# Chapter 14
# Socio-economic Development and Its Effects on the Ecological Environment of the Yellow River Source Zone

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**Abstract** Socio-economic development and protection of ecological environments are critical mutual challenges to human growth. This chapter provides an initial overview of the relationships between economic activity and the eco-environment in the Yellow River Source Zone on the Qinghai–Tibet Plateau. The broad geography, regional context and economic situation in the Yellow River Source Zone are first outlined. The catchment area and administrative districts of the Yellow River Source Zone are summarized, and the population history is overviewed. Key elements of the regional economy, animal husbandry and agricultural prospects are appraised. Landscape changes, grassland degradation and the causes of ecological degradation are related to the impacts of economic activities and legal considerations, showing how policy framings and management practices have affected the health of rangelands in the Yellow River Source Zone. These factors underpinned to the establishment of the Sanjiangyuan National Nature Reserve for ecological protection.

**Keywords** Alpine grasslands · Grazing · Animal husbandry · Ecological degradation · Economic activity · Eco-environment protection · Tibetan areas · Qinghai–Tibet Plateau · Sanjiangyuan National Nature Reserve

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## 14.1 Introduction

The Yellow River Source Zone is an important part of the Sanjiangyuan region. It has a similar geographical position, soil conditions and climatic conditions to those experienced in the source regions of the Yangtze River and the Lancang (Mekong) River. However, different trajectories of change are evident for these three rivers. In recent years, the annual run-off of the Yellow River Source Zone has significantly reduced, while flow of the Yangtze River and the Lancang River has remained stable or even risen (Yellow River Source Zone research group of Qinghai Province, 2005). Since 2005, the Yellow River has dried up several times. Problems of ecological degradation in the Upper Yellow River Basin are much more severe than those in the adjacent Upper Yangtze River Basin. For these reasons, the Yellow River Source Zone has attracted much attention from "natural" scientists, but to date research on the relationship between social sciences and environmental impacts has received very limited attention. This chapter seeks to address this limitation, providing an initial overview of the relationships between economic activity and the eco-environment in the Yellow River Source Zone.

Given its clear boundary and ease of access to historical records of population and economy, the Yellow River Source Zone is described in this chapter solely in relation to administrative districts within Qinghai Province. In this definition, the Yellow River Source Zone refers to 15 counties, which includes six counties in Golou, four counties in Huangnan and five counties in Hainan prefectures. This covers a total area of 137,700 $km^2$ (see NDRC 2014). Importantly, this definition is consistent with that used in the Qinghai Ecological Protection and Construction in the Sanjiangyuan—Phase II, which has been implemented in the Yellow River Source Zone since 2013 and for which most of the environmental data are available (NDRC 2014) (Fig. 14.1).

Given its special geographical location and natural resources, the Sanjiangyuan region has distinctive circumstance in relation to its social and economic development. The natural resources in the region are very abundant, but their development and utilization are constrained by many factors, including the physical environment, accessibility and logistical considerations, available funding and investment and access to recent technology. Like other places in the region, the economy of the Yellow River Source Zone relies heavily on animal husbandry, with a limited area of farmland in the east and south-east of this region, and a very small industrial area in an early stage of development. Despite pockets of development, the region as a whole remains underdeveloped.

In this chapter, we use historical records from the late Qing Dynasty until the present to assess stages of economic development and their relationships to the environment. We identify two turning points in development trends: (a) the foundation of the People's Republic of China in 1949 and (b) the establishment of the Sanjiangyuan Provincial Reserve in 2000.

Historically, the region between the Yellow River and the Yangtze River was referred to as Amdo. This was one of the three traditional regions of Tibet, the

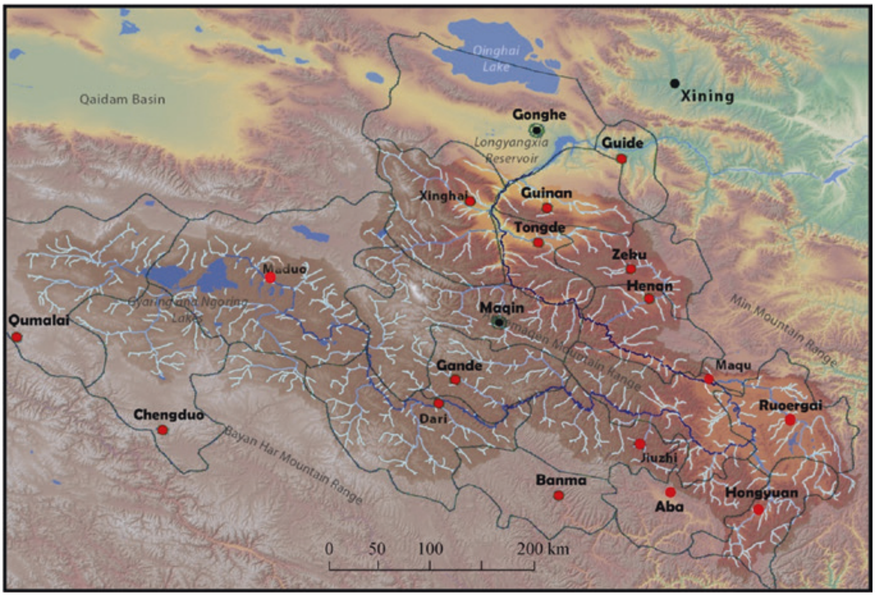


**Fig. 14.1** The catchment area and administrative districts of the Yellow River Source Zone. The catchment area is from Blue et al. (2013), and the administrative districts with 19 counties are from the administrative maps of Qinghai, Sichuan and Gansu provinces. In this chapter, the Yellow River Source Zone refers solely to the 15 counties in Qinghai Province (i.e. Aba, Hongyuan and Ruoergai counties in Sichuan and Maqu County in Gansu are excluded)

other two being Ü-Tsang and Kham. While historically, culturally and ethnically a Tibetan area, Amdo has been administered by a series of local rulers since the mid-eighteenth century and the Dalai Lamas have not governed the area directly since that time (although the 14th Dalai Lama was born in this area in 1935). From 1917 to 1928, much of Amdo was intermittently occupied by the Hui Muslim warlords of the Ma Clique. In 1928, the Ma Clique joined the Kuomintang, and during the period from 1928 to 1949, much of Amdo was gradually incorporated into Qinghai Province (and part of Gansu Province) of the Nationalist Republic of China. By 1952, Chinese Communist forces had defeated both the Nationalist Army and the local Tibetans and had assumed control of the region, solidifying their hold on the area by 1958 and formally ending the political existence of Amdo as a distinct Tibetan province.

A harmonious relationship between economic development and the ecologic environment was evident in the late Qing Dynasty. The foundation of the People's Republic of China initiated economic development, increases in population and an increase in livestock numbers. In combination with declining rainfall, these changes triggered an ecological crisis in the Yellow River Source Zone, characterized by the emergence of "*Heitutan*" (degraded alpine meadows, see Li et al. 2016a, Chap. 7). The foundation of the Sanjiangyuan Provincial Reserve in 2000 (upgraded to a national reserve in 2003) has brought about moves towards restoration and protection of the ecological environment. Approaches to ecological restoration and protection remain a contentious issue, competing against pressures for economic development in this region. This presents significant concerns for researchers and for the national and provincial governments.

