Chapter 12
Climate, Vegetation and Human Land-Use Interactions on the Qinghai–Tibet Plateau Through the Holocene

Meiqin Han, Gary John Brierley, Carola Cullum and Xilai Li

Abstract The Qinghai–Tibet Plateau is renowned for its geomorphologic diversity and high sensitivity to climatic changes and human disturbance. These relationships vary markedly across the region, shaped by factors such as the elevation, vegetation cover, water distribution, climate variability and the history of human settlement and land use. This chapter presents an overview of Holocene environmental evolution and human settlement history across the region, based on an assessment of the key literature on palaeoenvironmental conditions (e.g. glacial records, lacustrine strata, river deposits, aeolian (sand dune) histories) and analyses of Palaeolithic and Neolithic relics. A summary of climate–vegetation–human activities, relationships, interactions and evolution is provided. Climate changes are shown to be key drivers of regional variability in vegetation and hydrological patterns. It is very likely that long-term grazing activities have brought about a pronounced transition to grazing-adapted ecosystems in many grassland areas across the region. An overview of the human settlement history includes assessment of Dadiwan, Yangshao, Majiayao and Qijia cultures, and their associated agriculture (grazing) economies.

Keywords Qinghai–Tibet Plateau · Holocene · Palaeoclimate · Palaeoenvironmental conditions · Vegetation cover · Vegetation evolution · Human settlement · Human activities · Grazing-adapted ecosystems

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G.J. Brierley et al. (eds.), *Landscape and Ecosystem Diversity, Dynamics and Management in the Yellow River Source Zone*, Springer Geography,
DOI 10.1007/978-3-319-30475-5_12

12.1 Introduction

Across the world a delicate balance is played out between environmental capacity to support human activities, the consumption of natural resources, the provision of ecosystem services and the human adaptation to environmental conditions. This balance must be successfully negotiated in the quest for survival, especially under extreme conditions such as those found on the Qinghai–Tibet Plateau. Harmonious relationships and the quest for sustainability take very different forms in different places. They reflect human history, as people have evolved and adapted to recurrently cope with variability and conflict. Much may be learnt from past experiences. Indeed, the imprint of history provides the context for contemporary choices. Flexibility and resilience are required to cope with new situations and circumstances. Whatever form these adjustments may take, it is now acknowledged that wilderness is dead across our planet (Wohl 2013), and we now live within a no-analogue state (Hobbs et al. 2009; Williams and Jackson 2007). In the Anthropocene, human activities are the dominant forces shaping our world.

It is fascinating to consider how these issues are played out in the most challenging, extreme and marginal environments of the world. Such is the case atop the Qinghai–Tibet Plateau, where remarkable adaptations have been required in response to altitudinal, climatic and environmental conditions. Indeed, recent research points to genetic adaptations from a Denisovan gene pool that supports human adjustments to oxygen-depleted high-altitude conditions (Huerta-Sánchez et al. 2014; Keim 2014). Despite the fascinating stories that can doubtless be told, our understanding of long-term (post-glacial) environmental changes and human adaptations on the Qinghai–Tibet Plateau remains in its infancy. Here, we convey a sketch of recently derived understandings, recognizing explicitly that far more complete and intriguing analyses are likely to emerge in the future years.

Pollen analysis indicates considerable climate changes during the Holocene (the last 12,000 years), associated with tectonic uplift of the plateau and global shifts in atmospheric patterns. These adjustments have led to considerable changes in vegetation. However, not all the vegetation changes covary with the patterns of climate change. Anomalies are particularly evident in areas of human habitation, suggesting that humans have been responsible for some modification of vegetation patterns. Thus, the vegetation seen today is a result not only of contemporary and historical landforms and climate, but also of the history of human activity.

This chapter presents a geographic overview of post-glacial climatic and environmental conditions across the Qinghai–Tibet Plateau and their interactions with human activities. Many of the contemporary grassland areas of the plateau were once quite heavily forested. It seems very likely that humans were responsible for deforestation and that domesticated yaks have grazed the lands for thousands of years (i.e. these are now grazing-adapted ecosystems; see Li et al. 2016, Chap. 7; Tane et al. 2016, Chap. 13). Thus, both the humans and the vegetation have adapted to the climate and environment, shaping the landscapes and ecosystems of this region.

We start this chapter with a summary of the contemporary climate and vegetation distribution across the plateau. We then assess the post-glacial vegetation history through a regional assessment of selected pollen records. This work is complemented by an appraisal of human occupation sites that provide insights into long-term land-use changes in the region. Finally, this overview is synthesized to provide an assessment of prospective future socio-cultural adaptations in this area.

12.2 Contemporary Climate and Vegetation Across the Qinghai–Tibet Plateau

Considerable climate gradients influence both horizontal and vertical vegetation patterns across the Qinghai–Tibet Plateau (Fig. 12.1). Elevation- and monsoon-driven climates induce transitions from the colder and drier deserts of the north-west to the wetter and warmer forested areas of the south-east (Tang et al. 2000; see McGregor 2016, Chap. 2 for further detail). Altitudinal gradients from the world's highest peaks to relatively low-lying (though still very high) plains control the distribution of plants at multiple scales.

Moving successively from south-eastern areas of the plateau to the west, forest vegetation is replaced by alpine shrub/alpine meadow, alpine grassland/temperate alpine grassland and alpine desert/montane desert (Wu 1980; Zhang 1978):

- In the south-east, the terrain is slightly lower (3000–4000 m), with a warm and humid climate that supports dense forests.
- From the eastern plateau to western Sichuan, and from southern Qinghai Province to the eastern region of northern Tibet (where the terrain is generally 4000–4500 m), the climate is cold and humid and is unsuited to tree growth. As a result, these areas are characterized by alpine meadow and shrubs.
- To the north and west of the region, in the source area of the Yangtze River and the hinterland of the Qinghai–Tibet Plateau, the terrain has an average elevation of 4500–5000 m and is characterized by alpine meadows and alpine desert steppe vegetation.
- In southern Tibet, lower elevation valleys (<4400 m) have a cooler and relatively dry climate that supports warm temperate grasslands and arid deciduous shrub vegetation. In contrast, elevations above 4400 m are characterized by alpine meadows and shrubs.
- In the lake basin areas of the farthest north-west of the Qinghai–Tibet Plateau, at an average altitude of more than 5000 m between the Karakulun and Kunlun mountains, the climate is extremely cold and dry, with large areas of permafrost and arid desert vegetation.
- To the west, the Ali region has a slightly lower altitude (4200–4500 m), the climate is relatively warm but very dry, and mountain temperate desert or steppe desert vegetation has developed.

