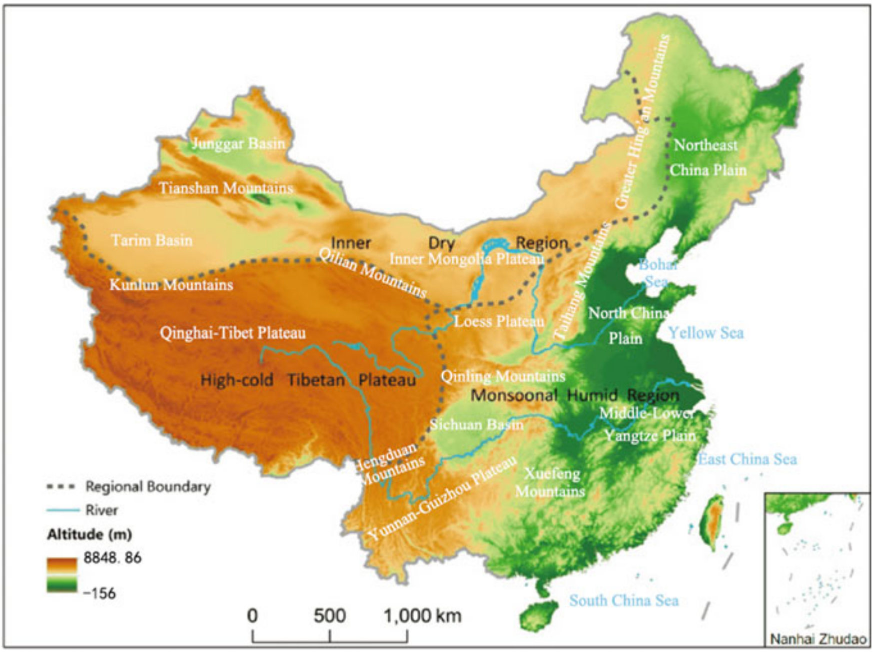

Fig. 1.1 Topography of China and physiogeographical regionalization (Zheng et al. 2005)

mountains. The boundary of the second and third steps lies along the Greater Khingan Mountains, the Taihang, Wu and Xuefeng Mountains. The area east of this boundary to the sea coast is the third topographic step of China, with an average elevation less than 500 m. It consists of plains (Northeast China, North China and Middle-Lower Yangtze Plains), hills and low mountains. To the east and south of the coastline lie the seas of the continental shelf, with water depths generally less than 100–200 m. Overall, mountains, plateaus and hills account for about 67% of China's land area, while basins and plains account for about 33%. This means that flat and arable land is limited in China and this has placed a constraint on its agricultural and population distribution patterns.

Governed by the three-step landforms, China's major rivers, such as the Yellow the Yangtze Rivers, mainly originate from the Qinghai-Tibet Plateau or other mountainous areas that divide the topographic steps of the landform and flow into the ocean from the west to east. Therefore, the hydrological processes and soil erosion in the upper and middle reaches have a profound influence on the river channel evolutions and disasters (such as floods and droughts) in the eastern downstream plains. For example, the upper and middle reaches of the Yellow River flow through the Loess Plateau, which was one of the first areas where farming was developed in ancient China because of its deep, fertile soil. However, the soil erosion on the Loess Plateau has not only resulted in the landforms featuring numerous gullies and ravines but also in large amounts of loess sediment being carried through the Yellow River to the North China Plain. The accumulation of loess sediment caused the silting up of the riverbed and the formation of a "suspended Yellow River" above the ground in the lower reaches. The lower Yellow River was renowned for frequent channel migrations and levee breaches, which have had a profound impact on the North China Plain throughout history. The flooding of the Yellow River caused devastating blows several times to local agriculture, population, settlements and the economy.