This chapter is structured as follows. First, the broad geography, regional context and economic situation in the Yellow River Source Zone are outlined. Second, the population history is overviewed. This is followed by an appraisal of key elements of the regional economy, focusing on animal husbandry, agricultural prospects more broadly and the limited industrial development of the region. Fourth, a summary of ecological degradation is presented, focusing primarily upon grassland degradation and the emergence of *Heitutan*. Section 14.5 relates ecological degradation to the economic situation. The next section describes the establishment of the Sanjiangyuan Reserve and efforts to protect and restore ecosystem services in the region. The chapter closes with a comment on future prospects, highlighting how future environmental conditions are intimately linked to socio-economic circumstances.

## 14.2 Economic Status of the Yellow River Source Zone

By the end of 2013, the population of the Yellow River Source Zone was 0.92 million. Tibetans comprise 77.6 % of this population. 75.5 % of the population was made up of herdsmen or farmers.

The gross domestic product of Yellow River Source Zone was 21.57 billion RMB (Chinese yuan). Of this, 25.1 % was contributed by the primary production (animal husbandry, agriculture and forestry), 45.1 % from the secondary sector (manufacturing, mining and construction) and 29.6 % from the tertiary service sector (which includes commerce, transport and tourism). The disposable income of urban residents was 19,657 RMB per capita per year, while that of farmers and herdsmen was 5458 RMB per capita per year.

## 14.3 Historical Population Changes in the Yellow River Source Zone

Because of the geography, climate, environment and economy, the population density in this region is, and always has been, very low. Based on existing historical materials, the earliest record of population in the region dates from the Daye period in the Sui Dynasty (607–615), which refers to Guide County in Hainan Prefecture (Cui et al. 1999). There were 2240 households in this prefecture in the Daye period of the Sui Dynasty (607–615). Later, in the 6th year of the Yonghui period of the Tang Dynasty (655 AD), there were 4261 households with a population of 24,400 people. At the time of the Zhiyuan period of the Yuan Dynasty

(1264–1294), there were about 6000 households, while in the 11th year of the Qianlong period of the Qing Dynasty, in 1746, the population was over 115,601. By 1853, the population of Guide County had exceeded 198,050 people (GSHTAP 2009).

According to the “Local Records of Toshi, Annals of Sichuan” (1814), there were 350 households in Golou, with a population of 1510. In 1941, there were 51 tribes in Golou, with 13,300 households (GSGTAP 2009). In the late Qing Dynasty in 1914, the population was about 70,000 (map annals of Ganzi County, 1961; Zhou 1968). In 1949, the census reported the population of Golou Prefecture as 53,652 (Committee of Qinghai Provincial Conditions, 1986).

Jing and Xu (2005) estimate that the total population of the Sanjiangyuan region in 1814 was about 40,000, growing to 150,000 by 1949. These figures suggest that a population increase of 75 % (about 5.61 % per year) occurred in the Sanjiangyuan region from the mid-Qing Dynasty to the Min period (1814–1914). The rate of increase was notably faster in the Min period (1914–1949), with a 90 % increase at an average rate of 18.62 % per year.

After the foundation of the People’s Republic of China, the four prefectures of Sanjiangyuan region (Yushu, Golou, Huangnan and Hainan) were founded, and the population grew dramatically. In 1953, the population in the Yellow River Source Zone was 249,841, but had almost quadrupled by 2013 (Table 14.1).

In terms of population density across the Yellow River Source Zone, numbers increased from 1.12 people km$^{-2}$ in 1964 to 1.45 in 1970, 2.2 in 1982, 2.31 in 1985, 2.74 in 1995, 3.28 in 2005 and 4.16 in 2013. The impact of human activities upon the environment is likely to be closely related to population density. However, it should be remembered that the overall population density in this area is very low, with some places largely uninhabited.

**Table 14.1** Population changes in the Yellow River Source Zone 1953–2013, based on census data

| Prefectures | 1953 | 1964 | 1982 | 1990 | 2000 | 2010 | 2013 |
|---|---|---|---|---|---|---|---|
| Hainan | 115,721 | 166,699 | 324,995 | 361,355 | 401,743 | 441,689 | 463,440 |
| Huangnan | 79,800 | 85,463 | 147,364 | 181,995 | 225,462 | 256,716 | 268,061 |
| Golou | 54,320 | 56,067 | 103,708 | 119,973 | 140,397 | 181,682 | 192,926 |
| Total | 249,841 | 308,229 | 576,067 | 663,323 | 767,602 | 880,087 | 924,427 |

*Notes* The data were collected from the Qinghai statistical yearbooks published in 1954, 1965, 1983, 1990, 2001, 2011 and 2014 (QBS 1952, 1954, 1965, 1983, 1990, 2001, 2011, 2014). In Golou, there were no data published for 1953, so the data from 1952 are substituted. Note that Yushu Prefecture is part of the Upper Yangtze River Basin and is not included here

## 14.4 Economic Activity in the Yellow River Source Zone

Animal husbandry, agriculture, forestry, mining, industry, commerce, transportation industry, tourism, engineering construction and service provision are the primary economic activities in the region. The influence of human activities depends not only on population size, but also on the industrial structure. For instance, vegetation destruction and soil erosion in the Yellow River Source Zone are mainly associated with animal husbandry, while localized water and air pollution mainly result from mining and industry.

### *14.4.1 Animal Husbandry*

Since ancient times, animal husbandry has been the key primary industry of the Yellow River Source Zone. Western Qiang people were the first tribe to develop animal husbandry in the Yellow River Source Zone, followed by nomadic peoples of Xianbei, Tuyuhun, Tibet and Mongolia (Zhai and Cui 2004). Unfortunately, historical records retain little information on the livestock population. The first record referred to as "notes of Qinghai" stated that in the late Qing Dynasty (around 1910), the livestock belonging to Mongolians in Qinghai and Tibetan people around Qinghai Lake totalled about 2.52 million (Kang 1968). Based on these numbers, the total livestock in Qinghai Province would have been more than 4 million. This estimate contrasts with the estimate of the total livestock in Qinghai Province in the early Min period (around 1915) provided by Zhai and Cui (2004) of 7.53 million, rising to 12.28 million in 1937 and 7.49 million in 1949. In 2013, the total livestock in the Sanjiangyuan region took up 53.3 % of the total livestock in Qinghai Province. Based on this ratio, estimates of the livestock population in the Yellow River Source Zone from 1814 to 2013 are summarized in Fig. 14.2.

