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Landscape and Ecosystem Diversity, Dynamics and Management in the Yellow River Source Zone

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To our families and colleagues who provided immense support that helped us make this project happen

Preface—A Personal Comment

> Just as landscape defines character, culture springs from a spirit of place.
>
> Wade Davis (2009, p. 33).

Landscapes evoke multiple memories and emotions through layers upon layers of interactions and interpretations, convergent and divergent, steadfast and emergent, contemporary and historical. They evoke notions of place. Identity. Home. Belonging. Nostalgia (Solastalgia). Perhaps inevitably, contestation is common. Hopefully, a 'duty of care' emerges from the midst of these connections.

Just as 'beauty lies in the eye of the beholder', scientific framings that are used to tackle any issue bring particular perspectives to bear, shaping what is seen (entities, patterns, linkages, etc.) and how it is assessed. Inevitably, approaches to landscape analysis reflect our training and experience. Everything is contextual. Instinct and intuition come to the fore. What is new/familiar? How does it relate to what has been seen/experienced previously? This has enormous implications for how these understandings are derived and how they are used to inform management applications.

The Upper Yellow River is an intriguing and awe-inspiring place. Although it presently attracts relatively few overseas visitors, rapid infrastructure developments will make the area much more accessible in coming years. To date, most environmental research in this region has been derived from remotely sensed and modelled applications. This book supplements these analyses through various field investigations. Work conducted by researchers at Qinghai University is supplemented by insights and perspectives from various researchers at the University of Auckland in New Zealand, who worked alongside researchers at Tsinghua University and the Chinese Academy of Sciences in Beijing as part of the environmental arm of the Three Brothers (Plus) Project since 2007.

Writing and compiling this book has been a very demanding process, pulling together threads of enquiry from divergent sources and perspectives. Given many contestations relating to various issues in environmental science and management in the region, we have not tried to force a consistent perspective throughout the book. Such is the nature of research. Having said this, we hope that the book does justice to our own voices among many others that are not directly considered here.

Although it is not always possible to avoid technical terminology, we have tried to minimize the use of jargon in efforts to make the book accessible to a non-specialist audience.

The landscapes and ecosystems of the Upper Yellow River have their own particular magic. Hopefully, our efforts in this book enable others to share some of that magic, and encourage others to experience it directly. At the same time, we have to look after the special values of such places …

The dark night gave me black eyes,

I use them nonetheless seeking for the light.

A Generation: Gu Cheng

Reference

Davis, W. (2009). *The wayfinders: Why ancient wisdom matters in the modern world*. House of Anansi.

Oneroa, Waiheke Island Gary John Brierley
November 2015

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Although this book is first and foremost New Zealand–China collaboration, a recurrent thread of Australian thinking pervades those parts of the book with which the lead editor was involved. Reflections upon vast landscapes provide an ongoing sense of intrigue and inspiration, providing a distinctly calming influence among tempestuous circumstances (anyone undertaking such ventures should carefully consider the practicalities of workload, professional and personal commitments within which such work is completed, remembering that opportunistic moments of inspiration may be somewhat delusional). With patience and hard work, we got there in the end! This would not have happened without support structures around us. We extend particular thanks to family and friends who helped us get there, in the sincere hope that our efforts to work through challenges that were faced, and successfully negotiated, prove to be both productive and worthwhile. Truly, sincere thanks!

We particularly acknowledge the efforts of many colleagues who supported field ventures in the Upper Yellow River Basin. This includes those who helped make this happen through logistical and administrative support from afar. Conversations and sharing of perspective were truly invaluable. Thanks to all participants for openness in promoting a healthy and lively spirit of enquiry. Also, the parties were truly memorable, underpinning the remarkable social and cultural spirit of the New Zealand–Qinghai connections. And if these spirits weren't quite sufficient, the baijou did the rest!

We extend particular thanks to Louise Cotterill at the University of Auckland who drafted and modified many of the figures in this book. In addition, we thank various publishers who granted permission to reuse or modify numerous figures in the book. We thank Wiley for permission to use figures from:

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- Figure 1 on page 2 in Yao, T., Masson-Delmotte, V., Gao, J. et al. (2013). A review of climatic controls on δ^{18O} in precipitation over the Tibetan Plateau: Observations and simulations. *Reviews of Geophysics*. 51: 525–548.
- Figure 1 on p. 2941 in Chen, H., Zhu, Q., Peng, C. et al. (2013). The impacts of climate change and human activities on biogeochemical cycles on the Qinghai-Tibetan Plateau. *Global Change Biology*. 19: 2940–2955, doi: 10.1111/gcb.12277
- Figure 3 on p. 77 in Li X.L, Gao J., Brierley G., et al., (2013a). Rangeland degradation on the Qinghai-Tibet Plateau: Implications for rehabilitation. *Land Degradation and Development*, 24: 72–80.

