

Cindy Q. Tang

The Subtropical Vegetation of Southwestern China

Plant Distribution, Diversity and Ecology

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Springer

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*The woods are lovely, dark and deep,
But I have promises to keep,
And miles to go before I sleep,
And miles to go before I sleep.*

—Robert Frost, 1923

Preface

Over recent decades, a number of superb studies have been carried out on the vegetation of China, but up to now, no Chinese geographic zone as a whole has received the kind of quantitative, systematically rigorous analysis that today's vegetation science demands. Southwestern China lags in knowledge regarding the dynamics, succession, ecology, and diversity mechanisms of its subtropical vegetation. This book is born of a desire to provide valid scientific information on the patterns and processes of vegetation change across a broad range of spatial and temporal scales in the region. I hope that it will serve this primary purpose. It is perhaps fitting that the first such treatment should be devoted to southwestern China, whose exceptional interest and importance will become evident in the pages that follow. As a plant ecologist and an educator of graduate students in the fields of ecology and geobotany, I am hopeful that it will also provide readers with some understanding of how vegetation dynamics evolve, how plants persist, and how plant diversity has changed over time and space in this specific geographic region.

The arrangement of chapters in this book is intended to promote an integration of ecological perspectives on China's marvelous subtropical vegetation. Following an introduction (Chap. 1), each chapter concentrates on the Yunnan area, except that Chap. 7 also focuses on the Yangtze River valley near the boundaries separating Chongqing, Sichuan, and Guizhou.

Without the help and support of others, this book would not have been realized. I am greatly indebted to my field coinvestigators through whose efforts the present studies have become possible: Long-Yuan He and Yongchuan Yang. I am very grateful to the staff of nature reserves and to local villagers who accompanied me in the field; through their efforts, I have been able to visit extremely remote areas. Their dependable good humor added tremendously to the pleasure of my field journeys, and their resourcefulness under difficult conditions was remarkable. I feel very grateful for the technical expertise of Long-Yuan He, who helped me to make the maps for the book. I especially express my gratitude to Professor Marinus J. A. Werger for his continuous encouragement through all stages of the production and for invaluable editing and critical comments on the manuscript, to Professor Masahiko Ohsawa, whose broad and profound knowledge of the vegetation of East

Asia has inspired me in the study of southwestern China, for his comments and suggestions on the manuscript, and to my colleagues and graduate students who have given me limitless assistance in obtaining research material. I particularly value and acknowledge the help of Thomas Montgomery, my husband, for his ongoing inspiration, support for my field research, and polishing and editing of the English text, and of Ian Tang Montgomery, my son, for his patience and understanding of my absence from home during my numerous long journeys in the field.

Kunming, Yunnan, China
February 2015

Cindy Q. Tang

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Chapter 1

Introduction

Abstract The region known as southwestern China (SW China, 21°08'32"-34°20' N, 97°30'-110°10' E) includes Yunnan, Sichuan, Guizhou provinces and Chongqing Municipality. Topographically, it lies between the first altitudinal step, the Tibetan Plateau, and the third step, the middle-lower Yangtze Plain, and stretches over a vast area (1,135,567 km²). The region includes the Hengduan Mountains, the Yunnan-Guizhou Plateau, and the Sichuan Basin. The Hengduan Mountain Range, situated at the juncture of Tibet, Sichuan and Yunnan in the southeast of the Tibetan Plateau, has an average elevation of 2,000–6,000 m. Its highest peak, Gonggashan, reaches 7,556 m above sea level. The climate is dominated by the Asian monsoon system. It falls into latitudes classified as subtropical, except for the small tropical area of southernmost Yunnan. With that exception, altitudinal climates range from subtropical to temperate, alpine and frigid.

The crust movements of various parts of SW China have undergone tortuous and complicated evolutionary processes over the long development of geological history. The most striking geological characteristic of the region is a massive crust movement strongly linked with the forming of the Hengduan Mountains – an extension of the eastern Himalayas.

The soils vary widely, including red earth, yellow, yellowish brown, brown, purple, and mountain gray-brown types.

In the Early Tertiary period, the areas now including eastern Yunnan, Sichuan, Chongqing and Guizhou bore subtropical dry and semi-dry sparse woodlands, while most areas now comprising Yunnan had a warm-rainy winter and hot-dry summer climate supporting subtropical evergreen broad-leaved forests. In the Late Tertiary period, the vegetation of SW China became a subtropical mixed evergreen and deciduous broad-leaved forest, except in southern Yunnan, home to a subtropical evergreen broad-leaved forest. In the Quaternary, vegetation changes were taking place at about 10,000 years BP (years before present), and by 7,000 years BP the pattern of the mixed evergreen and deciduous forest had become more complex. Parts of this region had not been covered by the ice sheet during the Quaternary. In general, since the Holocene, the natural vegetation types of SW China have been similar to those of the present time.

The rich flora and complicated plant geographic patterns of SW China result from a combination of elements from the Sino-Japanese, Sino-Himalayan, African-Mediterranean, and Indo-Malesian floristic regions. SW China is one of the most botanically diverse terrestrial regions on earth, with a high level of endemism.

The vegetation includes tropical rain forest, subtropical evergreen broad-leaved forest (the vast majority), warm-temperate deciduous broad-leaved forest, temperate coniferous and broad-leaved mixed forest, cold-temperate coniferous forest, alpine scrub community, meadow, and wetland, as well as thorny shrubland and savanna in hot-dry valleys. There are also precious remnants: Tertiary relict forests in specific habitats such as scree slopes, limestone areas and stream banks. The subtropical vegetation of SW China offers an unparalleled diversity of plant life and has far-reaching importance for the entire world.

In the last few centuries human activities have increasingly changed the subtropical vegetation. Man's activities destroyed most of the original primary evergreen broad-leaved forests dominated by species of *Cyclobalanopsis*, *Castanopsis*, *Lithocarpus*, *Machilus*, *Phoebe*, *Cinnamomum*, *Schima*, *Michelia* etc. and they became restricted to remote mountain areas, nature reserves, steep slopes, and temple grounds. Complex mosaics of stands of varying ages, composition and structure intermingle with agricultural fields or mono-species plantations. So, SW China is truly a land of plant diversity, vegetation dynamics, and succession in time and space.

