Natural Vegetation Changes and Their Driving Mechanism in the Northeast of the Qinghai–Tibet Plateau Between 1726 and 1934

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Abstract. The reconstruction of past land use and land cover changes in the Qinghai–Tibet Plateau has been based mainly on pattern reconstruction, and there have been few studies of organically combining the effects of human activity with land-cover changes. Based on the reconstructed historical LULCC data of cropland, forest, shrub, and grassland, this study is combined with the changes of cropland representing human activities during the corresponding period, an analysis of how human activities have impacted on the natural vegetation and a description of the land cover changes resulting from human activities at the regional scale. Our major conclusions are as follows: (1) To better depict the land cover changes resulting from human activities in the historical period at typical region of the Qinghai-Tibet Plateau, we designed three intensity index of human activities affecting natural vegetation. (2) Combing with using the three intensity index and the leading human factors, the natural vegetation changes in the Hehuang Valley in corresponding period can be divided into five main periods. (3) The different types of natural vegetation reclaimed by humans were not only affected by the natural environment and policy factors but also by the degree of human understanding of the ecological environment.(4) In the Hehuang Valley, the range and intensity of human reclaimed different natural vegetation types may had threshold throughout the history. Within this threshold, the agriculture could normally develop, otherwise the ecological environment will be damaged.

Keywords: Natural vegetation changes, Human activities, Driving mechanism, Qinghai–Tibet Plateau

1 Introduction

Land use and land cover changes (LULCC)[1] is one of the most important performance of global change [2]. Of the anthropogenic land cover types, cropland not only directly has transformed the original natural land surfacebut it also indirectly has influenced environmental changes from the regional to the global scale by altering the physical conditions land and its biogeochemical cycles, since the advent of agricultural activities [3]. In many regions of the world, significant LULCC is one of the most significant manifestations of global change and is also an ideal entry point for the study of

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the relationship between the environment and human activities [2]. Therefore, LULCC is both the foundation and prerequisite for research into the earth's surface processes, the carbon cycle, and climate change [4-5].

So far many studies have been done to reconstruct the global historical LULCC [6-7]. However, the accuracy of these historical global LULCC datasets has been demonstrated inaccuracies by many regional reconstructions [8-11]. Historical LULCC reconstruction at regional scale with high resolution not only is an effective way to improve the accuracy of global datasets, but also can precisely depict the detailed interactions between LULCC and human activities in typical regions. Therefore, based on abundant historical literature, Chinese scholars have done many historical reconstructions of cropland cover [12-17] and natural vegetation cover [18]. However, research studies of the Qinghai–Tibet Plateau are of relatively weak [19], especially the study of natural vegetation cover change, such as forest and grassland cover. In order to truly and accurately show the actual historical changes in LULCC for the Qinghai–Tibet Plateau, scholars have carried out many studies based on local historical literature and allocation model. These studies have the following three characteristics.

Most of reconstructions of cropland in Qinghai–Tibet Plateau cover the last 300 years, and some even cover the last 1,000 years. Scholars' research has evolved from the past 100 years of cropland pattern [20] to the Ming dynasty [21] and the Qing dynasty [19] periods. Furthermore, some researchers have reconstructed land use patterns in some vital time sections over the last 1000 year, such as the Tang Dynasty. The types of reconstructed land cover are comprehensive, including forest, grassland, shrub, cropland, irrigation, and settlements. Furthermore, the human factors were incorporated into the gridded allocation method, such as settlements, improving the accuracy of allocation results [21-25].

To sum up, most historical LULCC studies of the Qinghai–Tibet Plateau have focused on the reconstruction of land use patterns, few studies have focused on the interaction between the human activities and land cover changes. Given long agricultural history of Hehuang Valley where located on the northeast the Qinghai–Tibet Plateau, relatively abundant historical literature are available. Therefore, we conducted a case study of in Hehuang Valley between 1726 to 1934, using the reconstructed datasets of cropland and natural vegetation such as forests and grasslands, to obtain the interactive datasets between human activities and LULCC. This case study attempts to explorer the changes of natural vegetation in historical period and their driving mechanism.

2 Study Area

The study area located in the northeastern the Qinghai–Tibet Plateau (36°—38°N, 101°—103°E), where included the Yellow River in Qinghai province and its tributaries in the Huangshui Valley. The area is 3.5×104 km^2 accounting for 4.86% of the total area of Qinghai Province. It is located in the farming–pastoral zone between the Loess Plateau and the Qinghai–Tibet Plateau and lies at edge of the summer monsoon region (Figure 1). Its administrative scope includes Xining City (including Chengzhong, Chengbei, Chengxi, and Chengdong four districts and Huangyuan, Huangzhong, and

Datong three counties), Haidong City (including Ping'an, Ledu two districts and Mutual Aid, Hualong, Xunhua, and Minhe four counties), and Menyuan County of Haibei Tibetan Autonomous Prefecture, Jianzha and Tongren Counties of Huangnan Tibetan Autonomous Prefecture and Guide County of Hainan Tibetan Autonomy.