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Contents

Chapter 1
Introduction: Landscape and Ecosystem Diversity in the Yellow River Source Zone

Gary John Brierley, Xilai Li, Carola Cullum and Jay Gao

Abstract The Upper Yellow River lies at the margins of and atop the Qinghai–Tibet Plateau. This chapter provides an overview of contemporary understandings of the geography, geology, climate, geomorphology and palaeoenvironments, vegetation, and fauna of the area. Tectonic uplift and river incision have induced a wide range of charismatic landscapes, many of which retain a significant imprint from Quaternary environmental changes, especially the glaciated mountains, vast lake, river, permafrost, desert and loess landscapes, and countless wetland areas. The plateau is an important alpine biodiversity hot spot. The high elevation, along with prevailing semi-arid/arid climatic conditions and associated vegetation cover, has created distinctive but vulnerable ecosystems. Large grassland areas support sparse populations of nomadic herdsmen. Mounting evidence suggests that human activities over thousands of years have induced a regime shift from forest cover to grazing-adapted grassland across much of the plateau. In recent decades, population growth has accompanied demands for economic expansion as part of the 'Great Development of the West' in China. Climate change and human activities threaten the landscapes and ecosystems of the Upper Yellow River. Telltale signs of accelerated environmental adjustments include retreating glaciers, melting permafrost, decreasing river flows, shrinking lakes and wetlands, hillslope instability, degrading vegetation, declining grassland productivity, salinity problems, and

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accelerated desertification. In outlining the structure of this book, this chapter draws attention to three key threads of enquiry: the primacy of landscape diversity and notions of place as an integrative platform for applied research, the importance of field-based understandings alongside remotely sensed applications, and how viewing humans as part of ecosystems helps to shape prospects for more effective approaches to environmental management.

Keywords Landscape · Ecosystem · Geodiversity · Climate change · Human impact · Degradation · Ecosystem services · Environmental management

1.1 Opening Statement: What the Book Is About and Why It Has Been Written

Concerns for environmental and societal security are especially pronounced in those parts of the world where strong pressures for development exist alongside severe threats to biodiversity and the natural environment. These tensions lie at the heart of the sustainability agenda. They are played out on an ongoing basis in the source zone of the Yellow River, where societal pressures for rapid economic development compete against desires to preserve the natural resources upon which that development depends.

The source zone of the Yellow River is perhaps most renowned for its topographic setting atop the Qinghai–Tibet Plateau—the highest plateau in the world (Fig. 1.1). The plateau has an average elevation of 4000 m above sea level and an area of about 2.6 million km^2, stretching approximately 1000 km north to south and 2500 km east to west. Framed alongside adjacent mountain ranges, this area is sometimes referred to as the 'Third Pole' or the 'Roof of the World' (Qiu 2008). The area is peculiarly cold for its latitude—colder than anywhere else outside the polar regions. After the Antarctic and the Arctic, the Qinghai–Tibet Plateau and surrounding mountains make up the Earth's largest store of ice, with more than 100,000 km^2 of glaciers (Qiu 2008; Yao et al. 2012). In addition to being the source region for many of the world's great rivers, including the Tsangpo–Brahmaputra, Mekong, Yangtze, and Yellow Rivers, much of the surface of the high central plateau drains internally to large basins, such as the Qaidam and Qinghai Lake basins. The Sanjiangyuan (Three River Source Zone) comprises the headwaters of the Yellow, Yangtze, and Lancang (Mekong) Rivers. This region is known as the 'kidney of the earth', the 'cradle of living forms', and 'the water tower of China', acting as a vital reservoir for water resources in East Asia (Qiu 2008; Yao et al. 2012). Approaches to environmental management atop the plateau have enormous implications for much of China and, beyond, exerting a significant influence upon the social and economic development of China, India, Nepal, Tajikistan, Pakistan, Afghanistan, and Bhutan—collectively home for one-fifth of the world's population (Yao et al. 2012).

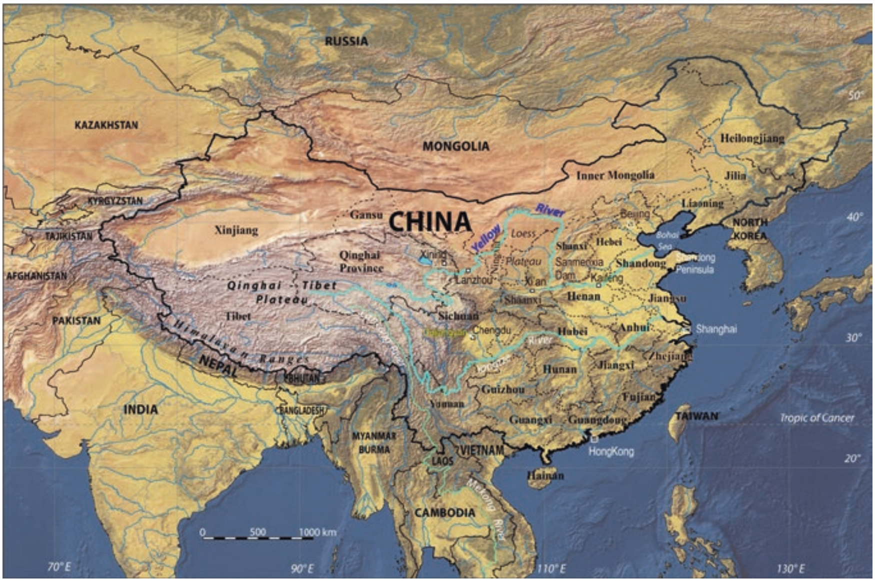

Fig. 1.1 The Yellow River Source Zone lies within the Qinghai–Tibet Plateau. This is the highest and largest plateau in the world, extending over an area of 2.58 million km^2. Elevations range from 3000 to 5000 m. Qinghai Province is shown in relation to adjacent mountain and desert area in China and neighbouring states. Collectively, the headwaters of the Yellow, Yangtze, and Lancang (Mekong) rivers make up the Sanjiangyuan (Three River Source Zone) in southern Qinghai Province