After the foundation of the People's Republic of China, animal husbandry developed rapidly, especially in the 1970s and the 1980s. Data trends in recent years can be derived from the analysis of the Qinghai statistical yearbooks (QBS 1996, 2006, 2011, 2014). In 1995, the gross productivity in the Yellow River Source Zone was 2 billion RMB, and the productivity of animal husbandry was 1.02 billion (i.e. 51 % of gross productivity). However, by 2005, the gross productivity was 5.97 billion RMB, only 1.79 billion of which came from animal husbandry (a reduction in contribution rate to 29.9 %). By 2009, the gross productivity was 10.84 billion RMB, of which animal husbandry provided 3.07 billion (a further decrease to 28.3 %). Finally, by 2013, the gross productivity was 21.57 billion RMB, of which animal husbandry provided 5.42 billion (25.1 %). These data indicate that industrial structures in the region changed significantly over this period (see also Li 2007a).

Three key traits can be discerned in the recent history of economic performance of the Yellow River Source Zone. First, while productivity increased sharply, the

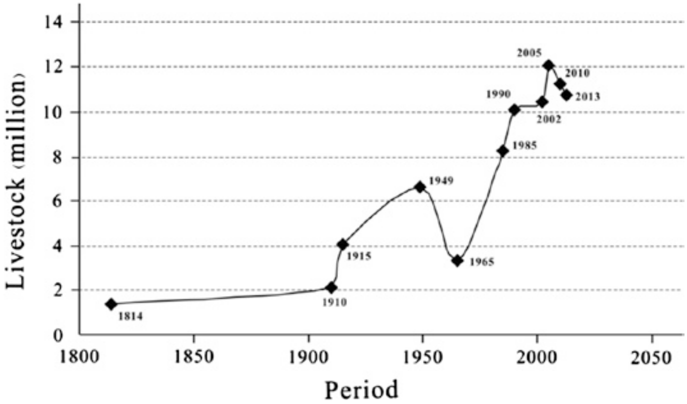


**Fig. 14.2** Estimated livestock population (yak and sheep) in the Yellow River Source Zone from 1814 to 2013 (see text for details). (Nb. The units are individual animals, not "sheep unit")

**Table 14.2** The composition of livestock in Golou Prefecture of the Yellow River Source Zone (*Source* QBS 1996, 2014)

| Year | Yak number (×10,000) | Sheep number (×10,000) | Yak proportion (%) | Sheep proportion (%) |
|---|---|---|---|---|
| 1995 | 103.15 | 136.21 | 43 | 57 |
| 2013 | 61.52 | 55.16 | 53 | 47 |

contribution rate from animal husbandry declined significantly. Second, although livestock numbers initially increased, since around 2003 they have decreased. Third, the composition of livestock has changed significantly, with the number of yak increasing while the number of sheep has decreased. This latter trend is evidenced from Golou Prefecture from 1995 to 2013, where the proportion of yak increased by 10 %, while the proportion of sheep decreased by 10 % (Table 14.2).

### *14.4.2 Agriculture/Crop Planting*

Crop planting in Qinghai Province is located primarily in the Hehuang Valley, making up only a very small area in the Yellow River Source Zone. Minor areas are located along the main valley floors in Tongde, Xinghai, Zeku and Maqin counties. The cropped area in the Yellow River Source Zone has remained relatively stable in the last 30 years ($2.66 \times 10^4$ hm$^2$ in 1985; $2.41 \times 10^4$ hm$^2$ in 1995; $2.66 \times 10^4$ hm$^2$ in 2013; QBS 1986, 1996, 2014).

### 14.4.3 Industry

Since ancient times, industrial development in the Yellow River Source Zone was largely restricted to a little traditional handicraft. As more and more machinery and equipment came into the area since the 1960s, various small enterprises such as factories and mines started to develop, marking the initial phases of emergence of an industrial system. Industry expanded to include processing of animal products, coal, power, gold mining, construction and wood processing. Industrial growth and economic development has been especially pronounced since the 1990s. The gross value of industrial output in the Yellow River Source Zone was 0.43 billion RMB in 1995, rising to 1.37 billion RMB in 2000, 2.40 billion RMB in 2005 and 9.72 billion RMB in 2013 (data from the Qinghai statistical yearbooks published in 1996, 2001, 2006 and 2014, adjusted for inflation). In 2013, there were 28 industrial enterprises, with 5 in Huangnan, 22 in Hainan and one in Golou prefectures.

### 14.4.4 Mining

The Yellow River Source Zone is relatively rich in mineral resources. Golou is mainly rich in coal, alluvial gold, lake salt, limestone and stibnite. Hainan is mainly rich in copper and ferroalloy. Existing records provide little indication for extraction of these resources prior to the foundation of the People's Republic of China. Mining commenced after 1958, with the rapid development in the 1980s and 1990s associated with the rapid growth of population, the formation of towns and the establishment and development of local industry. For example, the output of raw coal in 1958 ($2.16 \times 10^4$ t) rose to $6.49 \times 10^5$ t in 1995. Since 2005, government policies for environment protection have brought about gradual decreases in the output of raw coal (QBS 1959, 1996, 2006).

Golou is rich in alluvial gold. Initial mining endeavours began in the 1920s and 1930s. By 1985, the population of gold miners was 12,000, and two years later, the discovery of some major deposits brought about a significant increase in the number of gold miners and the amount of gold production. From 1996 to 1999, the cumulative production of gold in Golou was 419.38 kg and then fell to 94.84 kg in 2000 and 96.77 kg in 2001. A big copper mine in Maqin County has an annual production of around 110,000 tons. The mining industry in Huangnan was relatively small prior to 1992 but has experienced significant and rapid development since then with the development of many silicon carbide and ferrosilicon factories. In 2000, a big aluminium profile factory was set up here, generating 1157 t of aluminium ingots in 2005.

Summary of mining production statistics for the Yellow River Source Zone in 2013 is as follows: copper = $2.988 \times 10^4$ t, cement = $63.3 \times 10^4$ t, ferroalloy = $3.5 \times 10^4$ t, non-ferrous metal = $3.2 \times 10^4$ t and electrolytic aluminium = $3.2 \times 10^4$ t (data from the 2014 Qinghai statistical yearbook). The rapid development of the mining industry brought about a major boost to the local economy, but at the same time, it also impacted upon grassland vegetation cover and the local ecological environment.

## 14.5 Landscape Change and Grassland Degradation

### *14.5.1 Change in Land Use and Land Cover*

Pan and Liu (2005) and Huang (2012) note significant changes in land use and land cover in the Yellow Region Source Zone between 1986 and 2005. Construction land, unused land and cultivated land area increased rapidly, while the area of grassland was reduced, changing mostly into unused land. Wetland and the forest land decreased markedly. The degree of landscape fragmentation and the diversity index increased, as the land cover became more heterogeneous. The eco-environment was very vulnerable and sensitive to land use change, resulting in land desertification (Li and Wang, Chap. 8), soil and water loss (Tane et al. 2016, Chap. 13) and degradation of high-cold meadow vegetation (Li et al. 2016a, Chap. 7) and wetlands (Li et al. 2016b, Chap. 9; Gao 2016, Chap. 10).