The Hehuang Valley belongs to the alpine grassland area of the Qilian Mountain and most regions are covered by arid grassland and shrub [26]. Therefore, the environment is very fragile and sensitive to human activities [27]. The elevation of the region is 1630–5218 m, with 2600–3000 h of annual sunshine, an annual average temperature of 5–9°C and an annual average precipitation of 252–535 mm.

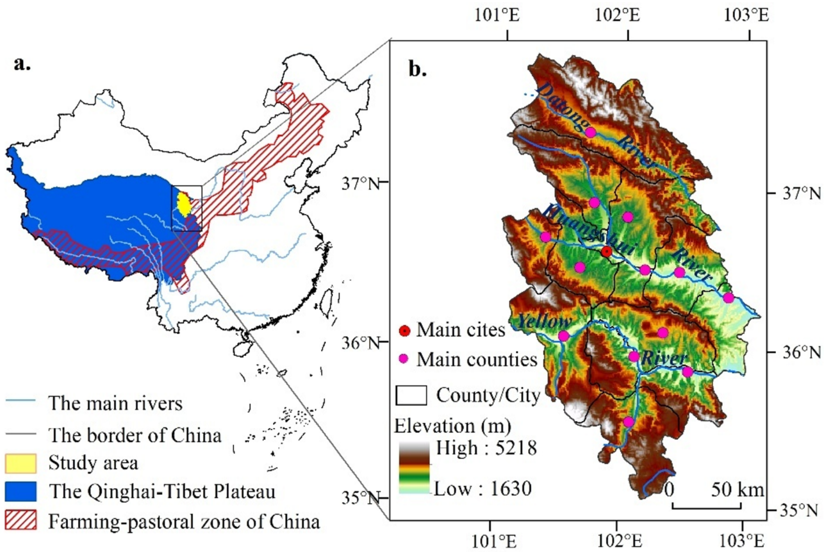

Fig. 1. Map of the study area. ((a) Geographic locations of the study area in China, the study area derived from a map of China's administrative divisions (www. geodata.cn); (b) The modern administrative boundaries, rivers, elevation in Hehuang Valley)

Although the Qinghai–Tibet Plateau are too cold or too dry to develop agriculture, most of the Hehuang Valley is relatively suitable for grow crops. About 5,000 years ago, the human's land reclamation appeared [25, 28]. Until the Han dynasty the cropland were mainly distributed alongside large rivers, such as the Yellow and Huangshui Rivers [29]. After that, the development of agriculture in the Hehuang Valley has experienced more than 500 years of turbulence [30-31]. It was not until the period of the Ming and Qing dynasties that the agricultural land use pattern of the Hehuang Valley was formed for the first time [32]. The population of the Hehuang Valley surged especially up to the the Qing dynasty, and the human's land reclamation reached an peak value throughout history. Land use unprecedented changed and the human-earth relationship became fraught.

3 Materials and Methods

3.1 Data Sources

3.1.1 Cropland data. Data on cropland area of the Qing dynasty, were converted by the grain yield which was collated from the historical literature for the research period by Luo et al. [33]. The cropland area of five periods were obtained: 1726 [33], 1772, 1806, 1845 and 1878 [33]. Data on cropland area for 1934 were obtained from The Survey Report on Agricultural Resources of Qinghai Province in the 23rd Year of the Republic of China which were examined and approved in conjunction with the record of the status of cropland in the Agricultural Weekly (The Republic of China) .

From the above-mentioned six-stage cropland area data were allocated by the gridding allocation method for cropland suitable for the valley region in the Qinghai–Tibet Plateau designed by Luo et al. [33], and the spatial and temporal changes in cropland during the research period with spatial attributes were obtained.

3.1.2 Recorded Data of Natural Vegetation (forest, grassland, and shrub). Historical data for forest and grassland in the Hehuang Valley were collected from The New Monograph on Geography form Xiningfu in Qing Dynasty , The Monograph of Xunhua Ting, The Collection Chorography of Qinghai: 1 Vol . Data for afforestation during the period of the Republic of China were derived from Construction Survey of Qinghai Province.

3.1.3 Historical Administrative Boundaries. The map of the administrative divisions of the Qing dynasty and the Republic of China, is based o definitions provided in the eighth volume of The Historical Atlas of China [34].