This book provides an overview of the remarkable landscapes and ecosystems of the Upper Yellow River in the north-eastern part of the Qinghai–Tibet Plateau. Tectonic uplift and river incision have induced a wide range of charismatic landscapes in this region, many of which retain a significant imprint from Quaternary environmental changes (Fig. 1.2). Large sedimentary basins were infilled by vast volumes of lacustrine, riverine, and aeolian (wind-blown) sediments over millions of years. These basins and intervening mountain ranges were then incised and reworked by the Upper Yellow River and its tributaries, creating dramatic gorges and extensive terrace sequences that are up to 1 km deep and tens of kilometres wide (Craddock et al. 2010). Uplift and river capture have realigned rivers and created new inland-draining basins, such as the Qinghai Lake. The imprint of past climates is seen in the glaciated mountains, vast lake, river, permafrost and desert landscapes, and countless wetland areas. Aeolian processes mould and reshape landscapes, with localized areas of active sand dunes representing a mere ‘drop in the ocean’ relative to the vast volumes of finer-grained loess deposits that drape the north-eastern part of the region and the adjacent Loess Plateau.

The climate of the region is harsh and inhospitable. Although the average annual temperature is below 0 °C, the area is subjected to very long hours of sunshine. Annual precipitation across the region decreases from the south-east to north-west, ranging from 250 to 750 mm.

Subdued landscapes of the 'headwaters' region of the Upper Yellow River above Zhaling Lake

Eling Lake, close to the headwaters of the Yellow River - the 'Mother River of China'

Dunes and wetlands at Star Lakes near Maduo

Antelope crossing a tributary of the Upper Yellow River near Maduo. Note the largely decoupled hillslope-valley floor interactions in this area

Tributary of the Upper Yellow River between Huashixia and Dari, with the Anyemachen Mountains in the background

Incisional landscapes of Chengen He, a tributary of the Upper Yellow River that has incised through the vast deposits of a previously inland-draining' (trapped) basin

Fig. 1.2 Characteristic physical landscapes of the Qinghai–Tibet Plateau

The high elevation, along with prevailing semi-arid/arid climatic conditions and associated vegetation cover, has created distinctive but vulnerable ecosystems, with many iconic and endemic species, some of which are threatened or endangered (Fig. 1.3). Spatial distributions of many living forms have been marginalized in this area. The plateau is an important alpine biodiversity hot spot, with estimates of the number of plant species ranging from 9000 to 12,000 (Liu et al. 2014).

Eroding sandstone landscapes of the middle reaches of the Upper Yellow River

Majestic sandstone landscapes of the middle reaches of the Upper Yellow River

Dramatic terraces of the Upper Yellow River at Kesheng, Henan County

A majestic telescopic fan of the Upper Yellow River downstream of Tongde

Dissected sandstone (Danxia) landscapes at Guide, adjacent to an anabranching reach of the Upper Yellow River

Dissected sandstone (Danxia) badland landscapes of the Upper Yellow River at Guide

Fig. 1.2 (continued)

Over 20 % of these species are endemic. Biodiversity tends to decrease with altitude, as well as towards the colder and drier north-west. Ecosystem types in the region range from subtropical rain forest in the south-east to alpine desert in the north-west. Much of the region now has a sparse cover of shrubs and occasional trees, with alpine grasslands comprising more than 50 % of the whole plateau area (Chen et al. 2014; Qiao and Duan 2016, Chap. 6). Large areas of grassland, characterized by a flourishing herbaceous layer when healthy, support sparse populations of nomadic herdsmen.

Fig. 1.3 Distinctive fauna of the Upper Yellow River

A distinct anthropogenic signature sits atop the natural variability of the region (Fig. 1.4). Despite its inhospitable environment, the Qinghai–Tibet Plateau is now occupied by over seven million people, mostly indigenous Tibetans. Tibetan families account for the vast majority of the herding families, with a small number of other nationalities such as Chinese Han, Hui, Sala, and Mongolian. The population is very small relative to the vast area.

The plateau was once considered one of the world's most recently populated areas by humans. However, archaeological, linguistic, and genetic findings have transformed this perspective in recent decades. Emerging understandings indicate that the population of this region has multiple origins, extending back at least 20–30,000 years (Aldenderfer and Yinong 2004; Brantingham and Xing 2006; Qin et al. 2010). Genetic studies indicate that the uniquely evolved physiological capacities seen among modern Tibetan populations required long-term exposure to high-elevation selective pressures. Seasonal foraging in high-elevation settings of the plateau likely began between 30,000 and 15,000 years ago. More permanent

Tibetan cultural values are a characteristic feature of the region

Agriculture at the margins (near Qinghai Lake), where water is a prized asset, and desertification an inevitable risk

A typical grassland scene. Tending yak is the mainstay of the agricultural economy of Qinghai Province

Yak grazing landscapes of the Qinghai-Tibet Plateau

A typical grassland scene: low relief landscapes and wetlands with yak between Huashixia and Maduo

Alpine meadow vegetation … 'golf course' rangelands of the Upper Yellow River

Typical grassland scene, Qinghai Province

Bee keeping among the rapeseed (canola) near Qinghai Lake

Regional towns such as Tongde are largely agriculturally based, with limited industrial development

Xining, the capital of Qinghai Province, is by far the largest city in the Upper Yellow River Basin

Fig. 1.4 Characteristic sociocultural landscapes of the eastern part of the Qinghai–Tibet Plateau occupation of the plateau probably did not begin until about 8200 years ago, when herders from low-elevation environments were driven further afield by emerging settled agricultural groups. By 6000 years ago, herders in mid-elevation areas were joined by agriculturalists, so herders migrated to still higher altitudes (Qin et al. 2010).