1.1 Environmental Setting

1.1.1 Physiography

The topography of China can be described as a series of steps decreasing in altitude from the Tibetan Plateau (Qinghai-Tibet Plateau), with a mean altitude of 4,000 m (highest elevation Mt. Everest, 8,848 m), which makes up one-third of the country, to the Xinjiang-Inner Mongolia, Loess, and Yunnan-Guizhou Plateau, followed by a descent eastward to a mean altitude of 2,000 m, and then a further descent to a mean altitude of 200–500 m, reaching finally to the sea (Liu and Ding 1984). These topographic variations make the terrain of China into a series of three altitudinal steps. Southwestern China, as referred to in this text, includes Yunnan, Sichuan, Guizhou provinces and Chongqing Municipality. This region (21°08'32"-34°20' N, 97°30'-110°10' E), lying between the first step, the Tibetan Plateau, and the third step, the middle-lower Yangtze Plain, stretches over an area of 1,135,567 km² (Fig. 1.1). It comprises a landscape of mountain chains interspersed with basins and alluvial plains. It includes the Hengduan Mountains, the Yunnan-Guizhou Plateau, and the Sichuan Basin (Fig. 1.2). The Hengduan Mountains are a series of parallel north-south ranges forming the south-eastern part of the Tibetan Plateau, Western Yunnan and Western Sichuan (Latitude 22°-32°05' N, Longitude 97°-103° E). Most parts of the region are characterized by a series of parallel north-south high mountain ranges alternating with deep gorges and rivers. The north-south orientation of the Hengduan Mountains intersects the predominant east-west mountain system of eastern Asia (Fig. 1.3). The Chinese name for this region is "Hengduanshan" which