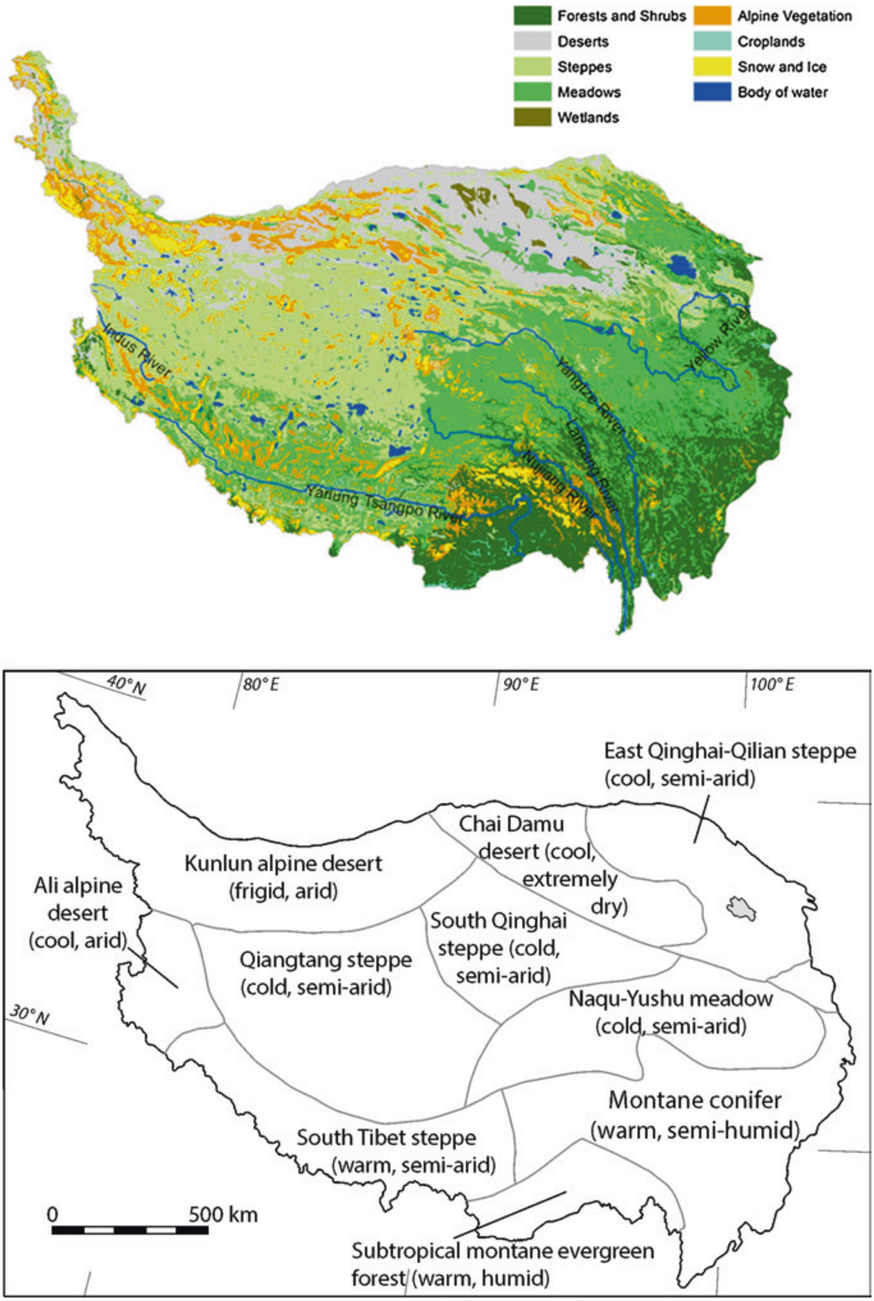

Fig. 12.1 Vegetation and climate gradients across the Qinghai–Tibet Plateau. Altitudinal climate gradients are seen both on individual hillslopes and between the mountainous areas and the plateau. Vegetation distribution of the Qinghai–Tibet Plateau. (Adapted from Chen et al. (2013) and Wang et al. (2015))

Vertical distribution characteristics complicate this simplified zonation:

- In *central* areas of the plateau, there is a relatively simple vertical structure, with mountain forest in the valleys, alpine meadows and alpine cushion-shaped shrub vegetation on the lower slopes and sparse subalpine vegetation below permanent snow on the highest slopes. These structural relationships vary with aspect (see Tane et al. 2016, Chap. 13). In the subalpine coniferous tree zone, for example, cedar trees are found on shady hillslopes and cypress trees on sunny slopes. In alpine shrub meadow zones, alpine shrubs are found on shady hillslopes but alpine meadows on sunny slopes.
- From the *south-east margin to the central area,* the vertical vegetation structures are simpler with less pronounced aspect-induced differences. For example, in the Changtang highland, there are only three types of structures: alpine grassland, sparse vegetation and permanent snow, with similar plant communities on shady and sunny hillslopes.

Vertical transitions in vegetation cover tend to occur at higher elevations moving from the south-east to the north-west. For example, in the forests of the Hengduan Mountains, alpine meadows are found up to 4800 m, while in the north-east area around Maduo, they exist up to 5000 m. Similarly, alpine grasslands extend up to 4600 m in southern Tibet, but only to 5000 m in the central area (Wu 1980; Zhang et al. 2014).

In summary, as altitude and relative relief gradually increase from the south-east to the north-west of the plateau, differences in vegetation type reflect climate changes from warm and wet to cold and dry, changing from evergreen broad-leaved forest/boreal coniferous forest to alpine shrub/alpine meadow, alpine steppe (temperate grasslands in low-altitude valleys) and finally to alpine desert (temperate mountain desert in arid valleys with lower elevations).

These spatial relationships have varied markedly in the post-glacial period as vegetation has responded to quite dramatic climate shifts, as well as to human activities.

12.3 Glacial History in the Qinghai–Tibet Plateau

The oxygen isotope record extracted from the Guliya ice core on the north-west plateau indicates that severe climate changes have taken place over the last 125,000 years, with several millennia-scale oscillations between warm and cold periods (Yao 1999, 2000):

- An extensive system of interconnected lakes, with an estimated area of 360,000 km^2 and a total volume of about 53×10^8 km^3, was evident from around 65–53 to 40–30/35 thousand years ago. Rapid uplift of the plateau and cooler climate conditions around 30,000 years ago were coincident with rapid drainage of these lakes. The Upper Yellow River adopted its contemporary course at this time, flowing through the Gonghe Basin to the Huanghai Sea, reforming the lake and river systems at the margins of the plateau, with extensive transfer of cold water to the Indian Ocean and the western Pacific Ocean (Brierley et al. 2016a, b, Chaps. 1 and 3; Zheng et al. 2006). Around the same time, extensive salt bed development was initiated at Qaidam Lake, where a large number of organisms became extinct, indicating transition to dry and cold climatic conditions (Fan et al. 2012; Jing and Sun 2001).

- During the Last Glacial Maximum (about 32–16,000 years ago), temperatures were around 7 °C colder than present on the Tibetan Plateau, while precipitation was only 30–70 % of present (Shi et al. 1997).
- Around 30–23,000 years ago was an even colder period, with temperatures roughly 10 °C lower than present (Yao 2000).
- From 25–15,000 years ago, a large part of south-eastern Tibet, including Zoige, Qaidam and Kekexili, was characterized by desert grassland, with cold and dry climate conditions and annual temperatures 6 °C lower than present. At this time, the forests in the Qinghai Lake area were replaced by grassland vegetation (Tang et al. 1998).
- Despite several cold events, temperatures have gradually increased in the last 15,000 years, becoming notably warmer after about 10,500 years ago (Yao 2000).

12.4 Climate and Vegetation History Through the Holocene

More detailed climate and vegetation history is available for the Holocene (from about 11,700 years ago to the present day). Holocene paleoclimatic fluctuations on the Qinghai–Tibet Plateau are broadly consistent with the global glacial/interglacial sequence of events, as evidenced by pollen records across many different parts of the plateau. In the following section, regional differences are appraised through records from the research sites shown in Fig. 12.2.

12.4.1 Eastern Plateau: Ruoergai Plateau, Gonghe Basin and Qinghai Lake

In the southern part of the eastern plateau, vegetation has changed from forests to alpine meadows as temperatures have decreased through the Holocene. In contrast, in the semi-arid areas to the north, vegetation has shifted from forests to temperate steppe, driven largely by changes in precipitation (Zhao et al. 2011a, b).

In the southern area, atop the Ruoergai Plateau in Sichuan Province, analysis of tree pollen and peat properties suggests that forest conditions were evident from 12–11,000 years ago, with spruce, fir (15 %) and birch (10 %) prominent

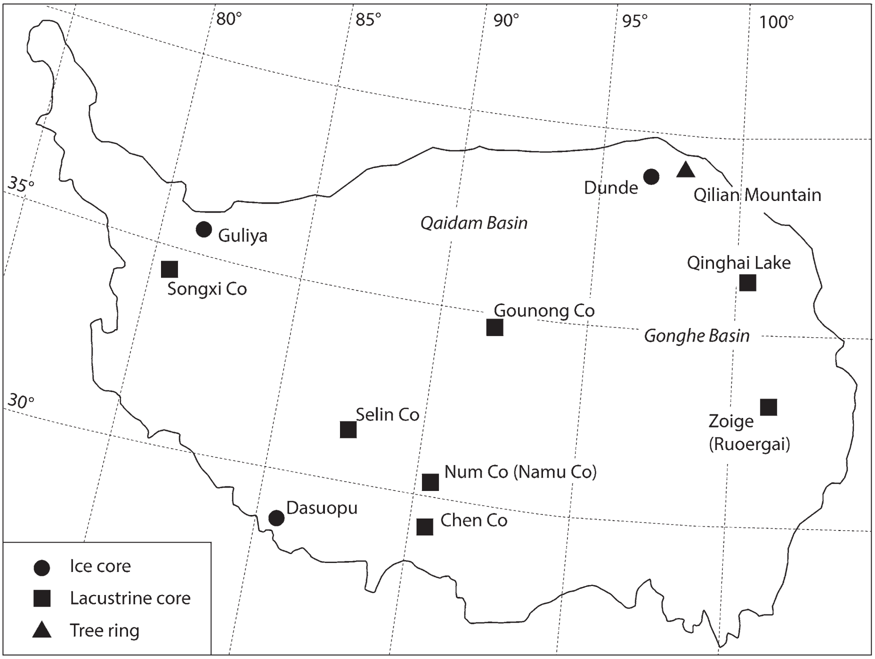

Fig. 12.2 Main sites used to reconstruct regional variability in past climates atop the Qinghai–Tibet Plateau (modified from Li et al. 2012). Note that Song(mu)xi Lake and Sumxi Lake are different names for the same feature

(Wang et al. 1993). In this area, the warmest period in the Holocene (known as the 'climate optimum') occurred around 6.5–4.7 thousand years ago. Since then, forests have declined, giving way to alpine meadows. This decline corresponds with increases in clastic sediment input and in peat decomposition, suggesting a drying and cooling trend that may be associated with weakening monsoon intensity and decreasing summer insolation (Zhao et al. 2011a, b).