There is mounting evidence to suggest that human activities over thousands of years have induced a regime shift in vegetation dynamics across much of the plateau from forest cover to grazing-adapted grassland ecosystems (Miehe et al. 2009). While grassland vegetation would have been present within the open basins and valleys of the plateau, woody vegetation and trees would have been found on sunny mid-slopes and sheltered gorges (Tane 2011). However, these forested areas have disappeared over the last 6000 years, due likely to human activities (Herzschuh et al. 2010; Miehe et al. 2009). The history of nomadic people herding yaks possibly stretches back over 8800 years (Miehe et al. 2008a, b, 2009). The emergence of modern grazing systems around 2200 years ago instigated the establishment of grazing-adapted *Kobresia* pastures (see Miehe et al. 2009, 2011, 2014; Schlütz and Lehmkuhl 2009).

Livestock grazing is the main component of the regional economy (Fig. 1.4). Although agriculture is practised up to an elevation of 3300 m, the area of tillage atop the plateau is very limited, restricted primarily to fertile valley floors at the margins of the plateau. It accounts for only 0.3 % of the land area of the Yellow River Source Zone.

Low population numbers, the low intensity of farming practices, and the lack of industrial development have restricted the impacts of human activities upon landscapes of the region. In general terms, animal husbandry practices associated with the predominantly Tibetan peoples of this area have been 'sustainable' for several thousand years. However, population growth and development pressures are increasing—both in their extensiveness and their intensity. Demands for economic expansion as part of the 'Great Development of the West' have been supported by extensive infrastructure programmes that make the region increasingly accessible, helping to establish primary industries, mining developments, and tourism. Inevitably, the rapid development of the region is impacting upon traditional lifestyles and land use practices. Some researchers contend that population increases and policy-induced land use changes since the 1980s have led to overgrazing and consequent grassland degradation, wetland loss, and desertification (Fan et al. 2010; Gao 2016, Chap. 10; Li et al. 2012; Li et al. 2016a, Chap. 7; Qiao and Duan 2016, Chap. 6; Li and Wang 2016, Chap. 8; Tane et al. 2016, Chap. 13; Zhang et al. 2015). Others attribute these changes to shifts in climate (see discussion in Li et al. 2016a, Chap. 7). To date, a coherent picture of the underlying mechanisms causing these changes is yet to emerge (see Chen et al. 2013; Harris 2010; Li et al. 2013). Lack of clarity on these issues adds to uncertainty as to the most appropriate management responses (see Brierley et al. 2016b, Chap. 15; Harris et al. 2015; Wen et al. 2013; Wu et al. 2013; Zhang et al. 2013).

The United Nations Convention to Combat Desertification (UNCCD) defines land degradation such as that seen in the landscapes of the Upper Yellow River as 'a persistent reduction in biological and economic productivity' (UNCCD 1994).

It is especially prevalent in dryland regions, where degradation exerts adverse impacts on biomass productivity and landscapes and ecosystems are characterized by extremely low primary productivity, nutrient poor soils, and sparse and patchy vegetation, impacting upon prospects for food security, biodiversity, and environmental sustainability (Mueller et al. 2014). Physical processes of land degradation include soil erosion by wind and water and changes to soil structure such as crusting and compaction. Significant chemical processes include acidification, leaching, salinization, and nutrient depletion. Biological processes include alterations to plant cover and ecosystem functionality (e.g. invasive species) resulting in a loss of biodiversity. Collectively, these processes reduce soil fertility and the economic productivity of the land. As a consequence, these systems become increasingly vulnerable to social and environmental perturbations, impacting on the ecosystem services provided by these landscapes.

Both climate change and human activities threaten the landscapes and ecosystems of the Upper Yellow River. In recent decades, telltale signs of accelerated environmental adjustments have become evident: retreating glaciers, melting permafrost, decreasing river flows, shrinking lakes and wetlands, hillslope instability, degrading vegetation, declining grassland productivity, salinity problems, and accelerated desertification (Fig. 1.5). Mean temperature across the plateau as a whole has increased by up to 0.3 °C a decade over the last 60 years—approximately three times the global rate (Piao et al. 2011; Qiu 2008). Climate and cryospheric changes have been especially pronounced over the last three decades (Kang et al. 2010). Increasing precipitation trends in central areas of the plateau in recent decades contrast with decreasing trends at the plateau margins. Evaporation is increasing across the area. As a result, river discharge shows a declining trend in the semi-humid and humid zones in the eastern and southern plateau. Permafrost areas are especially at risk, as rising temperatures cause the active ground layer—which freezes and thaws every year—to thicken. This not only presents challenges for construction and infrastructure maintenance, but also endangers the plateau's alpine ecosystems (Qiu 2008). The lower limit of permafrost has risen by 40–80 m over the last 50 years, with the total area declining by about 7 % (Jin et al. 2007).