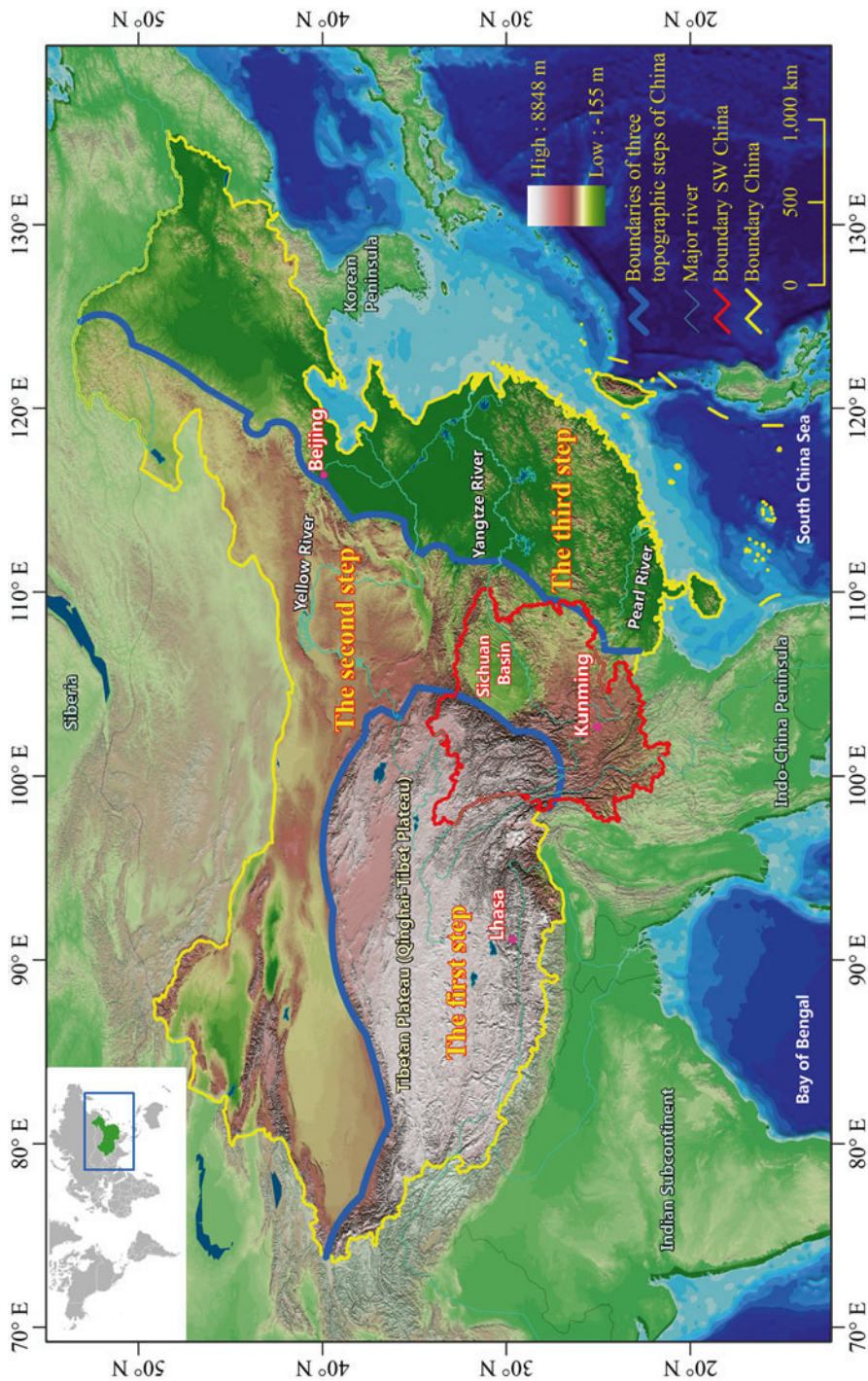


Fig. 1.1 Three topographic steps of China

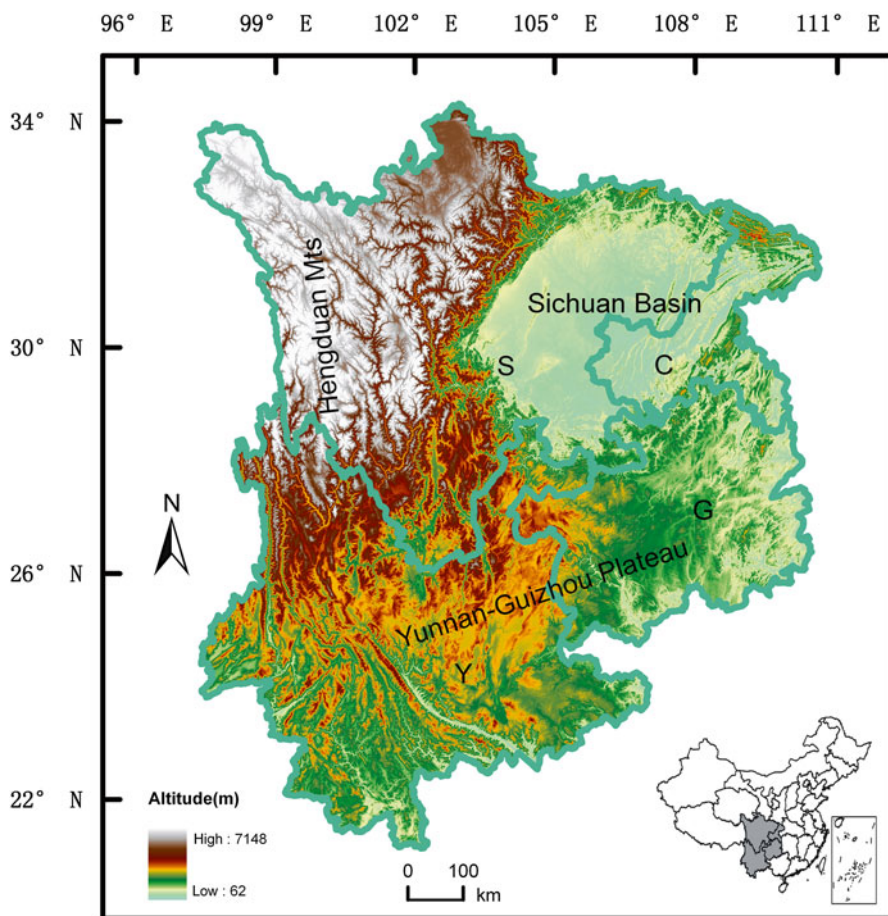


Fig. 1.2 SW China. Y Yunnan Province, G Guizhou Province, S Sichuan Province, C Chongqing Municipality

means “traverse cutting mountains”. These high ranges are, from west to east, the Gaoligongshan (“shan” means “mountain”), the Nushan, the Yunling (“ling” also means “mountain”), the Daxueshan, the Qionglaihan, and the Minshan, defining the eastern edge of the Tibetan Plateau, western Yunnan, and the western rim of the Sichuan Basin. Branching further out from the Yunling Range are some secondary ranges – the Wuliangshan and the Ailaoshan in the south-central area and the Wumengshan in the northeast part of Yunnan. The Gaoligongshan at the southern end of the Hengduan ranges forms the border between Myanmar and China. The Minshan in western Sichuan is at the eastern end of the Hengduan system (Fig. 1.3). Four rivers run in deep parallel valleys separated by mountains of the Hengduan range (Fig. 1.4). They flow in parallel out of Tibet to the south for a certain distance and then each takes its own way: the Dulongjiang (upper Irrawaddy) and Nujiang (upper Salween) to the Andaman Sea, the Lancangjiang (upper Mekong) to the

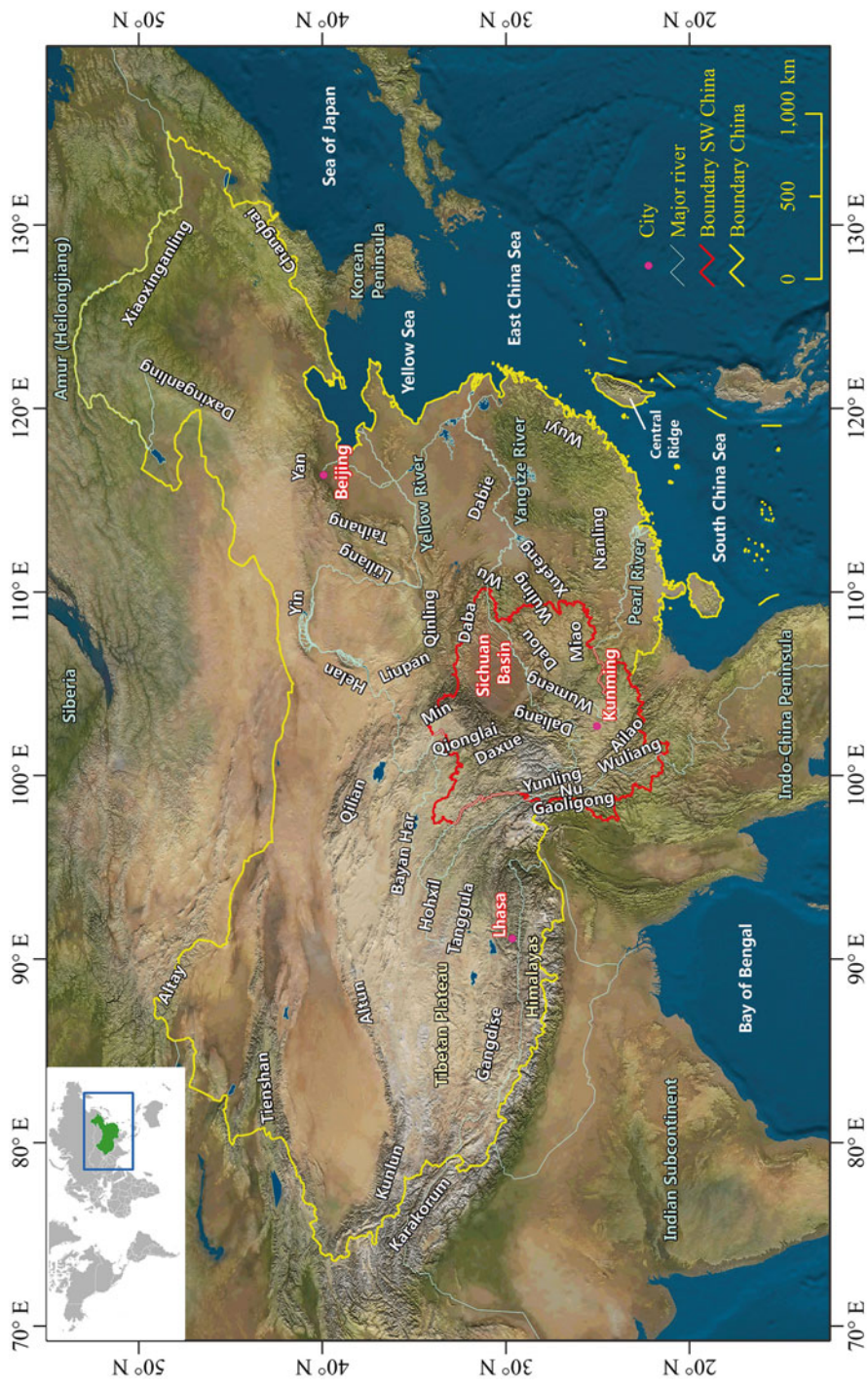
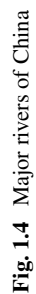


Fig. 1.3 Major mountain ranges of China



South China Sea, the Yangtze River (the Upper Yangtze is called Jinshajiang in Chinese) – flowing for 6,380 km (the longest river in Asia and the third-longest in the world) from glaciers on the Tibetan Plateau eastward across southwestern, central and eastern China before emptying into the East China Sea at Shanghai. The Yangtze, a major transport route, provides water for a large agricultural area where more than half of China's rice and other grains grow.