1.1.2 The Typical Monsoon Climate

China is one of the regions with the most typical monsoon climates in the world. Taking the line along the Greater Khingan Range, Yin, Helan, Wushao, Bayan Har, Tanggula Mountains and the Kailash Range as the boundary, the area to the east and south of it is the Eastern monsoon region of China. In this region, influenced by the monsoon circulation systems in East Asia, South China Sea and India, the Winter and Summer monsoons are both prominent. The vast area north of the Leizhou Peninsula to the Qinling Mountain-Huaihe River in China has a humid subtropical climate, contrasting sharply with most arid desert belts of the same latitudinal zone on Earth that are under the control of the Subtropical High Pressures. This is the result of the monsoon circulations influencing the control of the planetary wind system over China's near-surface atmosphere.

In winter (roughly October to March), the Winter monsoon circulation dominates the weather system in China's monsoon region. The surface airflow below 2000 m in this place is mainly affected by the Siberian High Pressure. The near-surface wind is cold and dry and its direction is mainly North (Northwest, due North or Northeast). In summer (June to September), the Summer monsoon circulation dominates the weather system in the monsoon region and the direction of the near-surface wind is mainly South (Southeast, due South or Southwest), which carries a large amount of moisture from the ocean and makes the rainfall on the land.

The transitions of Winter and Summer monsoon during the year bring about significant seasonal changes in heat and humidity and in turn form the characteristics of the climate in the Eastern monsoon region, dominated by the four distinct seasons and the time overlap of rainy season and hot season. It is colder in winter and hotter in summer compared to other areas at the same latitude. Precipitation decreased from southeast to northwest, with great seasonal difference and inter-annual variation. In addition, China's meteorological disasters are characterized by various types, high frequency and high intensity, which are also closely related to the monsoon climate.

The precipitation in most parts of China is concentrated in the Summer monsoon period, while the Winter monsoon period is generally dry and less rainy. Most regions receive less than 5% of their annual rainfall in winter (December to February), while the middle and lower reaches of the Yangtze River and areas south of it, as well as the northern Xinjiang receiving more than 10%. The relatively low and flat topography of the eastern China allows the Summer monsoon to sweep in and bring monsoon rains. With the front of Summer monsoon pushing from south to north, the main rain belt stepwisely shifts in the same direction in the Eastern monsoon region. Precipitation in South China increases significantly in April and by May the rain belt extends to the south of the Yangtze River. From early June to early July, the rain belt moves rapidly north to the Yangtze-Huai River Basin and stagnates, causing the "plum rain"[2] along the persistent stationary front. June and Julyare characterized by prolonged gloomy and rainy weather. After mid-July, the rain belt continues to move to North China and Northeast China. However, at this time in the South, the area around the southeastern coast is affected by precipitation brought by tropical cyclones, while the Jianghuai region is experiencing Summer drought under the control of the Subtropical Ridge. In September and October, the Summer monsoon withdraws southwards and, rapidly, the rain belt also retreats southwards to South China. Generally, the seasonal distribution of precipitation, droughts and floods in China are influenced by the passage of the rain belt. On the one hand, the concentration of precipitation in Summer is most pronounced in Northeast and North China, which makes them prone to spring droughts and summer floods. On the other hand, precipitation in southern China is distributed evenly throughout the year and common disasters include floods in summer and autumn and droughts in mid-summer in the Jianghuai region.

The combination of China's monsoon climate and topographic features makes the Eastern monsoon region a place of frequent and severe droughts and floods. The in the abnormal onset time, intensity, extent, duration and movement paths of the East Asian Summer monsoon could all lead to anomaly of inter-annual precipitation, resulting in successive drought and flood or alternating from drought to flood. In addition, the precipitation is too concentrated in Summer, the similar direction of the rain belt and the main river systems in distribution, leads to simultaneous abundance or shortage of water in both upper and lower reaches of the river. This makes it have to carry out both flood and drought prevention together on a regular basis. Organizing the construction and maintenance of flood and drought prevention and water conservation facilities has become an important responsibility of every government in the history of China. In the lower reaches of the Yangtze River, when the limited plain was reclaimed out, people gained new farmland by reclaiming land from lakes to alleviate the growing population pressure. This placed the agricultural production at a greater risk of flooding. Moreover, the high concentration and annual variability of precipitation are more significant in the North than in the South, making the former more prone to droughts and floods.