Significant controversy surrounds approaches to the protection of environmental values in the region, with differing perspectives upon the role of local peoples as agents of landscape change, impacts upon ecosystems (especially grassland and wetland degradation), and prospective environmental futures (see Brierley et al. 2016b, Chap. 15). Balancing the benefits of economic development and societal well-being against environmental risks and desires for conservation and rehabilitation is a critical challenge. Immense environmental, political, developmental, and cultural issues are at play.

Despite the global significance of the area, in biophysical and sociocultural terms, the formal literature on the landscapes and ecosystems of the Upper Yellow River is remarkably thin and lacking in coherence. Sound, integrated guidance for informed decision-making is lacking. The marked variability in the diversity of landscape forms and processes is seldom appreciated, with few attempts to appropriately contextualize understandings in spatial and temporal terms.

Retreating glacier atop the Qinghai-Tibet Plateau, viewed from the Xining-Lhasa railway

Changes to permafrost impact upon hillslope processes such as these solifluction lobes at Huashixia

Hillslope wetlands, valley margin features and floodplain ponds are sensitive to climate and land use change

Desertification threatens local areas of the Upper Yellow River basin as a result of changing vegetation patterns

Dust/sand storm at the margins of Qinghai Lake

Plateau pika: Friend or foe? Ecosystem engineer or pest?

Fig. 1.5 Environmental and sociocultural values of the Upper Yellow River and adjacent regions that are under threat

Biological diversity is inextricably linked to the variety of landscapes in any ecoregion. Geodiversity is fundamental to habitat diversity, presenting a major control on the distribution of life, as ecological potential is highly dependent on the quality and quantity of available habitat. Understanding controls on the quantity, quality, and distribution of natural habitat provides fundamental insights into the health and resilience of associated ecosystems and their potential for recovery if degraded. More importantly, analyses of landscapes also provide an integrative basis to assess economic opportunities and sociocultural connections, from which a sense of identity and belonging emerges.

Biophysical attributes also exert a critical influence upon ecosystem services, such as water quality and quantity, habitat availability and viability, nutrient cycling, soil fertility/health (including microfauna), and key measures of ecosystem functionality. These issues are fundamental to societal well-being. Despite their importance, scientific understandings of environmental issues in the source zone of the Yellow River remain fragmented, with relatively little integration among fields such as geomorphology, terrestrial and aquatic ecology, hydrology (water resources), climatology, and human ecology (see Qi 2016, Chap. 11). More importantly, discipline-bound framings seldom extend across to meaningful incorporation of socio-economic and cultural associations, and local knowledge. Such fragmentation engenders incomplete and possibly incorrect understandings of socio-ecological systems, limiting our capacity to generate appropriate approaches to the management of complex environmental issues. Appropriate management programmes strive to establish healthy, productive, and resilient ecosystems that are able to recover from, rather than resist, disturbance. A sound information base that conveys coherent process-based understanding of spatial and temporal diversity, variability, and evolutionary traits is a fundamental requirement for effective management practice.

Among many factors, the inaccessibility of the region has inhibited efforts to generate coherent, systematic understandings of key biophysical attributes of the landscapes and ecosystems in this region. In recent decades, this shortcoming has been rectified, in part, by much greater availability of remotely sensed information. While such data sources provide an invaluable basis to establish a sense of context and variability, they are only a partial alternative (and not entirely appropriate) substitute for field-based analyses.

This book seeks to start to address this shortcoming, using a geomorphic (landscape) approach to relate locally derived, field-based understandings of landscapes and ecosystems to broader, remotely sensed applications undertaken across the Upper Yellow River. In this book, the distinctive landscapes of the Upper Yellow River provided a fundamental backdrop for collaborations among researchers from differing cultural and disciplinary backgrounds, including environmental scientists (geomorphologists, hydrologists, soil scientists, ecologists (terrestrial and aquatic)), agricultural scientists, and engineers. A concerted effort has been made to link threads together in an effective manner, reflecting upon spatial and temporal variability across the region.

Scientific and managerial controversies abound in the source zone of the Yellow River. Examples of major issues include the following:

- The specific timing of the development and infilling of sedimentary basins atop the Qinghai–Tibet Plateau, their relationships to phases of tectonic uplift, and subsequent responses to river incision (and associated timings of river capture that fashioned the evolution of drainage networks) are yet to be resolved.
- Although it is now broadly recognized that the Last Glacial Maximum (around 15,000 years ago) was much smaller than previous phases of glacial expansion, the magnitude and extent of past phases of glacial activity remains contentious.

- Accurate and comprehensive understanding of lake, desert, and sand dune histories is underdeveloped.
- Relationships between landscape forms and processes and vegetation interactions, soil development, biodiversity patterns and traits, etc., are poorly established.
- Controversy surrounds the history of human settlement atop the plateau and associated impacts upon environmental conditions. Additional insights are required to assess how and why humans adapted to (and in turn impacted upon) environmental conditions upon the plateau.
- There is significant disagreement about the extent, timing, gravity, and underlying causes of environmental degradation in differing parts of the region, and the designation and implementation of management responses. Key examples include issues such as ecological migration programmes through an imposed reserve (Ran et al. 2016, Chap. 14), and approaches to the management of grassland, wetland, and desertification issues (such as the use of enclosures, revegetation programmes, whether plateau pika is a fundamental ecosystem engineer or a pest).