In the south, southeast and west Yunnan Province borders on Laos, Vietnam, and Myanmar, respectively. The major landforms in Yunnan are mountains (84 %), highlands (10 %), small basins and valleys (6 %). The Yunnan-Guizhou Plateau mainly covers eastern Yunnan Province (the Ailao Mountains serve as a center line dividing the province into the western and eastern parts) and the major part of Guizhou Province. Two distinct areas mark this plateau: one of high plateaus averaging about 2,000 m with mountain peaks as high as 4,344 m (Jiaozishan) and 4,042 m (Yaoshan) in eastern Yunnan, and a second area of rolling hills, deep river-carved gorges, and mountains marked by geological faults in western Guizhou. Easily-eroded limestone underlies the plateau, allowing for spectacular karsts. The highest elevation in Guizhou is 2,900 m at Jiucaiping in Hezhang to the west, while the lowest altitude is 137 m, to the east. The mountainous area, hilly land and river valley account for 61.7, 31, and 7.3 %, respectively of the territory. The Sichuan Basin comprises the central and eastern portions of Sichuan Province as well as Chongqing Municipality. It is an expanse of low hills and plains completely encircled by mountains. Tibetan borderlands lie to the west (e.g. Daxueshan and Daliangshan) and north (e.g. Longmenshan and Mingshan). The Yunnan-Guizhou Plateau extends to the south (e.g. Daloushan). Hills of the Yangtze River valley lie to the east (e.g. Wushan); Dabashan and Qinling to the northeast (Fig. 1.5). The topography in Sichuan is extremely varied and complex. There is a Chinese saying, "The road to Sichuan is harder than the road to heaven". In Sichuan Province, four geomorphic types: mountainous areas, hilly areas, plains and plateaus, account for 77.1, 12.9, 5.3, and 4.7 % respectively of the total area.

In SW China, the altitudinal gradient is one of the longest bioclimatic gradients in the world extending from lower than 500 m asl (e.g. Hekou with 76.4 m in southeastern Yunnan; the central Sichuan Basin area with 250–700 m) to over 6,000 m (e.g. the Meili Mountains with 13 peaks over 6,000 m in northwestern Yunnan; Mt. Gongga or Minya Konka with 7,756 m at the southern section of the Daxue Mountains in western Sichuan. Minya Konka means "the Highest Snowy Mountain" in Tibetan) (Figs. 1.6, 1.7, 1.8, and 1.9). The topographic profiles of Yunnan, Sichuan and Guizhou are shown in Fig. 1.10. Also shown are scenes characteristic of SW China: picturesque limestone karsts and plentiful plateau lakes (Figs. 1.11, 1.12, and 1.13).

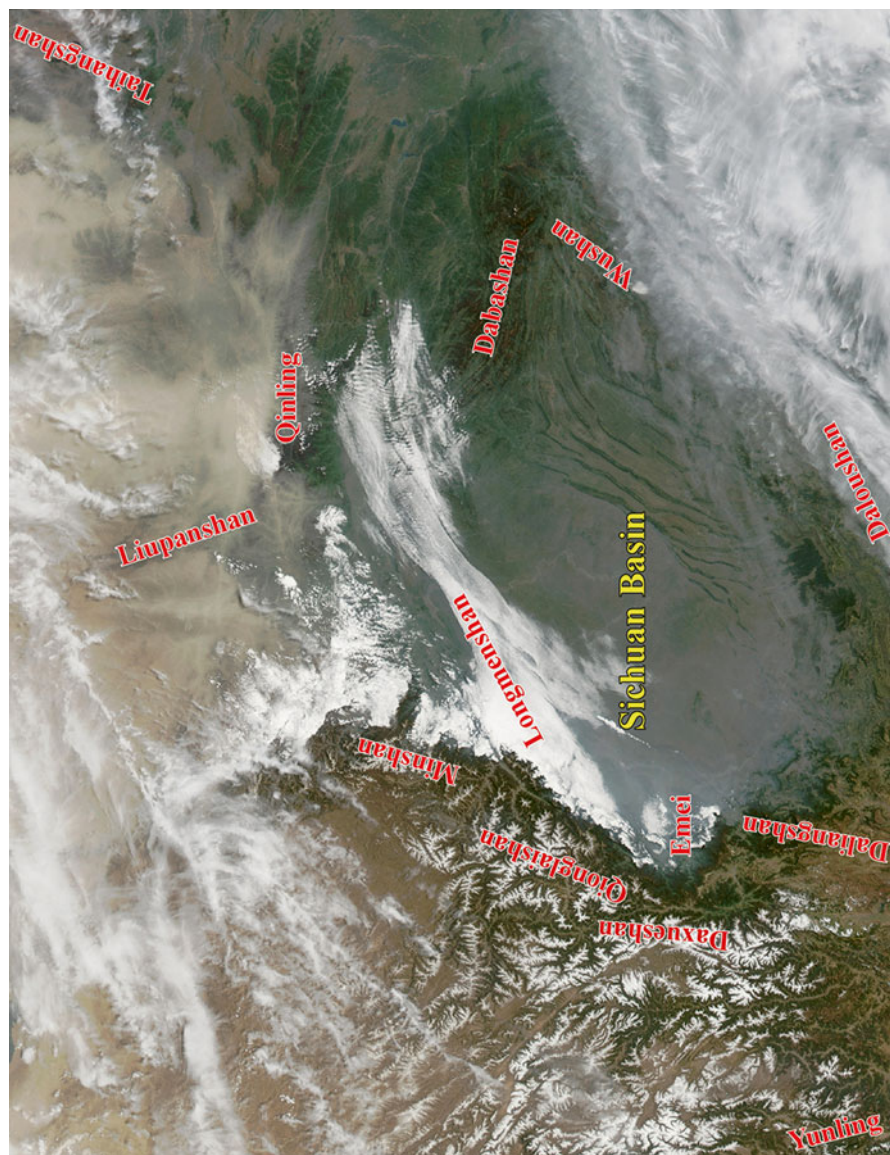


Fig. 1.5 The Sichuan Basin encircled by mountains



Fig. 1.6 An Evergreen broad-leaved forest ecosystem at 1,700–2,400 m asl in Bingzhongluo, northwestern Yunnan. Bingzhongluo is located in the northernmost part of Gongshan County; it is one of the largest valleys among the Nujiang gorges. It is also called the garden of the peaches of immortality, where the local people (mainly Nu, Lisu, Tibetan and Dulong) share an appreciation of nature's abundance that seems to have a parallel in their interracial harmony (Photograph courtesy of Huan-Chong Wang)



Fig. 1.7 A cloud forest dominated by evergreen broad-leaved tree species of *Lithocarpus*, *Cyclobalanopsis* and *Castanopsis* along with the Tertiary relict coniferous *Taiwania cryptomerioides* at c. 2,300 m asl in the Gaoligong Mountains, northwestern Yunnan