Pollen records from Qinghai Lake reveal that 15,200 years ago the climate was cold and dry. The Holocene climate optimum occurred at around 6700 years ago in this area (Liu et al. 2002). In the Early Holocene, the salinity of Qinghai Lake water was higher than that at present, reaching its highest value around 8400 years ago. From 7.7–5.1 thousand years ago, the salt content decreased greatly, but increased again from 3200 years ago to present. High lake levels, up to 17.5 m higher than the present lake level, occurred at 6.4, 5 and 3.5 thousand years ago. The frequent fluctuations of lake level suggest phases of climatic instability (Pengxi et al. 1994).

Further north, in the Gonghe Basin, tree pollen was replaced by shrub and herbaceous pollen from 12.3–11.3 thousand years ago, indicating a grassland desert landscape associated with a stable cold climate in the Early Holocene

(Cheng et al. 2013). Although the effective humidity started to increase about 11.3–9.7 thousand years ago, grassland remained, evidenced by the high herbaceous and shrub pollen content associated with this period. The ratio between Chenopodiaceae and Artemisia pollen (the A/C ratio is a useful indicator of humidity) continued to increase from 9.7–8.9 thousand years ago, indicating further increases in temperature and effective humidity. However, after about 8.9–6.8 thousand years ago, the overall concentration of pollen increased considerably, as did the proportion of pollen from tree species (predominantly spruce and pine). From 6.8–5.0 thousand years ago (the climatic optimum), the tree pollen further increased to levels equal to herbaceous pollen. The trend reversed from 5.0–3.4 thousand years ago, when a cooling period is suggested by decreasing proportion of tree pollen and increasing herbaceous and shrub pollen. The cooling continued from 3.4–1.0 thousand years ago, as herbaceous and shrub pollen continued to increase, with Chenopodiaceae, Artemisia and other grasses and sedges becoming dominant and tree pollen (mainly pine) falling to a low percentage of the total. The progressive decline in trees then continued, reaching the lowest proportion of all pollen by 1000 years ago, by which time the area had become temperate steppe (Cheng et al. 2013).

12.4.2 Southern Plateau: Chen, Nariyong and Peiku Lakes in Southern Tibet

In the south, vegetation has changed from sparse steppe shrubland some 11.0–8.0 thousand years ago, through a warm, semi-humid period with spruce, fir and some deciduous trees (8.0–3.0 thousand years ago). Current conditions are cool and semi-arid, with forest and shrub vegetation.

Analysis of the pollen record from Nariyong and Chen lakes in southern Tibet by Huang et al. (1995) suggests widespread sparse shrub steppe in this region from 11–8.0 thousand years ago. Herbaceous pollen occupies 70–80 % of the total record, with some spruce and fir indicating of cool, semi-arid high-mountain climate conditions. Vegetation thrived from 8.0–3.0 thousand years ago, with increases in tree pollen, including deciduous species such as oak, birch, Rosaceae and Azalea. At this time, herbaceous vegetation comprises 30–70 % of the record, with Artemisia, Asteraceae, Gramineae, Thalictrum and legumes indicating a forest shrub meadow landscape and a warm, semi-humid climate. Similar records are evident from the Peiku Lake area (Tang and Shen 1996; Huang 2000), where an apparent rise of birch, oak, cedar and hemlock is indicative of increasing humidity and temperature relative to the previous phases. From 3000 years ago to present, the proportion of woody plant pollen decreases from 30–34 % to under 20 %. Shrub vegetation dominates, with herbaceous plants making up 73–89 % of the pollen record. This is indicative of a transition to cooler, semi-arid climate conditions.

12.4.3 Western Plateau: Sumxi Lake and Bangong Lake

Pollen records from the western plateau indicate fluctuations through the Holocene from cold and dry conditions to a wetter period where grasses flourished, followed by increasing dryness and a reversion to steppe.

Analysis of pollen records from Sumxi Lake indicates cold and dry conditions around 10.5–9.9 thousand years ago. From 7.7–4.3 thousand years ago, more humid climate conditions and grasslands prevailed, indicated by the high Artemisia/Chenopodiaceae ratio. The wettest periods were between 8.0–7.7 and 7.5–6.0 thousand years ago, when the highest lake level was recorded. From 5.5–4.3 thousand years ago, the Artemisia/Chenopodiaceae ratio gradually declines while the proportions of Ephedra and tree pollen increase. The presence of Ephedra indicates a transition towards drier conditions in this period. From 43,000 years ago to present, decreases in the ratio of Artemisia/Chenopodiaceae alongside changes in the oxygen isotope record (reduced $\delta^{18}O$) and decreases in carbon content suggest a continuation of the trend towards drier conditions (van Campo and Gasse 1993).

Pollen concentrations in the Bangong Lake, some 170 km to the south-east of Sumxi Lake, show that from 9.9 to 9.6 thousand years ago, the region had a dry climate with very sparse vegetation and the lake area was occupied by a slightly saline marsh, rich in charophytes. An extremely abrupt environmental change from arid to wet conditions is recorded at around 9.6 thousand years ago, when steppe vegetation rapidly established over the region. A freshwater, oligotrophic, planktonic diatom flora developed in the lake, implying a sudden influx of dilute, nutrient poor water. From 9.6 to 6.3 thousand years ago, this rapidly flowing, freshwater lake persisted, as shown by the diatom flora and the stable isotope record. The lowest $\delta^{18}O$ values, regarded as reflecting minimum water residence time in the lake and maximum monsoon rainfall, are observed between 9.0 and 8.7 thousand years ago, and between 7.5–7.2 and 6.3 thousand years ago. From 5.7 to 3.8 thousand years ago, steppe and alpine meadow cover regressed in two steps, at around 5.5 and 3.9 thousand years ago. Influxes of detrital material increased in response to the lowering of the lake level. From 3.8–3.2 thousand years ago, relatively low $\delta^{18}O$ content suggests that the core site was directly subject to a river influence, likely a deltaic zone during a phase of very low water level. Ephedra pollen, characteristic of desert environments, makes up >10 % of the pollen record, indicating that this was an arid episode.

12.4.4 Central Plateau: Kekexili Kusai and Selin Lakes

In the Early Holocene, the central part of the plateau was cold and dry, with sparse vegetation. The warmest period occurred 9.6–6 thousand years ago, when there was a transition to alpine steppe and a few trees. Over the last 3000 years, the area has become drier, windier and colder. Trees have been lost and the vegetation is now sparse steppe.

Sun et al. (1993) document findings from a pollen record from the Selin Lake region. Sparse vegetation cover is indicated from the Early Holocene (11.0–9.6 thousand years ago), reflecting a cold and dry climate. A transition to alpine steppe occurred by the Mid-Holocene (9.6–6 thousand years ago), with warmer conditions, rising lake levels and swamp development adjacent to lakes from 8.5–7.5 thousand years ago. There is evidence for forest expansion in nearby areas. Although herbaceous pollen dominates the record from 6.0–3.8 thousand years ago (81 %, with sedges and Artemisia prominent), tree pollen is also found (13–28 %). Trees increase from 3.8–2.4 thousand years ago, dominated by spruce. A marked drop in pine pollen is evident from 1.2–0.7 thousand years ago, with a corresponding increase in herbaceous pollens from sedges, Chenopodiaceae and Ranunculaceae, but a decrease in Artemisia. This is indicative of drier and colder conditions during which tree cover decreased and swamps expanded around the lake. There is evidence for three-hundred-year-scale drought events in the central plateau, around 5.8–4.9, 4.4–3.9 and 2.8 thousand years ago (Tang et al. 2009).