One thing is for sure—there are countless opportunities for future research in this region!

The key premise of this book is a simple one—we must have appropriate understandings of resources before we can manage them effectively. Despite assertions that 'wilderness is dead' (Wohl 2013), and recognizing explicitly that we live in an increasingly human-dominated world (the Anthropocene), there are still some truly remarkable and remote areas where we remain in awe of nature's beauty and overwhelming majesty. Somehow, the vast yet diverse landscapes and ecosystems of the Upper Yellow River make humans feel quite insignificant! However, the pronounced and pervasive sociocultural imprint on the landscapes and ecosystems of the region presents ongoing concerns for human relations to nature, and our quest for notional 'harmony' in efforts to ensure that a 'duty of care' protects distinctive attributes of the region into the future. It is hoped that the scientific foundations outlined in this book can be used alongside local understandings to develop shared, authentic, and genuinely grounded approaches to environmental management of this remarkable place. Our intent is to support the development of socially situated science that effectively bridges and combines fieldwork and remotely sensed applications. However, prospects for the emergence and uptake of truly shared understandings are one thing—it is their uptake and ongoing adaptation that fashions environmental outcomes.

The remainder of this chapter presents contextual information on the geology, climate, geomorphology/soils, palaeoenvironmental conditions, vegetation, fauna, and human activities of the Upper Yellow River. The chapter concludes with a summary of the structure of the book. Prior to considering these issues, a geographic overview of the Yellow River Basin sets the scene for more detailed investigations of the landscapes and ecosystems of the region.

1.2 An Overview of the Yellow River Basin

The Yellow River (Huang He in Chinese Pinyin) has a special place in the hearts and minds of many Chinese people. As a source of great prosperity, it is often referred to as China's pride, the Mother River and the 'cradle of Chinese civilization'. The river has long-standing cultural associations. In traditional Chinese folklore, it was considered to flow from heaven as a continuation of the Milky Way (Elvin and Liu 1998). Conversely, the river is sometimes referred to as 'China's sorrow' or the 'Scourge of the Sons of Han'. Floods along the lower course of the river in 1332–1333 and in 1887 and 1931 are among the most devastating natural disasters anywhere in the world, as subsequent famines and disease killed more than a million people in each instance.

The Yangtze and Yellow rivers provide major links between the world's largest continent (Asia) and its largest ocean (the Pacific). From its origins in Qinghai Province, the Yellow River flows across eight other provinces and autonomous regions before emptying into the Yellow Sea north of the Shandong Peninsula (Fig. 1.6). The river provides water for around 150 million people, approximately 9 % of China's population. It is 5464 km long and drains an area of 753,000 km^2 (IRTCES 2005). Its basin extends approximately 1900 km from west to east and 1100 km from north to south. It is the third longest river in Asia and the sixth longest river in the world.

The average annual discharge of the Yellow River is greater than 2100 $m^3\ s^{-1}$. Around 60 % of the annual flow occurs during the rainy season from July to

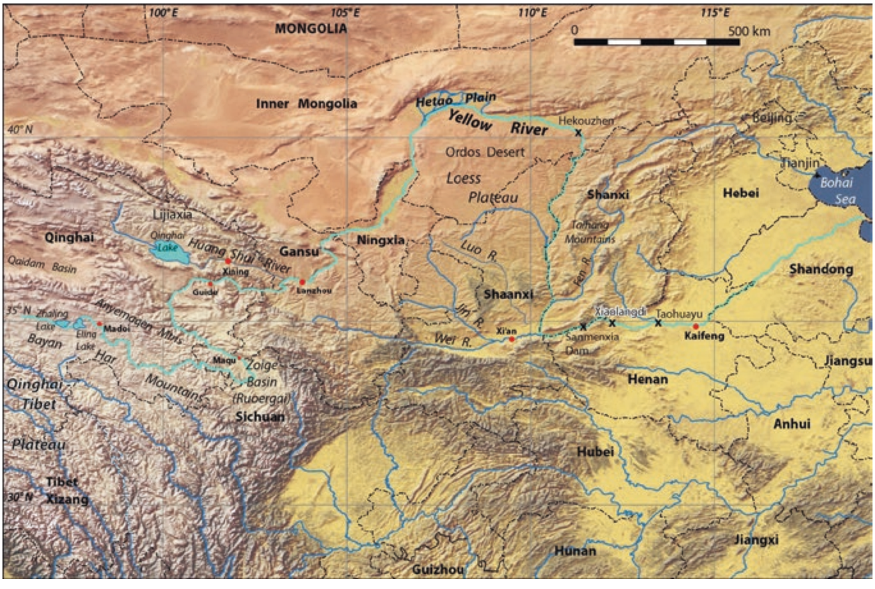

Fig. 1.6 A geographic overview of the Yellow River Basin

October, reflecting a strong monsoon-driven influence. The name ‘Yellow’ refers to the perennial colour of the muddy river water in the middle-lower reaches. Indeed, the traditional Mongolian name for the middle course was the ‘Black River’, in reference to high sediment loads. This is one of the most sediment-laden rivers in the world, with concentrations as high as 920 kg m^{-3} and annual sediment loads of around 1.6×10^9 tons (a peak of 3.9×10^9 tons was estimated for 1933). Although the Yellow River ranks 26th in the world in terms of drainage area, it is second only to the Amazon in terms of sediment delivery to the oceans.