Fig. 1.8 Yubeng Village at 3,140 m asl in the foot hills of the Meilixue Mountains, northwestern Yunnan. On the mountain slopes, mainly evergreen sclerophyllous *Quercus* and various coniferous trees



Fig. 1.9 The Meilixueshan range at 6,000–6,740 m asl in northwestern Yunnan. A holy site as confirmed by the Tibetan Buddhist Baitas

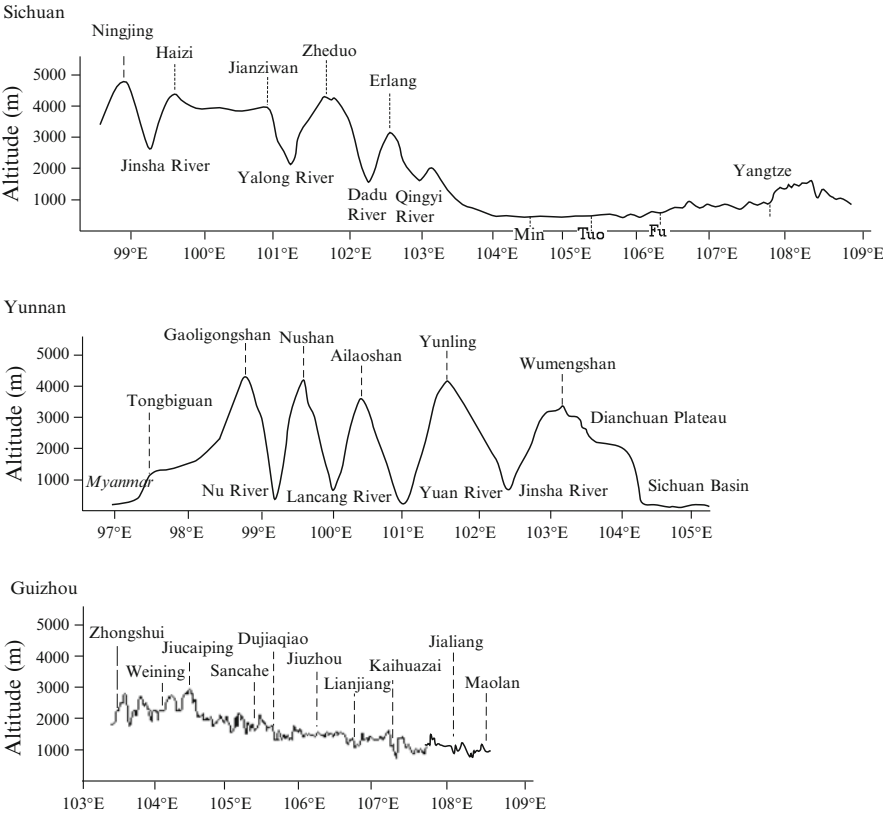


Fig. 1.10 Topographic profiles of SW China

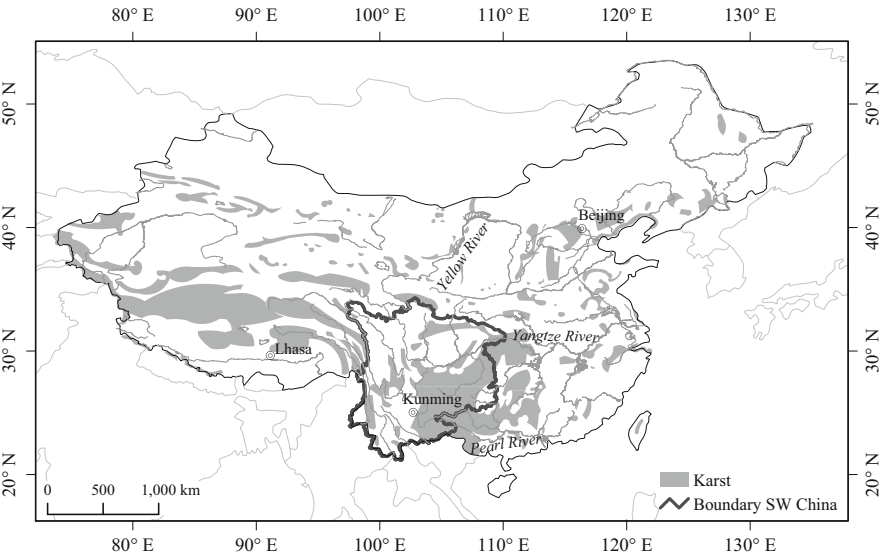


Fig. 1.11 Karst distribution in China (Data sources: Liu (1998), Huang and Cai (2009))



Fig. 1.12 Shilin (Stone Forest) at 1,800 m asl, central Yunnan. One of the world-famous karst landscapes



Fig. 1.13 Lugu, a plateau lake at 2,685 m, located between Linglong in Yunnan and Yanyuan in Sichuan

1.1.2 Climate

China's subtropical regions are bounded to the north by a line running between the Huai River and the Qinling Mountains (35° N), with a southern limit approaching the Tropic of Cancer. Eastward the subtropics extend to the coastlands and the islands of the East China Sea, the South China Sea and Taiwan; the westward limit is the Chinese national border, extending from the eastern slope of the Tibetan Plateau to southern Yunnan. The subtropical zone thus spans $11\text{--}12^{\circ}$ from north to south, 28° from east to west, and covers more than $2,400,000\text{ km}^2$ (Wu 1980). The region is divided into three different zones: (1) the southern subtropics (transitional tropics), extending from latitude 22° to 24° or 25° N; (2) the middle subtropics, which lie between 24° or 25° N and 31° or 32° N; and (3) the northern subtropics (transitional subtropics) which cover from 31° or 32° N to 34° or 35° N (Hou 1983). SW China is located at subtropical latitudes often distinguished as north, middle, and south subtropical (Fig. 1.14). A small part of southernmost Yunnan (e.g. Xishuangbanna) falls into the tropical zone. According to altitude, climates include tropical, subtropical, temperate, alpine and frigid. The climate is dominated by the Asian monsoon system, including the southwestern monsoon (the summer