### *14.5.2 Grassland Degradation*

Based on the interpretation of $10.44 \times 10^4$ km$^2$ of satellite remote sensing images, Wang et al. (2004) noted that the rate of grassland degradation in the 1980s–1990s was twice the rate of degradation experienced in the 1970s–1980s. Dai et al. (2006) stated that the grassland area changed greatly in the period of 1992–2000, decreasing at a rate of 1151.5 km$^2$ year$^{-1}$. Decreases in the average coverage of vegetation have been accompanied by an expansion in the area of land desertification. According to Jing et al. (2005), the grassland degradation in the Yellow River Source Zone is much more severe than that in the source region of the Yangtze River and the Lancang River (Table 14.3).

**Table 14.3** Comparison of grassland degradation in three areas of Sanjiangyuan region (*Source* Jing et al. 2005)

| Land kind | Yellow River Source Zone (%) | Source regions of the Yangtze River and the Lancang River (%) |
|---|---|---|
| Desertified | 17.84 | 12.37 |
| Pest infested | 33.15 | 13.30 |
| Heitutan | 7.34 | 3.36 |
| Secondary bare land | 16.87 | 5.48 |

## 14.6 The Cause of Ecological Degradation

Controversy abounds in determining underlying causes of grassland degradation in the Yellow River Source Zone (e.g. Harris 2010; see Li et al. 2016a, Chap. 7). In broad terms, researchers can be divided into two groups, those who favour a "natural" cause and those who favour an "anthropogenic" cause. The "natural" cause group believes that environmental changes in the Yellow River Source Zone are the result of global climate change, manifest as elevated temperatures, reduced precipitation and increased evaporation. Taken together, these factors have induced a drought trend that is considered to be the main cause of environment degradation in the region (Tang and Wu 1996; Wu and Li 2004). The "anthropogenic" cause group suggests that climate change is ultimately a relatively slow process and that overgrazing has been the main reason for degradation of grassland ecosystems in recent decades. Overgrazing is considered to have reduced grass biomass, changed the species composition, changed the compaction of grassland and promoted rodent outbreaks, such that all of these factors collectively have broken the balance and stability of the eco-system (Li et al. 2013, 2014). Given sustained high grazing pressure, the ecological environment has suffered continuing deterioration (Chen et al. 2014; Cheng and Wu 2007; Fan et al. 2010).

In reality, degradation of ecological environments in the Yellow River Source Zone is likely a response to both natural and anthropogenic causes. Climate changes are undoubtedly vital over long timescales, but over shorter (annual–decadal) timescales, many scientists and the government consider the effects of overgrazing (and associated economic development and resource depletion) to have induced enhanced desertification across much of Northern China, including the Yellow River Source Zone (Chen et al. 2014; Kang et al. 2007; Wang et al. 2007; Xue 1996; Yang et al. 2015).

Here, we review trends of environmental degradation in relation to the main anthropogenic causes, focusing upon the population record and economic data.

### *14.6.1 Economic Activity*

A clear linear relationship is evident between environment deterioration and population, livestock, economic development and industry structure. With the increase of population, the area and scope of human economic activities expanded and extended significantly. In the Yellow River Source Zone, the industry structure is almost entirely dependent upon animal husbandry. As a consequence, overgrazing has become the main cause of ecological degradation since the 1970s and 1980s. This period of rapid population growth across China was coincident with the fastest economic growth period in the Yellow River Source Zone. The population and livestock size in the Yellow River Source Zone in the 1980s were twice those experienced in the 1960s. By 2013, population and livestock size had increased by

**Table 14.4** Carrying capacity calculation table of usable grassland in the Yellow River Source Zone (units: 10,000 $hm^2$, 10,000 sheep unit)

| Prefecture | Available grassland after grazing prohibition | | Existing artificial grassland | | Existing improved grassland | | Total theoretical capacity | Actual carrying capacity | Theoretical livestock reduction |
|---|---|---|---|---|---|---|---|---|---|
| | Area | Theoretical capacity | Area | Theoretical capacity | Area | Theoretical capacity | | | |
| Golou | 223.91 | 198.08 | 1.78 | 13.66 | 1.38 | 4.14 | 215.88 | 455.48 | -261.76 |
| Hainan | 245.62 | 92.48 | 1.74 | 15.47 | 2.68 | 8.04 | 115.99 | 593.04 | -477.05 |
| Huangnan | 84.2 | 50.55 | 1.45 | 11.44 | 0.36 | 1.08 | 63.07 | 237.59 | -174.52 |
| Total | 553.73 | 341.11 | 4.97 | 40.57 | 4.42 | 13.26 | 394.94 | 1296.11 | -913.33 |

Data in the table were collected from the report of the second phase for the ecological protection and restoration of NRSS (NDRC 2014) and the general situation of Tibetan Autonomous Prefecture of Haungnan (Duojiecairang et al. 2009), Golou (Huagongjie et al. 2009) and Hainan (Doubenjia et al. 2009)

3.7 times. After the Reform and Opening-up of China, and the associated development of secondary and tertiary industries, the relative proportion of primary industries to total economic production continued to decrease. However, the absolute productivity from animal husbandry only decreased by a small proportion at this time, such that overgrazing in the Yellow River Source Zone became severe (Table 14.4).

The cost of economic development, especially consequences for overgrazing and excessive excavation, has accentuated grassland degradation and desertification on the one hand, but on the other hand, it has brought about heightened awareness of environmental sensitivity and impacts of human activities/behaviour. Under the influence of a market economy, modern herdsmen have become "economic practitioners", increasingly maximizing economic benefits by increasing stocking production and changing routines in their daily life. The law of a market economy that seeks to maximize economic benefits for minimum economic costs has indirectly brought about significant damage to the ecological environment of the Yellow River Source Zone.

### *14.6.2 Regulations, Policy, Legal and Cultural Factors*

First, from the regulatory perspective, the household contract responsibility policy did not work very effectively in Qinghai Province, with significant consequences for environmental management in the area. Since 1984, in the early stages of this policy, livestock production was greatly increased in all pastoral areas of the Yellow River Source Zone. Undue emphasis upon "separation" while excluding concerns for "integration", along with the market-based economic philosophy, brought about overgrazing and ecology deterioration in this area and other pastoral areas in China (Li 2007b).

Second, from a legal point of view, the Grassland Law issued in 1985 regulated between state and collective ownership, but the specific provisions for collective ownership were unclear. Furthermore, the separation of ownership of grassland surface resources and underground resources meant that grasslands often lacked an appropriate guardian, presenting an opportunity for their excessive exploitation (Wu 2014).

Third, from a cultural point of view, the traditional way of life, including the use of cattle and sheep manure for heating and cooking, has indirectly aggravated the ecological destruction of grassland (Dong 2009; Luo and Yang 2011). In the daily life of Tibetan herdsmen, 90 % of the total energy consumption is domestic energy, 99 % of which was provided by cattle and sheep manure, along with tree and grass roots. The average consumption of manure ranges from 5000 to 8000 kg for each family (Yu 2010). When manure is burnt, nutrients are not returned to the soil, such that the grasslands are slowly but surely stripped of nutrients (see Tane et al. 2016, Chap. 13).