Two major steps demarcate pronounced changes in topographic gradient along the course of the Yellow River: between the Qinghai–Tibet Plateau and the Loess Plateau upstream of Lanzhou and between the Loess Plateau and the North China Alluvial Plain near Xiaolangdi (Fig. 1.7). This book is concerned solely with the area above the first step, at the margins of and atop the Qinghai–Tibet Plateau.

From its source at an elevation of around 4600 m, the Upper Yellow River first flows east through a series of basins and deep gorges and then turns north-east at the city of Lanzhou in Gansu Province (Figs. 1.6 and 1.7). Officially, the Upper Yellow River extends from the river source to Hekouzhen in Inner Mongolia Autonomous Region at an elevation of 1000 m (see Section 1.3; Fig. 1.6; IRTCES 2005). Based on this designation, the Upper Yellow River contributes about 56 % of the total run-off but only 10 % of sediment load of the whole river basin (Huang et al. 2016, Chap. 4; Wang et al. 2006; Xu et al. 2007). Unlike middle and lower reaches, the upper section of the river has been subjected to limited flow regulation impacts. However, dam developments in various gorges at the margins of the Qinghai–Tibet Plateau are placing increasing pressure upon the flow and sediment regimes of the Upper Yellow River. Because of the low population numbers and densities, the extensive nature of farming practices, and the lack of industrial development, water quantity remains abundant in this region, and water quality is good (Ouyang et al. 2010). The river flows clear for large parts of the year, with low levels of sediment concentration and pollutants, only earning its ‘Yellow’ name in middle and lower reaches. The local Tibetan name for the upper river is Ma Chu (river of the peacock).

In contrast to the upper course, much of the middle and lower courses of the Yellow River has been subjected to intensive human disturbance throughout its long history, including deforestation, land reclamation, dam construction, and levee building (see Brierley et al. 2016a, b, Chaps. 3 and 15). Beyond Lanzhou, the river flows for many hundreds of kilometres through the Ordos Desert, an easterly extension of the Gobi Desert in Ningxia and Inner Mongolia, and the Loess Plateau (Fig. 1.6). As early as in the Qin Dynasty, from 245 to 206 B.C, ancient irrigation canals were built along the wide alluvial plains in this area. Subsequent water resource developments have greatly altered flow and sediment dynamics in this reach. Officially, the 1200 km middle reach of the Yellow River extends from Hekouzhen to Taohuayu in Henan Province, decreasing in elevation from 1000 to 110 m (Fig. 1.6; IRTCES 2005). This reach passes through the Loess Plateau, the primary source of the high sediment load of the river, the Ordos Plateau, Hetao Plain, and the Taihang Mountains. About 30 % of total run-off and nearly 90 % of total sediment load come from the middle reach. Low run-off and high sediment loads result in hyperconcentrated flows.

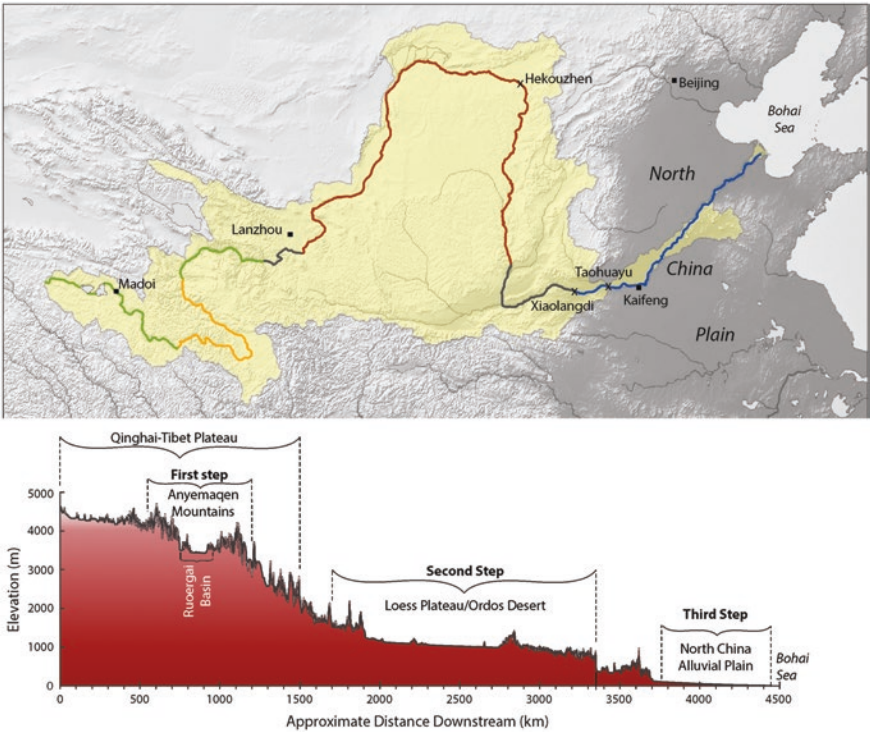

Fig. 1.7 The three topographic steps that make up differing altitudinal and landscape zones of the Yellow River across China. The *upper basin* lies predominantly atop the Qinghai–Tibet Plateau, the margins of which lie just to the west of Lanzhou. The *middle course* drains the Loess Plateau, from where large sediment loads are derived (hence the name of the river). The *lower course* extends over a wide lowland plain and has been characterized by major avulsions and associated hazards throughout historical time. We thank Tami Nicoll for assistance in developing this diagram