Wu et al. (2007) concluded that solar insolation exerted a dominant influence upon Holocene climatic changes on the central plateau. The δ^{18}O record indicates a gradually cooling trend since the climatic optimum of the Early Holocene. A prominent drought in the Mid-Holocene (around 4.7 thousand years ago) was marked by very high concentrations of dust and soluble aerosols (other than nitrates). Calcium concentrations have increased since 3500 years ago, while dust and δ^{18}O, and ion species, have all decreased gradually, signalling the onset of more arid and possibly windier conditions (Thompson et al. 2006). Analysis of mineral assemblages from Kekexili Kusai Lake indicates that the climate was relatively warm from 3.7–2.5 thousand years ago, with a gradual cooling trend from 2.5–2.15 thousand years ago followed by much more rapid cooling from 2.15 thousand years ago to present. Over the same period, humidity in the area decreased, salinity of the lake increased, and aeolian activity strengthened.

12.4.5 Northern Plateau: Yellow River Source Zone

Lacustrine strata deposited atop glacial moraines in the Yellow River source region indicate rapid glacial retreat in response to the transition from cold–dry to warm–wet conditions in the early post-glacial period. Fluctuations between these phases have occurred to the present day, with cold–dry periods characterized by desert steppe vegetation and alpine steppe and alpine meadow occurring during warmer, more humid periods.

Expansions in forest vegetation cover, high lake levels and high rates of soil development indicate that peak warm and humid conditions were experienced around 7–6 thousand years ago (Shi et al. 1997). The record from 7.5–5.8 thousand years ago has the highest pollen concentration, with high proportions of sedges and a low magnesium/calcium coefficient. This indicates that during this Holocene climatic optimum, conditions were relatively humid, with temperatures 4 °C higher than present. From 5.8–4.5 thousand years ago, the temperature fell and drier climate conditions prevailed. For instance, ice core studies from the Qilian Mountains indicate cold and dry conditions from 6.0–5.0 thousand years ago, but sporadic short-term temperature fluctuations are also evident (Yao et al. 2001). A warmer and more humid phase from 4.5–3.5 thousand years ago was characterized by temperature and humidity conditions that were slightly lower than the early period. The end of this period is demarcated by a rapid decrease in the proportion of tree pollen from 3500 years ago, with some distinct cooling phases (Shi et al. 1997; Zhang and Zhang 1995). Research at Eling Lake shows that around 1900 years ago, this region was relatively warm and humid, but between 1.9 and 1.6 thousand years ago, the climate became cold and arid, so that the vegetation changed to desert steppe. Since 16,000 years ago, the climate has been getting warmer and more humid again, with the vegetation changing to alpine steppe and alpine meadow, dominated by Cyperaceae, Brassicaceae and Artemisia.

12.4.6 Summary Overview of Regional Variability in Vegetation History Across the Qinghai–Tibet Plateau

Holocene pollen records vary markedly across the Qinghai–Tibet Plateau. Whereas evergreen conifers once occupied the south-east, little tree pollen is seen in records from northern areas (Tang and Shen 1996). In large part, this reflects the gradual weakening of summer monsoon precipitation from the south-east to the north-west. In general terms, conditions were cold and arid in the Early Holocene (12–9 thousand years ago), with the warmest and most humid conditions occurring around 8–6 thousand years ago. This climatic optimum for vegetation produced the highest biomass, as indicated by the highest pollen concentrations in lacustrine cores. The proportion of trees increased in all areas, with vegetation cover increasing, so that steppe turned to meadows and meadows turned to shrublands. The timing of this climatic optimum varied across the plateau. At Sumxi Lake, in the south, this environmental optimum occurred from 7.5–5.5 thousand years ago (Gasse et al. 1996), whereas at Ruoergai, in the north-east, it occurred from 8.2–6.4 thousand years ago (Wang et al. 2006). Shen and Tang (1995) postulate high water levels at Qinghai Lake from 7.4–6.0 thousand years ago. These various records suggest that the Holocene climatic optimum period occurred across the whole plateau, but lasted longer in the Zoige Basin and Qinghai Lake area (Shen and Tang 1995; Wang and Fan 1987; Zhu et al. 1994).

Since the Mid-Holocene, there has been a long-term trend towards drier and cooler climes across the whole plateau, likely linked to a weakening of the monsoons and decreasing summer insolation (Zhao et al. 2011a, b). A cold and arid event occurred at about 3500 years ago in many areas. Impacts of other Holocene climatic events such as the 8.2 thousand years ago cooling event, the Medieval Warm Period, the Little Ice Age and the twentieth-century warming trend have varied in space and time across the plateau (e.g. Duan et al. 2012; Yang et al. 2009).

12.5 The Long-Term History of Human Activities on the Qinghai–Tibet Plateau

There is a very patchy and incomplete record of archaeological sites and analyses across the Qinghai–Tibet Plateau. As a result, great reliance is made upon inferential reasoning in scoping phases and patterns of human land use and adaptation across the region.

The Qinghai–Tibet Plateau is inhospitable to human settlement because of low oxygen conditions (hypoxia), cold climate and scarce resources. At 4000 m elevation, each breath contains only about 60 % of the oxygen inhaled at sea level (Beall 2007). These extreme conditions have limited population migration, the exploitation of natural resources and technological developments—from the earliest times to the present day (Gao et al. 2008).

12.5.1 Human Adaptation to High-Altitude Conditions

Tibetans exhibit many biological features in common with other high-altitude mammalian species (such as antelopes), including the absence of chronic mountain sickness, thin-walled pulmonary vascular structure and high blood flow (Monge and Leon-Velarde 1991). These phenotypes are highly correlated with physiological responses to low oxygen concentration, which facilitate more efficient oxygen utilization. Evidence from the studies of Y chromosome suggested that Tibetans, together with the Yi people, were descendants of Tibeto-Burmans who diverged from ancient settlers of East Asia. Since the Himalayas present a strong barrier to gene flow from the south into the Tibetan Plateau, the valleys of the Hengduan Mountain range (to the west of the plateau) may have been a major migration route (Wang et al. 2011). Gayden et al. (2007) support the hypothesis that the Tibetan gene pool reflects significant contributions from East and/or Southeast Asia. Qian et al. (2000) concluded that Tibetan Y chromosomes may have been derived from two different gene pools in Central and East Asia.

Skoglund and Jakobsson (2011) found a genetic link between Tibetans with the Denisovan hominids that spread from eastern Eurasia through southern China to Southeast Asia and Melanesia. Huerta-Sánchez et al. (2014) found that a highly unusual haplotype structure could only be explained by introgression of DNA from Denisovan or Denisovan-related individuals into humans. This selected haplotype is only found in Denisovans and in Tibetans, and has very low frequency among Han Chinese. They concluded that this haplotype was introduced into humans before the separation of Han and Tibetan populations, and was then subject to selection in Tibetans after the Qinghai–Tibet Plateau was colonized, resulting in the distinctive Tibetan adaptation to high altitudes.

Archaeological evidence suggests that migration of the archaic human population to the Qinghai–Tibet Plateau occurred from the north-eastern margin of the plateau (Deng et al. 2004). It is suggested that people settled at lower altitudes in the north-east and gradually moved south and west as warmer climates allowed them to settle at higher altitudes (Gayden et al. 2007; Madsen et al. 2006).

12.5.2 Human Colonization of the Qinghai–Tibet Plateau

A widely accepted colonization model for the Qinghai–Tibet Plateau differentiates between three elevation areas:

1. The low-elevation source areas of the northern plateau below 3000 m, which consist primarily of Gansu Province, the Inner Mongolian Region and Xinjiang Uygur Autonomous Region.
2. An intermediate area between 3000 and 4000 m, including the large internal lake basins of Qinghai Province.
3. An extreme elevation step above 4000 m that includes portions of Qinghai Province and most of the Tibetan Autonomous Region (Brantingham et al. 2001, 2007; Brantingham and Xing 2006; Madsen et al. 2006).