The development of the Winter monsoon in China is embodied in the outbreaks of cold air (a drop of 5–10 °C) and cold wave (a drop of more than 10 °C) events. There are usually 4–5 cold waves and 6–7 powerful cold air events in winter each year. A Winter monsoon activity includes 3 important stages: the onset of the Winter monsoon, the accumulation of cold air over Siberia and the intrusion of masses of cold air to the southeast. In China, cold waves are caused by the rapid and strong southward movement of cold air coming from the Mongolian plateau and Siberia. Generally, cold waves may occur between October and May. Late Autumn and early Spring are the seasons when most cold waves occur in China. Cold waves are related

[2] As these months are the ripening period of plums, it is called "plum rain" season.

to the intensity of the Winter monsoon, which can affect the winter temperature of China. When the Winter monsoon is strong, the number of cold waves hitting China in that year will increase and winter temperature will be lower than usual. Cold waves can cause widespread and intense cooling, as well as windy, rainy or snowy weather along their paths. After the passage of cold waves, the climate in North China will be dry with low precipitation. In Spring, cold waves are likely to cause sandstorms. However, after passing the Huai River, the cold air masses will meet with the warm and humid air masses, generating continual rain in the Yangtze River Valley (even in the Nanling region). A powerful cold wave can then cross the Nanling Mountains to reach the South China Sea and even the further south.

1.1.3 Three Partitions: The Basis of Geographical Differences in China

The interaction of topography and climate in China has made its natural geographical environment very distinctive. Three partitions, *the Eastern monsoon region*, *the arid and semi-arid areas in the Northwest* and *the high latitudes and cold region in Qinghai-Tibet Plateau*, were formed, based on the patterns of regional differentiation. They have substantially influenced the spatial distribution and characteristics of China's agriculture, population and economy. As for the boundaries of the three natural partitions, *the high latitudes and cold region in Qinghai-Tibet Plateau* are bounded by the 3000 m contour line, while the rest of the region is divided into *the arid and semi-arid areas in the Northwest* and *the Eastern monsoon region* by the 400 mm average annual rainfall isohyet.

(1) **The Eastern Monsoon Region**

The Eastern monsoon region is mainly located to the east of the 400 mm average annual rainfall isohyet. Its northernmost point is at Mohe in Heilongjiang Province and the southernmost point is at the Nansha Islands of Hainan Province. This region has a typical monsoon climate. Cold and dry Winter monsoon blows from the inland provinces at middle and high latitudes, while Summer monsoon brings warm and moist air from the Pacific and the Southwest Indian Ocean at low latitudes. In the Eastern monsoon region, winter is relatively dry and cold while summer is hot and humid. From the south to the north, there is a clear latitudinal zonation based on temperature differences. The main body of the Eastern monsoon region is located in Northern-, Middle- and Southern Subtropical zones and Middle- and Warm Temperate zones. The average annual temperature is about – 4 °C in the northernmost point and more than 25 °C in the southernmost point. The temperature difference between the North and the South is large in winter (nearly 50 °C) and small in summer (about 10 °C). Besides, within the Eastern monsoon region, the annual precipitation is about 400–2000 mm. As the increasing distances from the sea, there is a meridional divergence of the humid and semi-humid climates and the biomes are forests and forest steppes, respectively.

The Eastern monsoon region includes not only the Loess Plateau, Sichuan Basin and Yunnan-Guizhou Plateau on the second topographic step, but also the Northeast China, North China, the Middle-Lower Yangtze Plains and the Jiao-Liao, Jiangnan and Zhejiang-Fujian Hills on the third topographic step. The regional climate differences are enhanced by significant landform differences, combined with the NE–SW, S–N and E–W running mountains within this region.