The second step at the margin of the Loess Plateau and the North China Plain marks the beginning of the lowland alluvial plain near Xiaolangdi (Figs. 1.6 and 1.7). Officially, the 768 km long lower reach of the Yellow River extends from Taohuayu east of the Taihang Mountains to the Bohai Sea, with elevation decreasing from 110 m to sea level (IRTCES 2005). The river enters the plains at the city of Kaifeng, where it changes from a torrent to a broad meandering stream that has now been enclosed by dikes. From west to east, the alluvial plain is made up primarily of alluvial fan, floodplain, and estuarine delta plain deposits. Rapid delta growth, along with changing sedimentation patterns and subsidence during the Quaternary, has exerted a primary control upon migration patterns of the Lower Yellow River, shifting the position of the river mouth. Hyperconcentrated flows have induced serious sedimentation and flood protection problems in this area. Major aggradation and levee development have perched the active channel zone above the adjacent plain. At Kaifeng, the lower course of the Yellow River lies

10 m above the adjacent floodplains. This area has a long history of flood disasters—a situation that has been recurrently exploited at times of war. Reduced sediment loads along the Yellow River in recent decades reflect the combined impact of flow regulation, climate change (reduced precipitation, especially in middle and lower reaches), and the influence of land use programmes (especially soil and water conservation projects; see Wang et al. 2015).

1.3 Defining the Yellow River Source Zone

Specifying the boundaries of the Yellow River Source Zone is a contentious issue, with little consensus regarding the definition of the geographical scope of the region. The catchment area and administrative districts of the Yellow River Source Zone are shown in Fig. 1.8. Differing authors have used at least five different interpretations of the boundaries of this zone:

- Pan and Liu (2005) stated that Yellow River Source Zone is the hinterland of Qinghai–Tibet Plateau, located in the south of Qinghai Province, including Madou, Maqin, Chengduo, Qumalai, Dari, and Gande Counties and covering a total area of 64,700 km^2.

Fig. 1.8 The catchment area and administrative districts of the Yellow River Source Zone. The catchment area is from Blue et al. (2013). Districts for the 19 counties are derived from the administrative maps of Qinghai, Sichuan, and Gansu provinces

- Some researchers indicated that the Yellow River Source Zone extends from the upper area of the Riyue Mountains east of Qinghai Lake and includes Longyangxia Dam. The geographical scope of this region covers an area of 92,000 km^2 (Feng et al. 2004).
- A biophysical, catchment-framed approach views the Yellow River Source Zone as comprising the administration districts upstream of Longyangxia Reservoir in the north-eastern section of the Qinghai–Tibet Plateau (Blue et al. 2013; Nicoll et al. 2013). This area includes 19 counties, with 15 counties in Qinghai (Qumalai, Chengduo, Madou, Dari, Gande, Banma, Jiuzhi, Henan, Zeku, Maqin, Tongde, Xianghai, Guinan, Gonghe, and Guide); three counties in Sichuan (Aba, Hongyuan, and Ruoergai); and one county in Gansu (Maqu). The geographical scope of this region covers a total area of 177,162 km^2.
- In the official designation used by IRTCES (2005), there are three sections of the Upper Yellow River atop the Qinghai–Tibet Plateau, and a fourth section of the Upper Yellow River extends downstream to Hekouzhen in the Inner Mongolia Autonomous Region.
- Finally, the Yellow River Source Zone can be described solely in relation to administrative districts within Qinghai Province. In this definition, the Yellow River Source Zone refers to 15 counties, with six counties in Golou, four counties in Huangnan, and five counties in Hainan Prefectures, and covers a total area of 137,700 km^2 (see NDRC 2014).

Different chapters in this book refer to differing geographic areas across the region. Some chapters incorporate comment on the Qinghai–Tibet Plateau and adjacent mountain ranges (Han et al. 2016, Chap. 12), while others refer to the Sanjiangyuan (Three River Source Zone, including headwater areas of the Yellow, Yangtze, and Lancang (Mekong) Rivers, e.g. McGregor 2016, Chap. 2; Li et al. 2016b, Chap. 9). Most chapters refer specifically to the catchment-framed delineation of the Upper Yellow River within the confines of the Qinghai–Tibet Plateau, setting the downstream boundary of the region at the margins of the plateau close to the provincial boundary between Qinghai and Gansu. This area includes three counties in Sichuan and one county in Gansu (these counties are located at the First Great Bend of the Upper Yellow River; see Fig. 1.8). In the socio-economic chapter (Ran et al. 2016, Chap. 14), analysis is restricted to data derived solely from administrative counties within the Yellow River Source Zone that lie within Qinghai Province. The specific area that is considered is outlined at the beginning of each chapter.

1.4 An Introduction to the Geography of the Upper Yellow River

1.4.1 Geology

Uplift of the Himalayas and the Qinghai–Tibet Plateau as a result of the collision of the Indian and Asian continents has been the most prominent tectonic event in