Variations in the climate of this area are largely controlled by spatial and temporal variations in the strength of the Southeast Asian summer monsoon (McGregor 2016, Chap. 2). As described in the previous section, climate and environmental changes in the middle- and high-elevation steps of the plateau parallels those in the surrounding low-elevation areas, alternating between cooler–drier and warmer–wetter periods, albeit with different starting points in each area (Brantingham and Xing 2006). Climate factors exerted a critical influence upon human colonization on the plateau (Brantingham et al. 2003; Chongyi et al. 2013; Hou et al. 2010). Prior to the Holocene, human activities were directly influenced by climatic fluctuations. Following the Holocene climatic optimum, the marked increase in the number of occupation sites indicates the blossoming of various cultures. Demographic pressure was a prime motivation for the Neolithic expansion (Davison et al. 2006). For example, the introduction of agriculture brought about significant population expansion in the north-eastern margin of the plateau, as evidenced at sites associated with the Dadiwan culture (5.8–5.4 thousand years ago).

The ‘three-phase’ model for human settlement on the plateau relates to changes in climate on each elevation step:

1. Initial stage occupation of lower elevations from 40–25 thousand years ago by highly mobile foragers collecting key resources. At this time, temperature was 2–4 °C higher and precipitation was 40–100 % higher than today (Liu et al. 1998; Shi and Liu 1999). Qinghai Lake appeared to be warm and wet, with high water levels and mixed forests occurring on the surrounding landscapes (Fan et al. 2012; Yao 2000; Zhou et al. 2003).
2. Immediately prior to and after the Last Glacial Maximum (25–10 thousand years ago), foragers ventured out from permanent home bases along the lower elevation margins of the plateau to occupy temporary, short-term, special-purpose foraging sites on the middle and upper steps of the plateau.
3. Increasing temperatures and decreasing effective moisture after the Last Glacial Maximum encouraged full-scale, year-round occupation of the upper regions of the plateau by Early Neolithic pastoralists (Fan et al. 2012). Although changing climatic conditions favored archaic population migration on the plateau, demographic pressure is also considered to be a prime driver of the Neolithic expansion (Lee 1997). For example, low-level agricultural activities at sites associated with the Dadiwan culture (5.8–5.4 thousand years ago) transitioned into intensive agricultural activities focused around large, complex permanent settlements associated with Yangshao (6.9–5.3 thousand years ago) and Majiayao (5.3–4.2 thousand years ago) civilizations. The subsequent rapid transition from warm–semi-arid to warm–arid conditions around 4/3.5 thousand years ago may have driven a reduction in the total number and distribution of agricultural settlements over the western Loess Plateau. Nomadic pastoralism appears to have become a viable alternative to rain-fed agriculture sometime during the Qijia cultural stage (around 4.3–3.9 thousand years ago) (Brantingham et al. 2013).

Several sources of evidence suggest that the plateau was initially populated by migrations from northern China. Grey green quartz stone tools found horizontally stratified between two well-preserved beach ridges at Lenghu on the northern margin of the Qaidam Basin (2804 m, around 37 thousand years ago, see Fig. 12.3) are typologically indistinguishable both from the Levallois-like blade technology seen at Shuidonggou site in northern China and from other Early Upper Palaeolithic occurrences (around 30,000 years ago) in the low-elevation source area of the plateau (Brantingham et al. 2001). Furthermore, the stone assemblages (quartzite cores, flakes, choppers, scrapers, end scrapers, rock drills and carvers) found at the Lesser Qaidam site (3170 m, 30 thousand years ago) are also typical of the traditional stone technology of northern China (Gao et al. 2008; Zhang 1990).

Hearths near Qinghai Lake provide evidence for the second stage of settlement. Dating from around 12–14,000 years ago, the archaeological evidence suggests single, short-term visits by small foraging parties, since there is evidence of cooking animals, but no evidence of preparing agricultural foodstuffs (Brantingham and Xing 2006; Gao et al. 2008; Madsen et al. 2006). Heimahe (Black Horse

Fig. 12.3 Location of major Palaeolithic sites in the north-eastern part of the Qinghai–Tibet Plateau. *1* Lenghu; *2* Lesser Qaidam; *3* Heimahe; *4* Jiangxigou; *5* Gouhou reservoir; *6* Loula reservoir; *7* Xiadawu (Xidatan); *8* Donggeicuona Lake (after Gao et al. 2008; Yi et al. 2011)

River; 3120 m; Gao et al. 2008) and Jiangxigou (3330 m; Madsen et al. 2006) are located along streams that fed into the southern margin of Qinghai Lake. A single hearth at Heimahe reflects occupation around 12.94–13.1 thousand years ago. Artefacts providing indicators of land-use activities include many bifacial thinning flakes, a quartzite core, two microblade fragments, a bifacially worked slate scraper, a ground stone cobble and fragmentary bone splinters. Most of the bone splinters appear to be from a medium-sized mammal, while others are from a mid-sized ungulate, possibly a gazelle (Brantingham and Xing 2006; Gao et al. 2008; Madsen et al. 2006). All bones have been broken and shattered for marrow extraction and possibly for degreasing. No evidence of seed processing or geophyte use has been found—ground stone seems to represent tool production rather than food processing. Two granite cobbles and two pieces of microdebitage related to microblade production were also recovered from two stratigraphically separate hearths at Jiangxigou (Madsen et al. 2006). Charcoal from the lower and upper hearths dates from 14.2–14.92 and 14.16–14.83 thousand years ago, respectively. Lithic collections from Jiangxigou and Heimahe are virtually identical, both in terms of the technology they imply and in the consistent small size of the specimens.

Charcoal, ash, burned bone fragments and lithic collections (mainly quartz, including blade, shatter and microblade fragments) were excavated from a hearth near the Loula reservoir (3395 m, around 13 thousand years ago; Yi et al. 2011). At Gouhou (3056 m; Gao et al. 2008), charcoal, ash and cobble with limited microblade specimens comprised primarily of quartz and chert suggest that the site was used for short-term food processing. Abundant stone cores, microstone

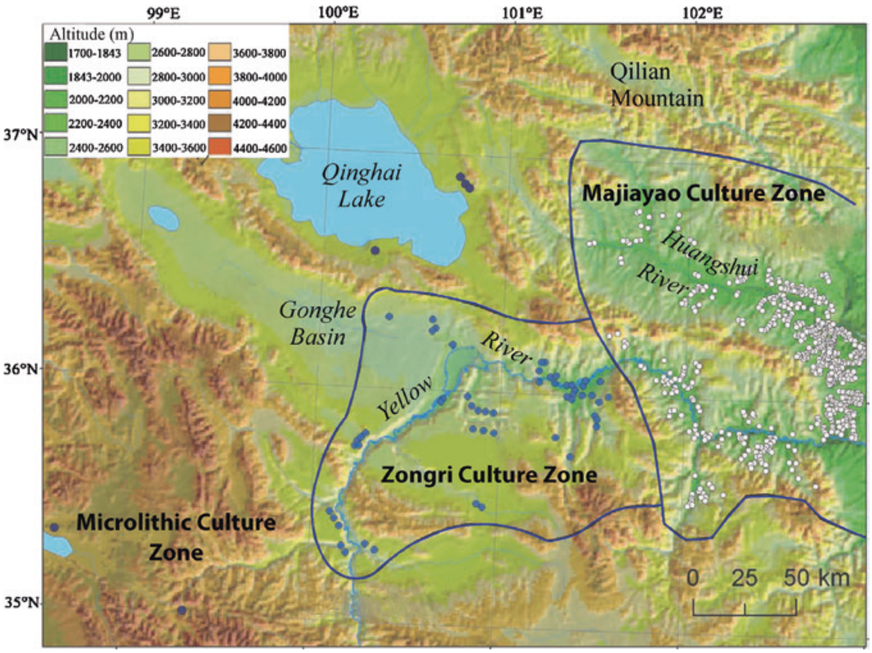

Fig. 12.4 Archaeological sites and the distribution of prehistoric cultures in the north-east of the Qinghai–Tibet Plateau (modified from Chongyi et al. 2013)

cores, scrapers and flakes found in the terraces of Donggeicuona Lake in Maqin County (4106 m) indicate that archaic populations settled in this area according to fluctuations of the lake shorelines (Yi et al. 2011).