## 14.7 Impact of Policy Framings and Management Practices upon the Health of Rangelands in the Yellow River Source Zone

Rangelands in China have been utilized for thousands of years with little trace of degradation. This likely reflects the limited intensity of land use practices. The mere fact that most rangelands of concern are considered to have been in much better condition only a few decades ago indicates that traditional pastoral systems are not inconsistent with long-term sustainability (Harris 2010). As such, these practices, of themselves, are not the underlying cause of grassland degradation. Sustainable production systems require a harmonious relationship between human utilization and natural resources, wherein grazing intensity does not impact negatively upon the health of rangeland ecosystems. Over the last 40 years, however, the rate of degradation has increased dramatically.

Rangeland degradation on the Qinghai–Tibet Plateau has been coincident with the rapid growth of human population, changes to land tenure that contracted rangeland areas to pastoralists (and subsequent increases in livestock numbers that induced overstocking) and subsequent irruptions of small mammals (Li et al. 2013). The population of pastoral areas in Qinghai doubled from 1949 to 2003, and livestock numbers increased 2.96 times during the same period, doubling the intensity of grazing in rangelands (Li et al. 2013). The urge to have large stocks resulted in an inadequate reserve of fodder and forage. Local animal husbandry production cannot escape the cycle of “survival in summer, fattening in autumn, thinning in winter and death in spring”. As a result, some pastoralists are forced to graze their livestock at higher elevations, spreading anthropogenic impact and damage to wider areas (Li et al. 2013). These factors, in turn, have accelerated rangeland degradation and contributed to rodent damage in some areas. Unfortunately, it is not possible to increase livestock size through purchasing more fodder as this is beyond the financial means of the pastoralists.

Grazing exerts an important influence upon plant community structure and productivity in natural grasslands (Li et al. 2016a, Chap. 7). In some instances, fencing to exclude grazers is viewed as an important management practice to "protect" grasslands. However, Wu et al. (2009) showed that while fencing significantly improved above-ground vegetation productivity, it reduced plant density and species diversity.

Overgrazing over an extended period gradually lowers the density of vegetation cover, leading to the degradation of alpine meadow. Original species are progressively replaced by unpalatable and even toxic plants, and soil fertility is depleted. Irreversible rangeland degradation and the formation of the "black soil beach" (*Heitutan*) in meadow areas is characterized by coarsening of the surface layers of the soil, increases in bulk density, porosity and saturated hydraulic conductivity, and a decrease in the water-holding capacity of the soil. These changes create favourable conditions for native rodents to thrive, which in turn accentuates the formation of *Heitutan*. The rapid expansion in numbers of native rodents over the past 40 years reflects alterations to the structure of the food chain of the plateau ecosystem. In addition, illegal hunting has restricted the beneficial role of eagles (*Accipiter* spp.), Tibetan fox (*Vulpes ferrilata*) and weasels in limiting the impacts of harmful rodents upon grassland (Li et al. 2013).

Notions of assumed sustainability and resilience of traditional herding systems framed in relation to large-scale movements to mediate short-term livestock–pasture imbalances often naively ignore the desires of some pastoralists for more sedentary lifestyles that include better access to schools or medical care. Inevitably, nomadic pastoralists respond to economic and political incentives, choosing the path that they perceive will bring the most benefit and least pain to themselves and their families (Harris 2010). Prior to imposition of state control, this meant a traditional semi-nomadic pastoral lifestyle, in which herd sizes were limited by a combination of natural factors and the needs of a largely subsistence lifestyle. During the collectivization period, when immediate livestock production requiring large numbers of animals was mandated by policy, herd sizes were increased to levels beyond what could be sustained. This encouraged high livestock densities. With the dissolution of collectives and the rapid transition to a market economy in the 1980s, many pastoralists modulated their herd sizes to those which they perceived would make them the most money (e.g. Cincotta et al. 1992; Zhang et al. 2004). With the increased prices available for sheep and goat products (largely arising from outside the local area) and the increased ease of access to distant markets (largely in the form of mobile livestock purchasers from Xinjiang, Gansu or eastern Qinghai), larger herds meant larger short-term profits (Harris 2010). Lack of power to negotiate higher prices meant that higher profit could only be achieved by increasing herd size.

Ecological modernization narratives take for granted both a crisis of ecological degradation and the premise that the "greening" of the state will improve environmental conditions in Western China (Yeh 2009). However, the contextual underpinnings of these assertions are contested, and significant concerns have been raised for prospective socio-economic and cultural consequences (e.g. Cao et al. 2013; Harris 2010).

Natural grassland has been regionally degrading since the 1980s. This reflects a complex range of factors which vary spatially and temporally across the plateau, including differing combinations of climate warming, increasing population, fast-growing grazing pressure and rodent damage (Chen et al. 2014; Harris 2010; Li et al. 2013). Li et al. (2013) contend that although there is general agreement that the Qinghai–Tibet Plateau is particularly sensitive to global climate change, these considerations have played a secondary role in the degradation of grasslands in this area. The harsh natural environment (e.g. climate and fragile soil) of the area does not cause rangeland degradation in its own right. Rather, the area is inherently vulnerable to degradation due to its fragile eco-environment, such that overgrazing, rodents and exploitative utilization of rangelands do more damage to ecosystems here than in less sensitive environments (e.g. areas with more water resources and more amenable temperatures). Rangeland degradation would not take place in the absence of intensive human disturbances.

Ecologically based technological solutions to reduce overgrazing on the Qinghai–Tibet Plateau include concentrating livestock in places where they can be protected from the elements and provided forage grown off-site, increased fencing to facilitate rotation of pastures, restructuring herds to increase the proportion of reproductive females, and manipulating herd size frequently to reflect seasonal rhythms of vegetation biomass and nutrient levels (Harris 2010). Suggested remedies for rehabilitating degraded rangelands include killing small mammals, temporary or permanent removal of livestock, fertilization and/or reseeding (Harris 2010). Some researchers, such as Wu and Yan (2002), consider the "set of four" programmes including subsidizing construction of permanent winter homes, fences and livestock shelters, providing plots for growing supplemental winter fodder, settling down local people instead of semi-nomadic herding on the plateau and retiring livestock and restore rangeland over the past 40 years, to be a success, whereas others question the effectiveness of these initiatives (cf., Harris 2010; Li et al. 2013). For example, concentrating livestock near settlements and fencing programmes may impact negatively on local vegetation. Use of winter houses for longer periods adversely affects vegetation, increasing the intensity of use and associated impacts of trampling (see Tane et al. 2016, Chap. 13). Liu et al. (2006) found a significant relationship between the severity of degradation with distance from settlements.

Efforts to "retire livestock and restore pastures" also break traditional land use and cultural practices. Even if such initiatives succeed in reducing rangeland degradation (which is questionable, as most rangeland species are adapted to some level of herbivory), it is likely to carry enormous financial burdens and create considerable social and cultural dislocation (Harris 2010). Such endeavours scarcely constitute a sustainable socio-economic, cultural and environmental system.