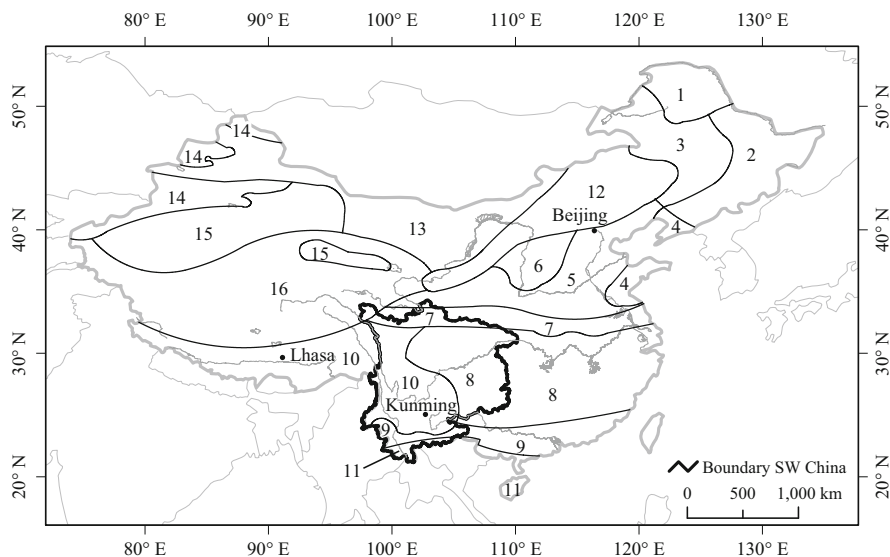


Fig. 1.14 Climate divisions of China. 1 Cold-temperate humid, 2 Middle-temperate humid, 3 Middle-temperate subhumid, 4 South-temperate humid, 5 South-temperate subhumid, 6 South-temperate subdry, 7 North-subtropical humid, 8 Middle subtropical humid, 9 South-subtropical humid, 10 Middle-subtropical subhumid and plateau, 11 Tropical humid, 12 Middle-temperate subdry, 13 Middle-temperate dry, 14 Middle-temperate alpine subdry, 15 South-temperate dry, 16 Plateau (dry and subdry) (Modified from The Normal College of Northwest China (1984), Winkler and Wang (1993))

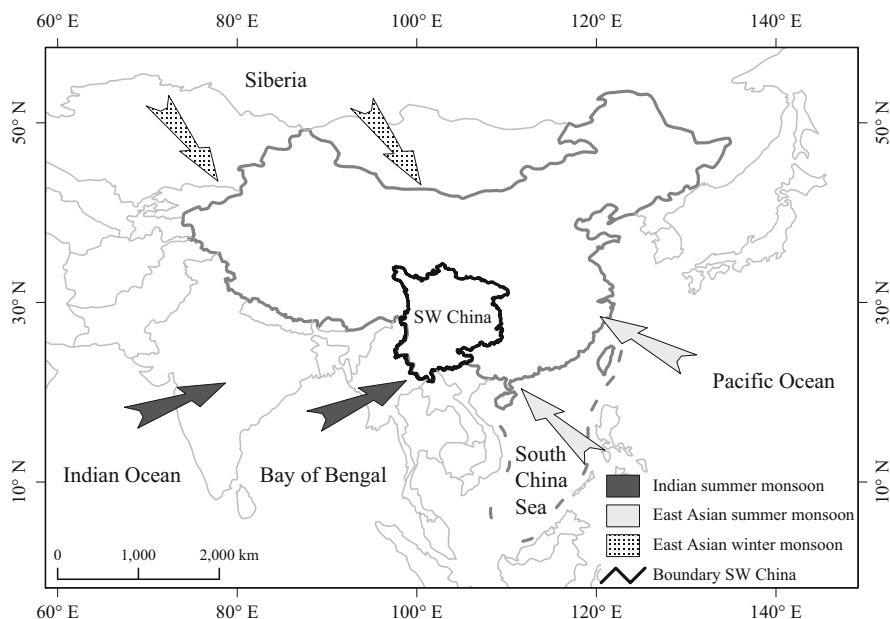


Fig. 1.15 Three monsoon winds in China

monsoon of India), the East Asian summer monsoon, and the East Asian winter monsoon, with dry continental winds in winter and moist oceanic winds in summer (Fig. 1.15). In China, generally the oceanic monsoon season begins earlier and ends later in the south than in the north, giving the south a longer rainy season and milder winter winds (Guo and Werger 2010). In early May, the southwestern monsoon (Indian summer monsoon) coming from the Bay of Bengal and the East Asian summer monsoon coming from the South China Sea advance onto the Yunnan-Guizhou Plateau. These two marine air masses become the source of summer rainfall and create these regions' hot humid summer climate, but they do not penetrate the interior of the Hengduan Mountains. As a result the deep mountain valleys of Yunnan are generally arid. Humidity to the west of the Ailao Mountains is generally higher than to the east, because of the stronger influence of the southwestern wind from the Bay of Bengal (Fig. 1.16). In winter the Tibetan Plateau hinders the invasion of the Siberian cold current into SW China. This is an important reason for the northward deviation of the limit of subtropical vegetation there. The Yunnan-Guizhou Plateau is rarely invaded by cold currents, but because the eastern plain of China lacks the protection of high mountains, the cold current from the Mongolian Cold High can reach to the far south, producing cold waves in the southeastern subtropics (Chang 1983; Wang 2005), for instance in Shanghai.

In Guizhou, the mean annual precipitation is 1,100–1,300 mm. In some areas (e.g. Fanjingshan) of eastern Guizhou, it reaches 2,600 mm. The annual rainfall generally decreases from the east to the west, and from the south to the north (Yang 1983; Wang and Wang 2002).