Sites associated with the third stage of settlement in the Neolithic and Bronze ages suggest several distinctive cultural zones in the Upper Yellow River (Fig. 12.4; An et al. 2006; Duan 2002; Hou et al. 2010; Lang 1992; Zhang et al. 2010). The Zongri cultural zone encompasses archaeological sites from the Dadiwan culture (7.80–7.35 thousand years ago), while the Yangshao culture dates from 6.8–4.9 thousand years ago, the Majiayao culture from 5.3–4.2 thousand years ago, and the Qijia culture from 4.3–3.9 thousand years ago.

A diverse array of raw materials and technologies has come from an archaeological site atop a terrace of the Kunlun River at Xidatan (4300 m, 9.2–6.4 thousand years ago; Brantingham et al. 2007). Cores, flakes and retouched tools document use of the site by highly mobile foraging groups, who may have engaged in seasonal foraging rounds that carried them onto and off the high-elevation plateau. Raw materials include quartzite, jasper, mudstone, obsidian, vein quartz and metamorphic rocks. The presence of obsidian at site JXG 2 (indicated on Fig. 12.4) suggests stone transport over distances up to 1000 km through the Kunlun Mountain Pass between the middle- and high-elevation steps of the plateau by approximately 8000 years ago (Brantingham et al. 2013). This pass likely served as a major corridor for human population movements onto the high plateau.

Early evidence of agriculture and animal domestication comes from Jiangxigou (3312 m), where microlithic artefacts including blades and bladelets date from 9.3–5 thousand years ago. Microlithic industries are represented by abundant microblades and blade fragments, microblade cores and core fragments, and four crested bladelets. The end-hafted blade points are very similar to those found at the Changtang sites on the high central Qinghai–Tibet Plateau (Brantingham et al. 2001). Many bone and teeth fragments of small- and medium-sized mammals suggest that they may have been processed for grease or marrow extraction. Species include sheep (most likely the bharal or Himalayan blue sheep, *Pseudois nayaur*, but possibly domestic sheep, *Ovis aries*), Tibetan gazelle (*Procapra picticaudata*), and a small deer (Rhode et al. 2007a, b). It is uncertain whether these mammals were domesticated. Chongyi et al. (2013) suggested that relatively high pollen content of Poaceae and its attendant weedy plants from 9–6 thousand years ago might relate to human activities. The proportion of Poaceae reached its highest level between 6.7 and 4.0 thousand years ago—a period associated with multiple pottery shards that are also likely to be associated with farming activities.

An isolated hearth at Heimahe (3202 m, 8.54–8.37 thousand years ago; Rhode et al. 2007a, b) contains highly fractured bone fragments from a medium-sized mammal (possibly a gazelle) likely indicate marrow extraction. Poplar wood charcoal and small, carbonized lumps of composite organic material identified as herbivore dung indicate the use of yak dung as fuel. It is likely that dried herbivore dung was used as a fuel by archaic people during much of the period of occupation of the plateau, even during periods when woody fuel was more plentiful in the area (Brantingham and Xing 2006; Rhode et al. 2007a, b). The hypothesis is consistent with the pollen records analysis from Tibet (Miehe et al. 2009). Indeed, yak dung is still used as fuel over much of the now largely treeless pasture lands on the plateau.

Dadiwan sites at Shaoan village (Qingan County, Gansu Province) contain evidence of rain-fed agricultural cultivation and animal domestication (1500 m; 7.8–7.3 thousand years ago; Zhang et al. 2010). Four stages of human activities in the area have been proposed, reflecting transitions from a primitive hunter-gatherer economy through phases of advanced hunter-gatherer activities and a primitive crop cultivation economy to a mature agricultural economy (Zhang et al. 2010). For example, the first period of Dadiwan culture was characterized by broomcorn, suggesting primary, rain-fed agriculture, whereas the emergence of millet in subsequent periods associated with Yangshao culture is indicative of a later stage of agricultural development (An et al. 2006; Liu et al. 2004).

12.6 Discussion

Both vegetation and human settlements on the Qinghai–Tibet Plateau have evolved against a backdrop of changing climates. The largely treeless landscape around Qinghai Lake today probably results from regional-scale climate changes inducing forest decline, which in turn may have initiated changes in the type and intensity of human activities (Herzschuh et al. 2005). However, the relative roles of climatic and human factors as drivers of changing vegetation patterns remain contentious, with some researchers contending that low population densities could not trigger the extensive vegetation shifts seen across the region (Chen et al. 2013; Herzschuh et al. 2005; Ji et al. 2005; Tang et al. 2009). Clearly, much more research is required to provide additional insights. However, one thing is sure: Humans were not passive, but acted as agents of change to at least some degree. Pastoralists took advantage of the Mid-Holocene climatic optimum to migrate onto higher lands, clearing forests through the use of fire (Miehe et al. 2009; Ren 2000, 2007). Furthermore, the dominant grass species now seen on the plateau are highly adapted to grazing, having evolved over the thousands of years that these pastures have been grazed by domesticated animals (Miehe et al. 2008a, b; Wischnewski et al. 2014). In many ways, the quest to separate human and 'natural' changes is futile—mutual adjustments are inevitable, since we are part of nature.

Our histories fashion who we are, our socio-cultural associations and how we live with this planet. The choices we make indicate the importance we give to concerns for equity, justice and sustainability and the prospects for those who follow. They reflect our choices and rights for self-determination, alongside political, institutional and governance framings that determine how these rights are expressed. Respect for our ancestors must be viewed alongside concerns for the future generations. Inevitably, these issues are played out in very different ways in different areas. Societal interactions are far from static. They reflect interactions among differing cultural groups, values and lifestyles. In an emergent world in which it is increasingly recognized that we live in a 'no-analogue state' where novel ecosystems are inevitable, it remains to be seen how traditional cultures will be sustained into the future. Although traditional ways of living cannot be frozen in time to form a 'museum', historically framed visions offer vital perspectives for scoping potential futures and reflections upon our personal and societal choices (see Brierley et al. 2016c, Chap. 15).

The landscapes and ecosystems of the Upper Yellow River present challenging sets of constraints upon human interactions and prospects for the development. A suite of culturally framed adaptations to these constraints has enabled distinctive and diverse societies to emerge, survive and thrive in this area over many thousands of years. Doubtless future generations will also rise to their challenges, surviving and thriving through harmonious relationships with nature.

Acknowledgments Research in this chapter was conducted under the auspices of the Three Brothers (Plus) project. Funding from the three institutions (The University of Auckland, Qinghai University and Tsinghua University) is gratefully acknowledged. The work was supported by grants from the Program for Changjiang Scholars and Innovative Research Team in University, Ministry of Education of China (IRT13074) and International Science & Technology Cooperation Program of China, MOST (2011DFG93160). This work also benefitted from two travel/workshop grants from NZ Education.

References

An, C. B., Wang, L., Ji, D. X., et al. (2006). Temporal-spatial change of Neolithic culture and its potential driving forces in Ganqing area. *Quaternary Research, 26*, 923–927.

Beall, C. M. (2007). Two routes to functional adaptation: Tibetan and Andean high-altitude natives. *Proceedings of the National Academy of Sciences, 104*(1), 8655–8660.

Brantingham, P. J., Gao, X., Olsen, J. W., et al. (2007). A short chronology for the peopling of the Tibetan Plateau. *Developments in Quaternary Sciences, 9*, 129–150.

Brantingham, P. J., Ma, H., Olsen, J. W., et al. (2003). Speculation on the timing and nature of Late Pleistocene hunter-gatherer colonization of the Tibetan Plateau. *Chinese Science Bulletin, 48*, 1510–1516.

Brantingham, P. J., Olsen, J. W., & Schaller, G. B. (2001). Lithic assemblages from the Chang Tang region, Northern Tibet. *Antiquity, 75*, 319–327.

Brantingham, P. J., & Xing, G. (2006). Peopling of the northern Tibetan Plateau. *World Archaeology, 38*, 387–414.

Brantingham, P. J., Xing, G., Madsen, D. B., et al. (2013). Late occupation of the high-elevation Northern Tibetan Plateau based on cosmogenic, luminescence, and radiocarbon Ages. *Geoarchaeology, 28*, 413–431.

Brierley, G. J., Cullum, C., Li, X. L., et al. (2016a). Conclusion: Environmental futures of the Upper Yellow River Basin. In G. J. Brierley, X. Li, C. Cullum, et al. (Eds.), *Landscape and ecosystem diversity, dynamics and management in the Yellow River Source Zone*. (pp. 353–370).Berlin: Springer.