It seems clear that Chinese policy will not tolerate a return to traditional nomadic pastoralism over large spatial scales, nor does this seem feasible given recent integration of livestock production systems on the plateau with distant markets and with ongoing socio-economic development taking place in pastoral areas (Harris 2010). Some kind of modernized livestock management, even if not what Chinese policy currently promotes, must ultimately be adopted. Ultimately, however, sustainable rangeland management and economic development of the Qinghai–Tibet Plateau is contingent upon local engagement and ownership of actions that fashion appropriate lifestyles and well-being, framing social, cultural and economic measures in an environmental context. Long-term sustainable outcomes will not be achieved unless they incorporate the aspirations of local citizens. Local knowledge and community-based institutions provide greater capacity for adaptation through shaping and mobilizing resource availability to reduce risks (Hu and Xie 2012). Large-scale ecological construction projects fashioned by state institutions provide one mechanism by which this may be achieved, prospectively promoting environmental improvement and economic growth within a virtuous, mutually reinforcing circle (e.g. Yeh 2009).

## 14.8 Establishment of the Sanjiangyuan National Nature Reserve for Ecological Protection

An initial nature reserve was established in the area in 2000. It was upgraded to a national nature reserve in 2003 (Li et al. 2012). In 2005, the first phase for the ecological protection and restoration of Sanjiangyuan was started, lasting until 2012. Establishment of the Sanjiangyuan National Nature Reserve prospectively provides an important step to address concerns for sustainable water resources management and biodiversity management, especially the protection of endangered flora and fauna (Li et al. 2012). The reserve comprises an area of 152,300 $km^2$, making up 21 % of the total land area of Qinghai Province (Chen and Zhao 2009; Li et al. 2012). The main protection targets include alpine wetland ecosystems, typical alpine meadow and alpine dry steppe, sparse alpine forest ecosystems and associated targeted wildlife species. The functional area of the Sanjiangyuan National Nature Reserve is divided into core, buffer and experimental areas (Fig. 14.3). *Core areas* are strictly protected areas; buffer areas are important protected areas; and experimental areas are normal protected areas in which consideration is given to both protection and utilization. The 18 core areas take up 31,218 $km^2$, equivalent to 20.5 % of the total land area of the reserve (Chen and Zhao 2009). Core areas are designated to protect typical natural ecosystems, fostering growth and reproduction of targeted wildlife, plants and organisms and their habitats by separating these areas of environmental protection and restoration from human activities. Zhongtie-Jungong, Douke River, Maixiu and Make River are core areas within the Upper Yellow River Basin that have been designated to protect typical forest and shrubbery, while Animaqin, Xingxingha, Nianbaoyuze, Yueguzonglie and Erlin-Zalin Lake protect wetland ecosystems (Chen and Zhao 2009).

*Buffer areas* surround core areas, or they connect core areas to assist in protecting targets (i.e. they address concerns for fragmentation), thereby controlling the impact of threatening factors/processes while restoring slightly degraded ecosystems. These areas buffer main protection targets from influences outside the

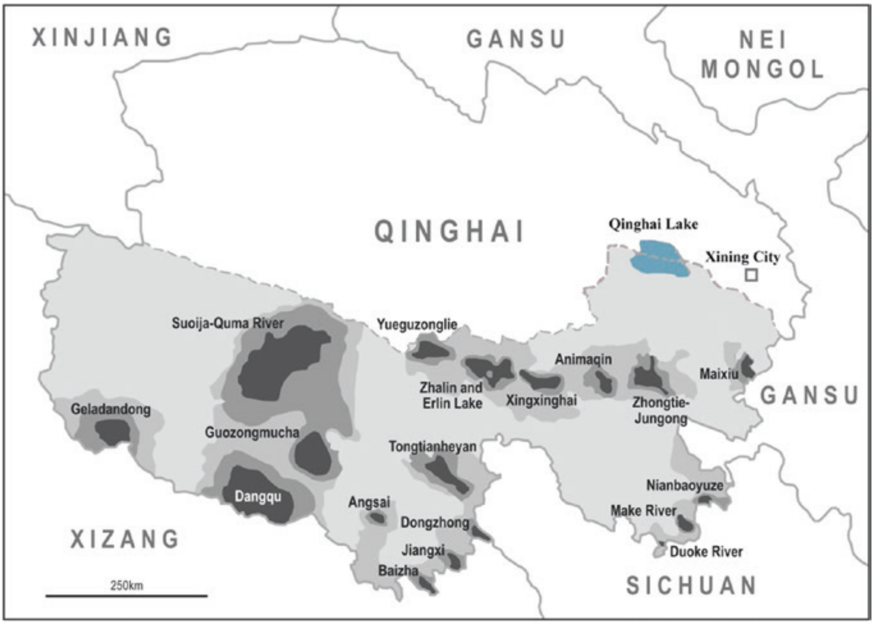


**Fig. 14.3** Distribution of core (*dark* tone), buffer (*middle* tone) and experimental (*light* tone) areas in the Sanjiangyuan National Nature Reserve

natural reserve, linking core areas to assist in the protection of wildlife and creating separation from towns, factories and mining sites. Measures taken in the buffer areas include reducing grazing livestock numbers to sustainable forage, controlling grazing intensity through rotational grazing and closing some areas for restoration of forest and grassland vegetation.

*Experimental areas* outside core and buffer areas take up 81,882 $km^2$ (53.7 % of the total land area of the reserve). Efforts to assist the restoration and rebuilding of degraded ecosystems in these areas enhance the management of fragmented protection targets by providing a natural defence for core and buffer areas. Projects in experimental areas aim to aid the development and improvement of socio-economic conditions and living standards of herders through measures such as:

- Resettlement away from areas where the carrying capacity is exceeded (i.e. ecological migrants).
- Suspending grazing in some areas based on the assessments of sustainable grazing livestock numbers relative to the quantity of available forage in the area. However, significant controversy and concern have been triggered by the fencing dilemma, as efforts to protect and manage small grassland areas from overgrazing on the one hand may impact negatively upon ecosystem functionality, especially for migratory animals on the other.
- Protect and rehabilitate forest and grassland vegetation, wetlands and wildlife.

- Develop wildlife management programmes, including the banning of fishing.
- Promote water conservancy and improve wetland conditions by enclosing wetland areas to promote self-regeneration of natural vegetation, resowing wetlands that have been subjected to severe degradation and reducing livestock numbers or stopping grazing adjacent to wetlands. Rodent disaster programmes target the management of pica and marmot.
- Undertake small-scale water and soil erosion measures to enhance livestock production and control the spread of desert and areas of degraded grassland.
- Construct water supply facilities and develop new energy for household needs, alongside improvements to local energy sources, enhance herders' income and reduce dependencies upon remaining areas of forest and natural grassland.
- Set up research and monitoring bases.

Over the eight-year period from 2005 to 2012, the Sanjiangyuan National Nature Reserve achieved its planning target for construction and protection and met the objectives and requirements of the State Council "*to realize the protection and restoration of the ecological function, to promote the harmony between man and nature and sustainable development, and to help the farmers and herdsmen to reach a well-off standard of living*".