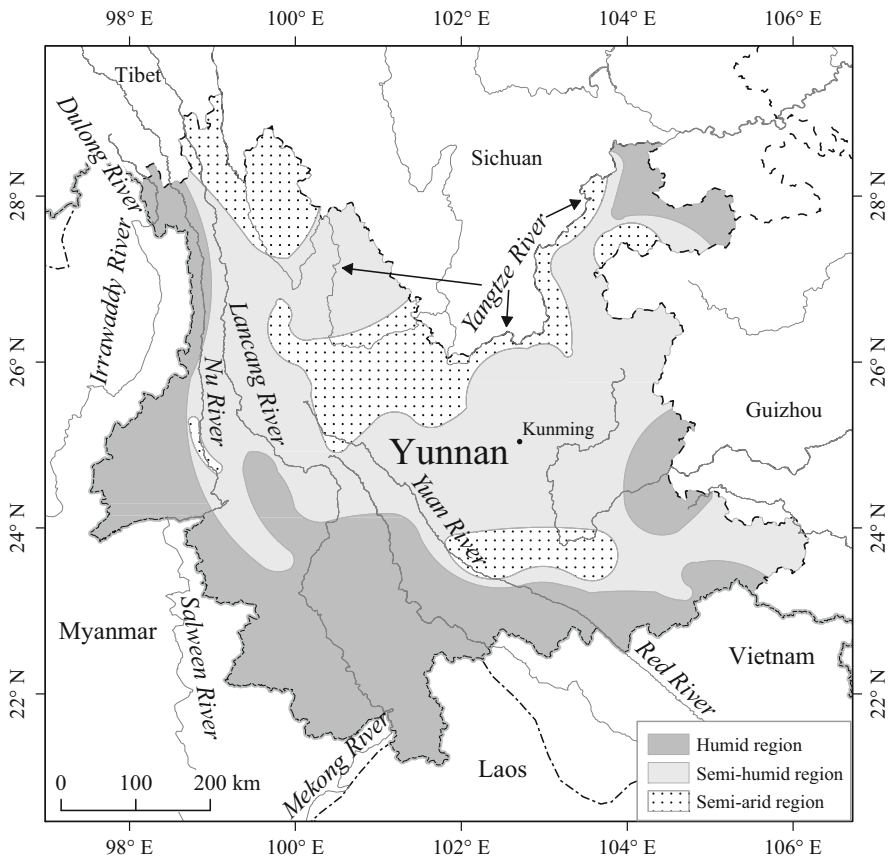


Fig. 1.16 Humidity patterns in Yunnan

The west of Sichuan is more strongly influenced by the southwestern wind from the Bay of Bengal, while the east (the Sichuan Basin) is more strongly affected by the southeastern wind from the South China Sea. The combination of strong seasonal winds and numerous mountain ranges results in many local climatic effects, from seasonally alternating windward and leeward slopes and rain shadows to the unusual, persistently cloudy climate of the Sichuan Basin. The overall characteristics of the climate of Sichuan can be summarized as follows: the warm, rainy monsoon climate is dominant. Regional climate differences are prominent: the east is characterized by cool winters, hot, hazy and rainy summers, humid autumns, almost year-round cloud and fog, and scant sunshine, while the north has moderately cold winters as it is protected from the southward movement of cold air from Central Asia; altitudinal climate variations are significant. The mean annual precipitation is generally 1,000–1,300 mm in the basin, but in the mountainous area at the basin’s west rim, it reaches 1,500–1,800 mm. This area is known as the “Rainy Zone of West China”. Sunny hours range from 900 to 1,300

per year. A local saying holds that in Sichuan, dogs bark when the sun appears. In contrast, a hot-dry climate predominates in the steeper river valleys, mainly in Yunnan and western Sichuan.

The climatic conditions of SW China in general are presented in Fig. 1.17a–f. Climate variations according to altitude, latitude and longitude in SW China are shown in Fig. 1.18.

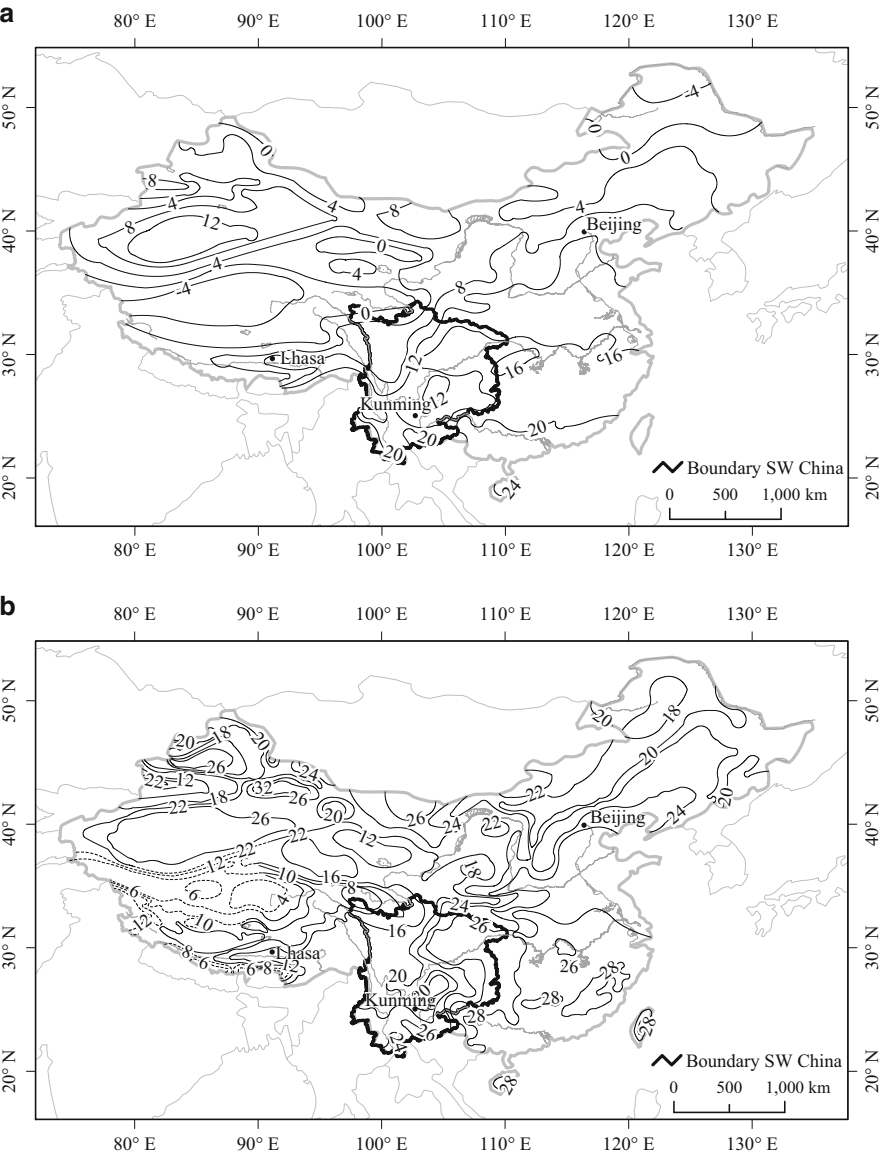


Fig. 1.17 Part 1 (a) Mean annual temperature (°C). (b) July temperature (°C). Isothermal lines at 4 °C intervals for (a), and 2 °C intervals for (b)