Brierley, G. J., Li, X., Cullum, C., et al. (2016b). Introduction: Landscape and ecosystem diversity in the Yellow River Source Zone. In G. J. Brierley, X. Li, C. Cullum, et al. (Eds.), *Landscape and ecosystem diversity, dynamics and management in the Yellow River Source Zone*. (pp. 1–34). Berlin: Springer.

Brierley, G. J., Yu, G. A., & Li, Z. W. (2016c). Geomorphic diversity of rivers in the Upper Yellow River Basin. In G. J. Brierley, X. Li, C. Cullum, et al. (Eds.), *Landscape and ecosystem diversity, dynamics and management in the Yellow River Source Zone*. (pp. 59–78). Berlin: Springer.

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.

Cheng, B., Chen, F., & Zhang, J. (2013). Palaeovegetational and palaeoenvironmental changes since the last deglacial in Gonghe Basin, northeast Tibetan Plateau. *Journal of Geographical Sciences, 23*, 136–146.

Chongyi, E., Hou, G. L., Sun, Y. J., et al. (2013). Human activities and environmental change in Holocene in the northeastern margin of Qinghai-Tibet Plateau: A case study of JXG2 relic site in Qinghai Lake. *Acta Geographica Sinica, 68*, 380–388.

Davison, K., Dolukhanov, P., Sarson, G. R., et al. (2006). The role of waterways in the spread of the Neolithic. *Journal of Archaeological Science, 33*, 641–652.

Deng, W., Shi, B., He, X., et al. (2004). Evolution and migration history of the Chinese population inferred from Chinese Y-chromosome evidence. *Journal of Human Genetics, 49*, 339–348.

Duan, J. (2002). *Gansu and Qinghai Prehistoric Archeology*. Heritage Press.

Duan, K. Q., Yao, T. D., Wang, N. L., et al. (2012). The unstable Holocene climatic change recorded in an ice core from the central Tibetan Plateau. *Scientia Sinica (Terrae), 42*, 1441–1449.

Fan, Q., Ma, H., & Hou, G. (2012). Late Pleistocene lake and glaciation evolution on the northeastern Qinghai-Tibetan Plateau: A review. *Environmental Earth Sciences, 66*, 625–634.

Gao, X., Zhou, Z. Y., & Guan, Y. (2008). Human cultural remains and adaptation strategies in the Tibetan Plateau margin region in the late Pleistocene. *Quaternary Sciences, 28*, 969–977.

Gasse, F., Fontes, J. C., van Campo, E., et al. (1996). Holocene environmental changes in Bangong Co basin (Western Tibet). Part 4: Discussion and conclusions. *Palaeogeography, Palaeoclimatology, Palaeoecology, 120*, 79–92.

Gayden, T., Cadenas, A. M., Regueiro, M., et al. (2007). The Himalayas as a directional barrier to gene flow. *The American Journal of Human Genetics, 80*, 884–894.

Herzschuh, U., Zhang, C., Mischke, S., et al. (2005). A late Quaternary lake record from the Qilian Mountains (NW China): Evolution of the primary production and the water depth reconstructed from macrofossil, pollen, biomarker, and isotope data. *Global and Planetary Change, 46*, 361–379.

Hobbs, R. J., Higgs, E., & Harris, J. A. (2009). Novel ecosystems: Implications for conservation and restoration. *Trends in Ecology & Evolution, 24*, 599–605.

Hou, G. L., Xu, C. J., & Fan, Q. S. (2010). Three expansions of prehistoric humans towards northeast margin of Tibetan Plateau and environmental change. *Acta Geographica Sinica, 65*, 65–71.

Huang, F. (2000). Vegetation and climate between 13 thousand years ago to 5 thousand years ago in Peiku Co, Tibet. *Acta Palaeontologica Sinica, 39*, 441–448.

Huang, C., van Campo, E., & Li, S. (1995). Holocene environmental changes of western and northern Qinghai-Xizang Plateau based on pollen analysis. *Acta Micropalaeontologica Sinica, 13*, 423–432.

Huerta-Sánchez, E., Jin, X., Bianba, Z., et al. (2014). Altitude adaptation in Tibetans caused by introgression of Denisovan-like DNA. *Nature, 512*(7513), 194–197.

Ji, D. X., Chen, F. H., Bettinger, R. L., et al. (2005). Human response to the last glacial maximum: Evidence from North China. *Acta Anthropologica Sinica, 24*, 270–282.

Jing, C. M., & Sun, N. D. (2001). Climatic evolution recorded by Ostracoda in Dabusun Lake in Qaidam basin during the past 30 ka years. *Marine Geology & Quaternary Geology, 21*, 55–58.

Keim, B. (2014). *Tibetans can thank ancient humans for gene that lets them live the high life*. National Geographic. Source: news.nationalgeographic.com/news/2014/07/140702 (viewed: 05.04.2015).

Lang, S. D. (1992). *Gansu prehistory research and development*. Northwest History, 2.

Lee, R.B. (1997). What hunters do for a living, or, how to make out on scarce resources. In: Gowdy, J. (Ed.). *Limited wants, unlimited means: A reader on hunter-gatherer economics and the environment*. Island Press. pp. 43-64.

Li, X. L., Perry, G., & Brierley, G. J. (2016). Grassland ecosystems of the Yellow River Source Zone: Degradation and restoration. In G. J. Brierley, X. Li, C. Cullum, et al. (Eds.), *Landscape and ecosystem diversity, dynamics and management in the Yellow River Source Zone*. (pp. 137–166). Berlin: Springer.

Li, S. J., Chen, W., Jiang, Y. J. et al. (2012) Geological records for Holocene climatic and environmental changes derived from glacial, periglacial and lake sediments on Qinghai-Tibetan Plateau. *Quaternary Science, 32*(1): 151–157.

Liu, C. J., Kong, Z. C., & Lang, S. D. (2004). Plant relics of the crops of different cultural period at Dadiwan site in Qinan, Gansu. *Central Plains Heritage, 4*, 26–30.

Liu, X., Shen, J., Wang, S., et al. (2002). A 16000-year pollen record of Qinghai Lake and its paleoclimate and paleoenvironment. *Chinese Science Bulletin, 47*, 1931–1936.

Liu, K. B., Yao, Z., & Thompson, L. G. (1998). A pollen record of Holocene climatic changes from the Dunde ice cap, Qinghai-Tibetan Plateau. *Geology, 26*, 135–138.

Madsen, D. B., Haizhou, M., Brantingham, P. J., et al. (2006). The late Upper Paleolithic occupation of the northern Tibetan Plateau margin. *Journal of Archaeological Science, 33*, 1433–1444.

McGregor, G. R. (2016). Climate variability and change in the Sanjiangyuan region. In G. J. Brierley, X. Li, C. Cullum, et al. (Eds.), *Landscape and ecosystem diversity, dynamics and management in the Yellow River Source Zone*. (pp. 35–58). Berlin: Springer.

Miehe, G., Kaiser, K., Co, S., et al. (2008a). Geo-ecological transect studies in northeast Tibet (Qinghai, China) reveal human-made mid-Holocene environmental changes in the upper Yellow River catchment changing forest to grassland. *Erdkunde, 2008*, 187–199.

Miehe, G., Miehe, S., Kaiser, K., et al. (2009). How old is pastoralism in Tibet? An ecological approach to the making of a Tibetan landscape. *Palaeogeography, Palaeoclimatology, Palaeoecology, 276*, 130–147.

Miehe, G., Miehe, S., Will, M., et al. (2008b). An inventory of forest relicts in the pastures of Southern Tibet (Xizang AR, China). *Plant Ecology, 194*, 157–177.

Monge, C., & Leon-Velarde, F. (1991). Physiological adaptation to high altitude: Oxygen transport in mammals and birds. *Physiological Reviews, 71*, 1135–1172.

Pengxi, Z., Baozhen, Z., Haijun, Q. G. L., et al. (1994). The study of paleoclimatic parameter of Qinghai Lake since Holocene. *Quaternary Sciences, 3*, 225–238.

Qian, Y., Qian, B., Su, B., et al. (2000). Multiple origins of Tibetan Y chromosomes. *Human Genetics, 106*, 453–454.

Ren, G. (2000). Decline of the mid- to late Holocene forests in China: Climatic change or human impact? *Journal of Quaternary Science, 15*, 273–281.