From 2005 to 2012, the average amount of surface water resources increased by 8.49 billion $m^3$ with the area of lakes increasing by 760 $km^2$ relative to the average level from 1988 to 2004. This instigated the recovery of the 'wetland of a thousand lakes' in the Yellow River Source Zone. Over the same period, vegetation coverage in areas of *Heitutan* (degraded alpine meadow) increased from 20 to 80 %, while the average yield of grass increased from 35.5 kg $mu^{-1}$ (1 mu = 0.0667 ha) ($2.37 \times 10^4$ kg $hm^{-2}$, average data of 1988–2004) to 45 kg $mu^{-1}$ ($3.00 \times 10^4$ kg $hm^{-2}$) in 2012. Also, the area of forestry increased 150 $km^2$ compared to 2005. In 2012, the annual average sediment concentration from river monitoring stations ranged from 0.046 kg $m^{-3}$ to 4.3 kg $m^{-3}$, much lower than previous levels (from 1988 to 2004). For example, compared with the records from 2004, the annual average sediment concentration at Zhimenda, Xinzhai and Tongren stations decreased by 11.4, 60.3 and 16.3 %, respectively. The area of desert grassland shrunk by 95 $km^2$, and the vegetation cover in desertification control areas increased from 15 % in 2004 to 38.2 % in 2012. Water quality improved, enhancing the ecological environment of freshwater areas such that their overall condition was good, and aquatic biological resources were relatively intact.

These improvements in ecological restoration and construction were accompanied by improvements in the lifestyle and productivity of local residents. Between 2004 and 2012, $5 \times 10^4$ mu of irrigable forage base, $3.04 \times 10^4$ barns and 86 ecological migration communities were constructed. Furthermore, the Provincial Finance spent 0.6 billion RMB to improve the infrastructure of 23 small cities and towns, 30 million to set up a business support fund for ecological migration and 40 million every year (since 2009) as a maintenance allowance for ecological migrants. With this help, the farmers and herdsman in the Sanjiangyuan National Nature Reserve experienced an annual net income increase of 10 % from 2004 to 2012 (see http://cpc.people.com.cn/n/2014/0822/c83083-25519100.html). It should be noted that the investment in the Sanjiangyuan National Nature Reserve to date has been primarily in restoration and construction projects (Ma 2006; Zhou et al. 2010). The improvement in environmental conditions has therefore been mainly as an indirect result of this investment, aided by sustained increases in precipitation from 2004 to present (Qin 2014).

## 14.9 Summary and Concluding Comment

Although natural and anthropogenic causes have led to ecological deterioration in the source zone of the Yellow River, recent management investment and activities in the Sanjiangyuan National Nature Reserve have started to remedy some of these concerns. Ultimately, this relates to management of problems associated with population density, associated livestock stocking rates and lifestyle practices. These problems became pronounced after the foundation of the People's Republic of China, especially following the rapid growth of population and gross production in the 1970s and 1980s. Accentuated disturbance by human activity had a negative impact on the ecological environment. The incompatibility between ecological health and human economic activities was exaggerated by the relatively unsophisticated forms of animal husbandry production and excessive exploitation of land and water resources, such that the environment in the Sanjiangyuan area was unable to support the population in the region. In response to this concern, ecological protection and construction initiatives in the Sanjiangyuan National Nature Reserve have brought about environmental improvements and the possibility for ecological systems and human beings to coexist in a sustainable fashion. Through policy, institutional and legal systems, humans now have improved prospects. It remains to be seen how progress will be maintained in the second phase for the ecological protection and restoration of the Sanjiangyuan.

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## References

Blue, B., Brierley, G., & Yu, G. A. (2013). Geodiversity in the Yellow River source zone. *Journal of Geographical Sciences, 23*, 775–792.

Cao, L., Zhang, K., Dai, H., et al. (2013). Modeling interrill erosion on unpaved roads in the loess plateau of China. *Land Degradation & Development*. In press.

Chen, H., & Zhao, Z.P. (2009). Analysis on the characteristics of land lover change in nature reserves in the Three River Source Region during recent 30 years. *Journal of Geo-Information Science, 11*(3): 390–399. (In Chinese with English Abstract).

Chen, B., Zhang, X., Tao, J., et al. (2014). The impact of climate change and anthropogenic activities on alpine grassland over the Qinghai-Tibet Plateau. *Agricultural and Forest Meteorology, 189*, 11–18. (In Chinese with English Abstract).

Cheng, G., & Wu, T. (2007). Responses of permafrost to climate change and their environmental significance, Qinghai-Tibet Plateau. *Journal of Geophysical Research: Earth Surface (2003–2012*), *112*(F2).

Cincotta, R., Zhang, Y., & Zhou, X. (1992). Transhuman alpine pastoralism in northeastern Qinghai province: An evaluation of livestock population response during China's agrarian economic reform. *Nomadic Peoples, 30*, 3–25.

Cui, Y., Zhang, D., & Du, C. (1999). *The general history of Qinghai*. Xining: Qinghai People's Publishing House (In Chinese).

Dai, J., Guo, W., & Yang, T. (2006). An analysis of grassland change and human factor function in headwater region of Yellow River based on NOAA-AVHRR data. *Technological Management of Land and Resources, 23*, 109–112.

Dong, J. (2009). *Culture introduction of Sanjiang source*. Xining: Qinghai People's Publishing House (In Chinese).

Doubenjia, Suonanjia, Huaqingjia, et al. (2009). *The general situation of Tibetan autonomous prefecture of Hainan, Qinghai province*. Beijing: Nationality Press (In Chinese).

Fan, J. W., Shao, Q. Q., Liu, J. Y., et al. (2010). Assessment of effects of climate change and grazing activity on grassland yield in the three rivers headwaters region of Qinghai-Tibet Plateau, China. *Environmental Monitoring and Assessment, 170*, 571–584. (in Chinese with English Abstract).

Gao, J. G. (2016). Wetland and its degradation 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. 209–232). Berlin: Springer.

GSGTAP (General situation on Golou Tibetan autonomous prefecture in Qinghai). (2009). *General situation on Golou Tibetan autonomous prefecture in Qinghai*. Nationalities Publishing House. Xining, Qinghai, 6, the first version (In Chinese).

GSHTAP (General situation on Hainan Tibetan autonomous prefecture in Qinghai). (2009). *General situation on Hainan Tibetan autonomous prefecture in Qinghai*. Nationalities Publishing House. Xining, Qinghai, 7, the first version (In Chinese).

Harris, R. B. (2010). Rangeland degradation on the Qinghai-Tibetan plateau: A review of the evidence of its magnitude and causes. *Journal of Arid Environments*, *74*, 1–12. http://cpc.people.com.cn/n/2014/0822/c83083-25519100.html. Fruitful results were gained from the first phase of the project for ecological protection and construction of Nature Reserve of Sanjiang Source. 25 Aug 2014.

Huagongjie et al. (2009). *The general situation of Tibetan autonomous prefecture of Golou, Qinghai province*. Beijing: Nationality Press (In Chinese).

Huang, Q. (2012). *GIS based research on the changes of ecological environment and the influence of human activities in Sanjiang source region*. Master's thesis, Minzu University of China, Beijing (In Chinese).

Hu, L. and Xie, A. (2012). Supervision Mechanism of the Basic Social Security Benefits of the Ecological Migrants in the Origin of Three Rivers. *Journal of Anhui Agricultural Sciences, 40*(12): 7494–7496.