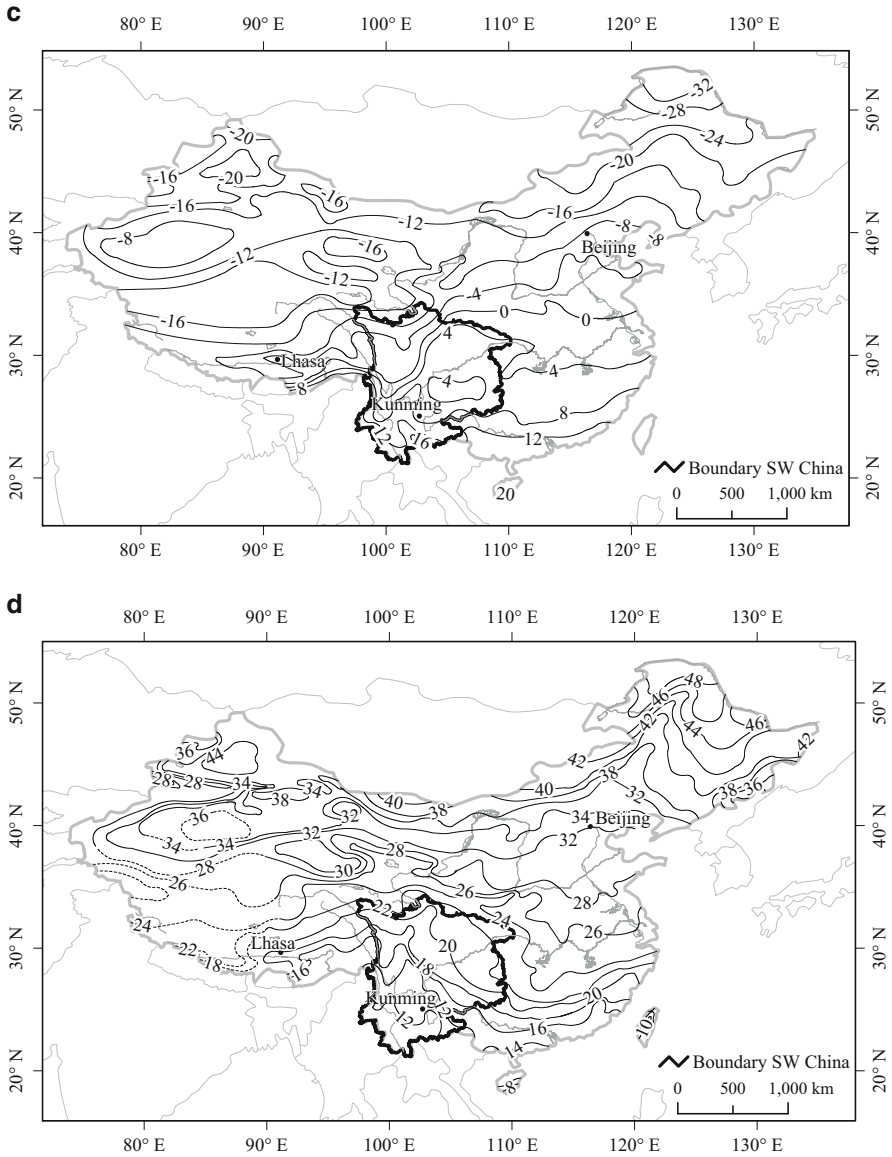


Fig. 1.17 (continued) Part 2 (c) January temperature ($^{\circ}\text{C}$). Isothermal lines at 4°C intervals. (d) Temperature ($^{\circ}\text{C}$) difference between coldest and warmest months. Isothermal lines at 2°C intervals

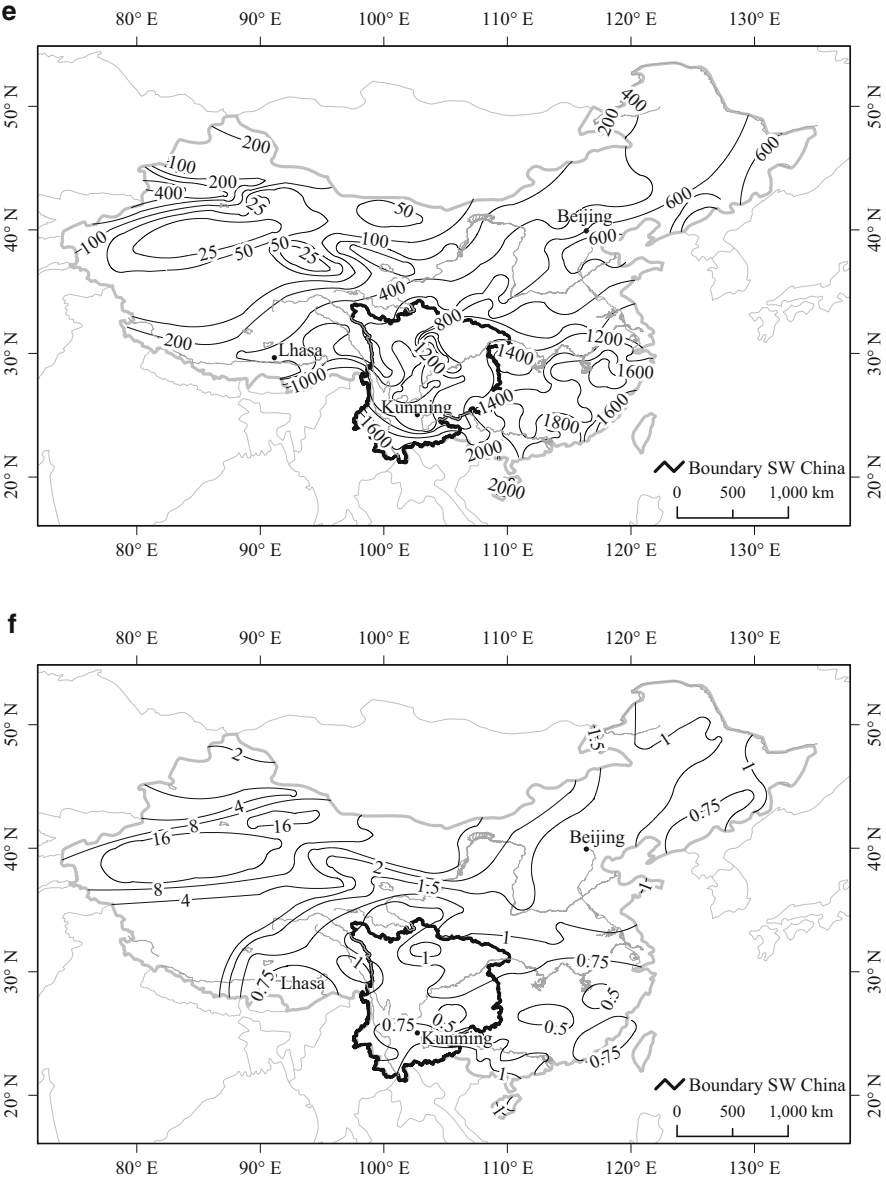


Fig. 1.17 (continued) Part 3 (e) Annual precipitation (mm), isohyetal lines at 200 mm intervals for areas that received over 400 mm. (f) Aridity index, isolines at 0.25 intervals (a–f are Modified from Ren et al. (1985), Winkler and Wang (1993))