The Eastern monsoon region enjoys the best natural conditions in China. Since ancient times, it has been China's major farming area and densely populated area. It is also the seat of China's political, economic and cultural centres. Because of the diversity of the geographical environment and favourable climatic conditions, most grain crops, cotton plants, fruits and vegetables in the world can be produced here, with a high cropping index. About 88% of arable land and 94% of the population in modern China are located in the area east to the Heihe-Tengchong line (also known as the "Hu line") in the monsoon region. With a large population and a long history, human activities have exerted substantial and extensive influences, which have brought great changes in the natural landscape. Most of the plains and basin areas have been developed for arable or residential land and most of the native vegetation in mountainous and hilly areas has been cut down and replaced by terraced rice fields and plantation forests. Crops and human landscapes are widely distributed. In the process of adapting to the natural conditions in this area, the resident peoples have developed a prominent agricultural culture. They have formed a social consensus of attaching importance to agriculture and farming, a pragmatic spirit of emphasizing practicality and a peaceful and optimistic attitude towards life.

(B) The Arid and Semi-arid Areas in the Northwest

The arid and semi-arid areas in the Northwest are located in the inland regions west to the 400 mm average annual rainfall isohyet and north to the Qinghai-Tibet Plateau. The climate of this partition is relatively homogeneous. The average annual range of temperature is between 0 and 16 °C. Most of the region belongs to the mid-temperate zone and small parts to the warm temperate zone. Because they are quite some distance from the ocean, summer monsoon and moist air are difficult to reach, resulting in very little precipitation. Annual precipitation is around 400 mm in the east and decreases to 100 mm or even less than 50 mm in the west. Most of the region is with hot summer and cold winter, scarce precipitation and year-round dryness. Aridity is the most significant natural feature, but this region is rich in wind and solar energy resources.

The arid and semi-arid areas in the Northwest are located on the second topographic step. The altitude is generally between 1000 and 2000 m, but with a significant internal variation. The main body of the eastern part is formed by plateaus (e.g., Inner Mongolia Plateau, northwestern part of Loess Plateau). There are also mountain ranges (Yinshan and Helan Mountains, etc.) and several basins of varying sizes. The Summer monsoon can only affect the eastern and southern parts where the annual precipitation was 250–400 mm in the mid-summer. The climate here is semi-arid in the temperate zone or the warm temperate zone. The dominant landscape is steppe, studded with some lakes and fixed or semifixed sand dunes. This region was called the “northern farming-pastoral transitional zone”, where has been half farming and half pasturing, and some time farming and other time pasturing in the history, as a transition area between the agricultural people of the Central Plains and nomadic people of the North.

While to the west of the Hexi Corridor, the regional morphological pattern shows an alternating distribution of large basins (e.g., the Tarim Basin and Junggar Basin) and high mountains (e.g., Tian Shan). The main climate type is the temperate arid climate. However, the southern part of Xinjiang is in the warm temperate zone with an arid climate. The landscape is mainly desert steppe, Gobi and desert. Influenced by the morphological pattern, there are usually significant high precipitation belt on the windward slopes of high mountains. And on the upper mountains, there are permanent snow and glaciers, which become the “solid reservoirs” in the desert. Rivers recharged by these “solid reservoirs” then formed oases of different sizes in the piedmont puluvial fan and along both sides of the rivers at their tails in the basins. Restricted by water resources, this region mainly develops animal husbandry. Pastures can be found on most of the steppes and desert steppes. This mode of production has given rise to the region’s unique nomadic cultural identity and style. Agriculture, however, is confined to the oases with irrigation conditions, forming the “oasis agriculture”. Agriculture in oases on the mountain fronts is quite well developed. The oases occupy less than 5% of the land area but with more than 90% of the population and social wealth. The farmland, villages and towns in this region are mostly distributed in dots or stripe patterns, as the water source is a decisive factor of agricultural development and the distribution of population and settlements.