Ren, G. (2007). Changes in forest cover in China during the Holocene. *Vegetation History and Archaeobotany, 16*, 119–126.

Rhode, D., Haiying, Z., Madsen, D. B., et al. (2007a). Epipaleolithic/early Neolithic settlements at Qinghai Lake, Western China. *Journal of Archaeological Science, 34*, 600–612.

Rhode, D., Madsen, D. B., Brantingham, P. J., et al. (2007b). Yaks, yak dung, and prehistoric human habitation of the Tibetan Plateau. *Developments in Quaternary Sciences, 9*, 205–224.

Shen, C., & Tang, L. (1995). Pollen evidence of changing Holocene monsoon on Qinghai-Xizang Plateau. *Acta Micropalaeontologica Sinica, 13*, 433–436.

Shi, Y. F., & Liu, X. D. (1999). Relationship between strong summer monsoon and Precession cycle in 40–30 ka in Qinghai-Tibetan Plateau. *Chinese Science Bulletin, 44*, 1475–1480.

Shi, Y. F., Zheng, B. X., & Yao, T. D. (1997). Glacier and the environment of Qinghai-Tibet Plateau during the last glaciation maximum. *Journal of Glaciology and Geocryology, 19*, 97–113.

Skoglund, P., & Jakobsson, M. (2011). Archaic human ancestry in East Asia. *Proceedings of the National Academy of Sciences, 108*, 18301–18306.

Sun, X. J., Du, N. Q., Chen, Y. S., et al. (1993). Holocene palynological records in Lake Selinco, northern Xizang. *Acta Botanica Sinica, 35*, 943–950.

Tane, H., Li, X. L., & Chen, G. (2016). Ecogenesis of the Huang He (Yellow River) Headwaters. In G. J. Brierley, X. Li, C. Cullum, et al. (Eds.), *Landscape and ecosystem diversity, dynamics and management in the Yellow River Source Zone*. (pp. 275–330). Berlin: Springer.

Tang, L. Y., & Shen, C. M. (1996). Holocene pollen records in Qinghai-Tibetan Plateau. *Acta Micropaleontologica Sinica, 13*, 407–422.

Tang, L. Y., Shen, C. M., Kong, Z. C., et al. (1998). Pollen evidence of climate during the last glacial maximum in Eastern Tibetan Plateau. *Journal of Glaciology and Geocryology, 2*, 133–140.

Tang, L. Y., Shen, C. M., Li, C. H., et al. (2009). Pollen-inferred vegetation and environmental changes in the central Tibetan Plateau since 8200 yr BP. *Science in China Series D: Earth Sciences, 52*, 1104–1114.

Tang, L. Y., Shen, C., Liu, K., et al. (2000). Changes in South Asian monsoon: New high-resolution paleoclimatic records from Tibet, China. *Chinese Science Bulletin, 45*, 87–91.

Thompson, L. G., Yao, T., Davis, M. E., et al. (2006). Holocene climate variability archived in the Puruogangri ice cap on the central Tibetan Plateau. *Annals of Glaciology, 43*, 61–69.

van Campo, E., & Gasse, F. (1993). Pollen-and diatom-inferred climatic and hydrological changes in Sumxi Co Basin (Western Tibet) since 13,000 yr BP. *Quaternary Research, 39*, 300–313.

Wang, F. B., & Fan, C. Y. (1987). Climatic changes in the Qinghai-Xizang (Tibet) region of China during the Holocene. *Quaternary Research, 28*, 50–60.

Wang, F. B., Yan, G., & Lin, H. (1993). Preliminary study in Ruoergai Plateau peat δ~(13) C. *Chinese Science Bulletin, 38*, 65–67.

Wang, B., Zhang, Y. B., Zhang, F., et al. (2011). On the origin of Tibetans and their genetic basis in adapting high-altitude environments. *PLoS ONE, 6*(2), e17002. doi:10.1371/journal.pone.0017002

Wang, C., Guo, H., Zhang, L. et al. (2015). Assessing phenological change and climatic control of alpine grasslands in the Tibetan Plateau with MODIS time series. *International Journal of Biometeorology, 59*, 11–23.

Wang, Y., Zhao, Z. Z., Qiao, Y. S., et al. (2006). Paleoclimatic and paleoenvironmental evolution since the last glacial epoch as recorded by sporopollen from the Hongyuan peat section on the Zoige Plateau, northern Sichuan, China. *Geological Bulletin of China, 25*, 827–832.

Williams, J. W., & Jackson, S. T. (2007). Novel climates, no-analog communities, and ecological surprises. *Frontiers in Ecology and the Environment, 5*, 475–482.

Wischnewski, J., Herzschuh, U., Rühland, K. M., et al. (2014). Recent ecological responses to climate variability and human impacts in the Nianbaoyeze Mountains (eastern Tibetan Plateau) inferred from pollen, diatom and tree-ring data. *Journal of Paleolimnology, 51*, 287–302.

Wohl, E. (2013). Wilderness is dead: Whither critical zone studies and geomorphology in the Anthropocene? *Anthropocene, 2*, 4–15.

Wu, Z. Y. (1980). *Vegetation of China* (pp. 1023–1035). Beijing: Science Press.

Wu, Y. H., Li, S. J., & Wang, S. M. (2007). Lake sediment geochemical records indicate Holocene climate change in central Qinghai-Tibetan Plateau. *Science China Press (D), 37*, 1185–1191.

Yang, B., Bräuning, A., Liu, J., et al. (2009). Temperature changes on the Tibetan Plateau during the past 600 years inferred from ice cores and tree rings. *Global and Planetary Change, 69*, 71–78.

Yao, T. D. (1999). Abrupt climate change of Qinghai-Tibet Plateau in the last glaciation, comparative study of Guliya ice core and Greenland GRIP ice core. *Science China Press (D), 29*, 175–184.

Yao, T. D. (2000). Oxygen isotope stratigraphy of the Guliya ice core. *Quaternary Research, 20*, 165–170.

Yao, T. D., Yang, M. X., & Kang, X. C. (2001). Comparative study of the climate changes in the past 2000 years by using ice core and tree ring records. *Quaternary Sciences, 21*, 514–519.

Yi, M. J., Gao, X., Zhang, X. L., et al. (2011). Qinghai-Tibetan Plateau marginal areas prehistoric sites in 2009 Excavation Survey Report. *Acta Anthropologica Sinica, 2*, 124–136.

Zhang, X. S. (1978). Vegetation of the Tibetan plateau. *Bulletin of Botany, 20*, 140–149.

Zhang, S. S. (1990). Paleolithic industry regional progressive and cultural communication in northern China. *Acta Anthropologica Sinica, 9*, 322–333.

Zhang, D. J., Chen, F. H., & Bettinger, R. L. (2010). The archaeological record and origins of rainfed agriculture since 60 kaBP in Dadiwan relics, Gansu. *Science China Press, 55*, 887–894.

Zhang, L., Guo, H., Wang, C., et al. (2014). The long-term trends (1982–2006) in vegetation greenness of the alpine ecosystem in the Qinghai-Tibetan Plateau. *Environmental Earth Sciences, 72*, 1827–1841.

Zhang, Y. F., & Zhang, J. P. (1995). Holocene paleoclimate evolution of the Yellow River source region of Earth Science. *China University of Geosciences, 20*, 445–449.

Zhao, D., Wu, S., Yin, Y., et al. (2011a). Vegetation distribution on Tibetan Plateau under climate change scenario. *Regional Environmental Change, 11*, 905–915.

Zhao, Y., Yu, Z., & Zhao, W. (2011b). Holocene vegetation and climate histories in the eastern Tibetan Plateau: controls by insolation-driven temperature or monsoon-derived precipitation changes? *Quaternary Science Reviews, 30*, 1173–1184.

Zheng, J. P., Yuan, H. R., Zhao, X. T., et al. (2006). Quaternary great lake period and paleoclimate in Qinghai-Tibetan Plateau. *Acta Geologica Sinica, 79*, 169–180.

Zhou, D. J., Horse, H. Z., & Tan, H. B. (2003). Human activity and the northern part of Qinghai lake evolution since the late Pleistocene. *Salt Lake Research, 11*, 8–13.

Zhu, Y. Z., Bell, J. H., & Lee, W. S. (1994). *New tectonic movement and evolution of salt lake in Qaidam basin*. Geology Press.