Jing, H., & Xu, J. (2005). Impacts of human activities on the ecological environment in the source area of Sanjiang source region since middle Qing Dynasty. *New Heights, 24*, 87–92. (In Chinese with English Abstract).

Jing, H., Xu, J., & Liu, A. (2005). The production capacity of land resources and population carrying capacity of the Sanjiang source region. *Qinghai Social Sciences, 26*, 46–49. (In Chinese with English Abstract).

Kang, F. (1968). *Notes of Qinghai*. Taibei: Chengwen Press (In Chinese).

Kang, L., Han, X., Zhang, Z., et al. (2007). Grassland ecosystems in China: Review of current knowledge and research advancement. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 362*, 997–1008.

Li, S. (2007a). *Study on adjustment of industrial structure in the 3 river sources*. Master's degree thesis, Northwestern University, Xian (In Chinese with English Abstract).
Li, T. (2007b). On grassland ecological culture. *Proceedings of the Fourth Symposium on grassland culture in Inner Mongolia*, China. (In Chinese).
Li, X., Brierley, G. J., Shi, D., et al. (2012). Ecological protection and restoration in Sanjiangyuan Natural Reserve, Qinghai Province, China. In D. Higgitt (Ed.), *Perspectives on environmental management and technology in Asian river basins* (pp. 93–120). Netherlands: SpringerBriefs in Geography.
Li, X., Gao, J., Brierley, G., et al. (2013). Rangeland degradation on the Qinghai-Tibet Plateau: Implications for rehabilitation. *Land Degradation & Development, 24*, 72–80.
Li, D., Lijiacairang, Q., et al. (2009). *The general situation of Tibetan autonomous prefecture of Huangnan, Qinghai province*. Beijing: Nationality Press (In Chinese).
Li, X. L., Perry, G., & Brierley, G. J. (2016a). 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, X., Perry, G., Brierley, G., et al. (2014). Quantitative assessment of degradation classifications for degraded alpine meadows (Heitutan), Sanjiangyuan, western China. *Land Degradation & Development, 25*, 417–427.
Li, Z. W., Wang, Z. Y., & Pan, B. Z. (2016b). Wetland ecosystems of 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. 183–208). Berlin: Springer.
Luo, K. L., & Yang, Z. H. (2011). On the relationship between traditional Tibetan nomadic way and the safety of the sources or three great rivers in China. *Journal of Jishou University (Social Sciences Edition), 32*, 37–42. (In Chinese with English Abstract).
Liu, L., Zhang, Y., Bai, W., Yan, J., Ding, M., Shen, Z., et al. (2006). Characteristics of grassland degradation and driving forces in the source region of the Yellow River from 1985 to 2000. *Journal of Geographical Sciences, 16*(2), 131–142.
Ma, H. (2006). A review of the research on the sustainable development of the Sanjiang source region. *Qinghai Social Sciences, 27*, 49–54. (In Chinese with English Abstract).
Mei, H. X., Zhang, Y., et al. (2009). *The general situation of Tibetan autonomous prefecture of Golou, Qinghai Province*. Beijing: Nationality Press (In Chinese).
NDRC (National Development and Reform Commission, China). (2014). *The second phase for the ecological protection and restoration of Sanjiangyuan*. http://www.sdpc.gov.cn/zcfb/zcfbghwb/201404/W020150203319341893483.pdf. (In Chinese).
Pan, J. H., & Liu, J. L. (2005). Land use and landscape pattern change in source region of the Yellow River. *Bulletin of Soil and Water Conservation, 1*, 29–32. (In Chinese).
QBS (Qinghai Bureau of Statistics). (1952, 1954, 1959, 1965, 1983, 1986, 1991, 1996, 2001, 2006, 2011, 2014). *Qinghai statistical yearbook* (pp 1952–2014). Beijing: China Statistics Press 08 (In Chinese).
Qin, D. (2014). *Ecological protection and sustainable development in Sanjiang source region*. Beijing: Science Press (In Chinese).
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, C., & Wu, Q. (1996). The effect of climate warming on the Qinghai-Tibet highway, China. *Cold Regions Science and Technology, 24*, 101–106. (In Chinese with English Abstract).
Wang, G., Ding, Y., Wang, J., et al. (2004). Land ecological changes and evolutional patterns in the source regions of the Yangtze and Yellow Rivers in recent 15 years. *Acta Geographica Sinica, 59*, 163–173. (In Chinese with English Abstract).
Wang, X., Lu, C., Fang, J., et al. (2007). Implications for development of grain-for-green policy based on cropland suitability evaluation in desertification-affected North China. *Land Use Policy, 24*, 417–424. (In Chinese with English Abstract).

Wu, X. (2014). On the legalization of ecological environmental protection in the Sanjiangyuan. *Journal of Qinghai Normal University (Philosophy and Social Sciences), 36*, 60–63. (In Chinese with English Abstract).

Wu, G. L., Du, G. Z., Liu, Z. H., et al. (2009). Effect of fencing and grazing on a Kobresia-dominated meadow in the Qinghai-Tibetan plateau. *Plant and Soil, 319*, 115–126.

Wu, Q., & Li, Y. (2004). Ground temperature monitoring and its recent change in Qinghai-Tibet Plateau. *Cold Regions Science and Technology, 38*, 85–92. (In Chinese with English Abstract).

Wu, N., & Yan, Z. L. (2002). Climate variability and social vulnerability on the Tibetan plateau: Dilemmas on the road to pastoral reform. *Erdkunde, 56*, 2–14.

Xue, Y. (1996). The impact of desertification in the Mongolian and the inner Mongolian grassland on the regional climate. *Journal of Climate, 9*, 2173–2189. (In Chinese with English Abstract).

Yang, X., Scuderi, L. A., Wang, X., et al. (2015). Groundwater sapping as the cause of irreversible desertification of Hunshandake sandy lands, inner Mongolia, northern China. *Proceedings of the National Academy of Sciences, 112*, 702–706. (In Chinese with English Abstract).

Yeh, E. T. (2009). Greening western China: A critical view. *Geoforum., 40*, 884–894.

Yu, X. (2010). *The role and mechanism of yak dung on maintenance for Qinghai- Tibetan plateau alpine grassland health*. PhD thesis. Gansu Agricultural University, Lanzhou (In Chinese with English Abstract).

Zhai, S., & Cui, Y. (2004). *Economic history of Qinghai*. Xining: Qinghai People's Publishing House (In Chinese).

Zhang, J., Liu, S., Li. H., & He, X. (2004). Analysis on the retrogression of the pasture in Naqu prefecture, Tibetan Autonomous Region. *Resources Survey & Environment, 25*(2): 116–122. (In Chinese with English Abstract).

Zhou, X. (1968). *Investigation report of Yushu*. Taibei: Chengwen Press (In Chinese).

Zhou, H., Zhao, X., Zhang, C., et al. (2010). The predicament of ecological migrants and sustainable development strategy in the source area of Three Rivers. *China population resources and environment, SS1*, 185–188 (in Chinese with English Abstract).