(C) The High Latitudes and Cold Region in Qinghai-Tibet Plateau

The main body of this region is the Qinghai-Tibet Plateau. Covering about one-fourth of China’s land area, where has an average elevation of more than 4000 m and is home to many high mountains, such as the Kunlun and Tanggula Mountains, the Kailash Range and the Himalayas.

The region’s high altitude contributes to its cold climate. It is with the alpine climate, characterized by cold and dry natural conditions. The annual average temperature in most areas is below 0 °C, significantly lower than that in other places at the same latitude. The annual range of temperature is small but the daily range is large. The thermo-isopleths appear to be closed circles and the values decrease with the increase of altitudes. The average precipitation is around 400 mm. However, in the southern part of the plateau, the precipitation is more than 800 mm due to the warm and humid air from the Indian Ocean, yet in the landlocked northern part, the precipitation is less than 100 mm. On the plateau, wind and solar radiation are strong and the air is thin, resulting in lower air pressure and availability of oxygen. The cold climate results in the formation of a large number of glaciers and the world’s widest and thickest permafrost at the middle and low latitudes. Besides, the seasonal and annual variability of snowpacks are also great. The redistribution of water and heat resources, due to the high elevation, has directly led to the altitudinal zonation and diversity of climate here. There is a plateau frigid zone, a plateau temperate zone and a plateau subtropical zone based on temperatures and four arid/humid types, namely, humid, semi-humid, semi-arid and arid. From the east to west, or from the low to high altitude, the distribution of natural ecosystems showed obvious patterns of forest–grassland–meadow–desert.

This region contains main sources of several great rivers in Asia, such as the Yellow River, the Yangtze River, the Ganges, the Mekong, the Indus, the Salween and the Irrawaddy. The plateau is home to numerous endorheic lakes, where was the end of many rivers. Except for a few freshwater lakes, most of them are brackish or salt lakes.

The production of this area is mainly animal husbandry as the natural conditions are harsh for farming (cold climate with large variability, short frost-free period, etc.). The largest and most extensively used pastures are located in the alpine meadows and the steppes in wide plateau valleys. The obvious vegetation zonation is conducive to the implementation of seasonal transhumance. Pastures are mainly stocked with Tibetan sheep, yaks and other livestock adapted to this alpine environment. Agriculture production, however, is mainly distributed in the river valleys and basins, such as Yellow River-Huangshui River Valley, Qaidam Basin and Yarlung Tsangpo River Valley. Highland barley and wheat are the staple crops. River valleys are not only the main areas for agricultural development, but also where human activities are most concentrated. Other areas in the plateau are sparsely populated or uninhabited.

1.1.4 The "North" and the "South" in the Eastern Monsoon Region

Due to the large latitudinal span of the Eastern monsoon region, there are considerable differences between the North and the South within this partition. Consequently, this region can be further divided into the "South" and the "North", with the "Qinling (Mountains)-Huaihe (River) line" as the boundary. This line is an important natural geographical boundary in China.

In terms of climatology, the "Qinling-Huaihe line" is roughly equivalent to the 800 mm annual rainfall isohyet, the 0 °C isotherm in January, as well as the 4500 °C contour of $\geq$ 10 °C cumulative temperature. It is also the dividing line of the humid and semi-humid climate regions and the subtropical monsoon climate and warm temperate monsoon climate regions in China. In addition, the Qinling-Huaihe line is also the boundary between the subtropical broad-leaved evergreen forests and the red and yellow soils in the South and the warm-temperate deciduous forests and the brown soil in the North. To the North of this line, the rivers, such as the Yellow River, are featured by lower flow, shorter flood season, larger range in seasonal water level, frozen, high sediment concentration and a sparse river network. However, for the rivers to the South of the line, such as the Yangtze River, the features are complete opposite.

In terms of agricultural resources, the Qinling-Huaihe line has the significance of a division between different types of agriculture. The South has a better combination