3.2 Intensity Indexes of Human Activities Affecting Natural Vegetation

Given China's long agricultural history, human activities to cultivated cropland have changed the natural vegetation [18, 35]. Based on reconstructed spatial data for natural vegetation (forest, shrub, and grassland) and cropland (the spatial resolution was 1 km by 1 km), we designed three intensity indexes of human activities affecting natural vegetation to depict the original natural vegetation changes because of human's land reclamation in historical period (the red part of the research technical route is the key part of this paper) (Figure 2). The three intensity indexes of human activities affecting natural vegetation are as follow:

Natural vegetation reduction area: this index could directly reflect the area that humans have reclaimed different vegetation types as cropland in the corresponding period (Equations (1) and (2)).

$$D_x(i,v_n) = Natural\,cover_{area}(i) - Cropland_{area}(i,v_n) \tag{1}$$

$$T_{Dx} = \sum_{i=n}^{n} Dx_{(i,v_n)} \tag{2}$$

In Equation (1), $D_x(i,v_n)$ denotes reducing the area of natural vegetation in year v_n and grid i, and the x denotes the different vegetation types. In Equation (2), T_{Dx} denotes the total reduction in area of vegetation type x in the corresponding year. (x represents forest, shrub, and grassland).

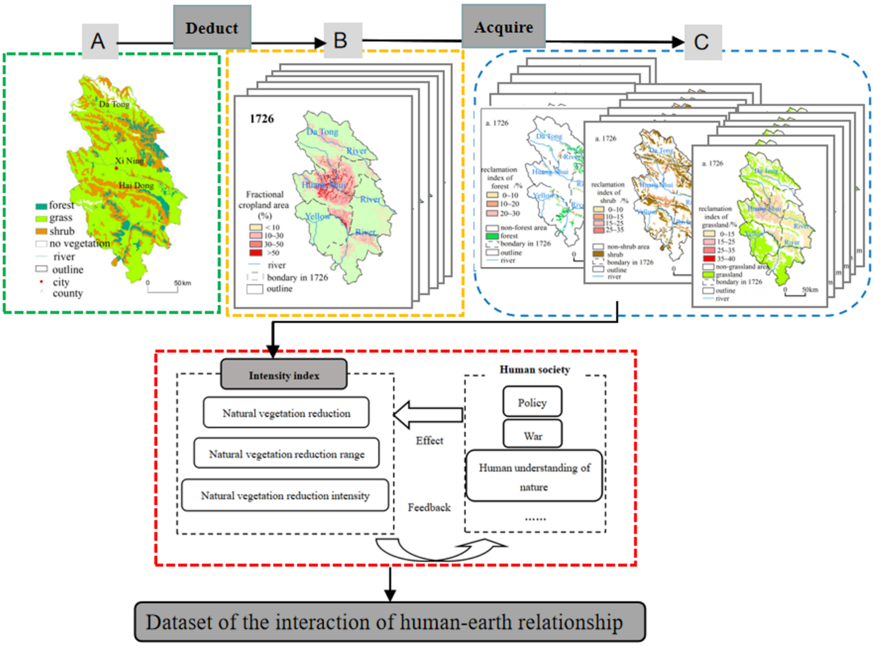

Fig. 2. Flowchart depicting the analytical outline of this study (A indicate the spatially explicit data for original natural vegetation; B indicate the spatially explicit data for cropland cover [33]; C indicate the spatially explicit data for changing of forest, grassland, and shrub cover.

Natural vegetation reduction range: this index was represented by grid numbers of human-reclaimed natural vegetation as cropland, reflecting the range of the natural vegetation that humans reclaimed and was obtained by calculating the number of grids that humans have reclaimed for different vegetation types (Equation (3)).

$$T_{Cx} = \sum_{i=n}^{n} c_x(i,v_n) \tag{3}$$

where T_{Cx} denotes the total number of vegetation types in year v_n, $C_x(i,v_n)$ denotes vegetation type x grid i were reclaimed as cropland in year v_n.

Natural vegetation reduction intensity: this index was represented by average percentage of human-reclaimed natural vegetation, reflecting the intensity with which of humans reclaimed different types of natural vegetation at different times, using the following equations:

$$F_x(i,v_n)=\frac{D_x(i,v_n)}{Area(i)} \tag{4}$$

$$AF_x=\frac{\sum_{i=n}^{n}F_x(i,vn)}{T_{Cx}} \tag{5}$$

In Equation (4), $F_x(i,vn)$ denotes the percentage of reclamation of grid i with vegetation type x. $Area(i)$ is the area of the 1 km by 1 km grid cell. In Equation (5), AF_x denotes the average percentage of human-reclaimed natural vegetation of type x.

4 Results

4.1 Degree of Change in Various Types of Natural Vegetation During the Qing Dynasty and the Republic of China

4.1.1 Changes in Forest Coverage from the Qing Dynasty to the Republic of China. According to statistics, areas of deforestation due to reclaimed cropland decreased by 86.6, 97.45, 88.90, 96.02, 72.34, and 71.48 km^2 in 1726, 1772, 1806, 1845, 1878, and 1934, respectively. We found that the region with reduced forest area did not significantly change throughout the above six time periods. Based on further comparing "forest reduction intensity" and "forest reduction range" (Figure 3), we found that the intensity and range of the forest in the Hehuang Valley were somewhat different in the research period.

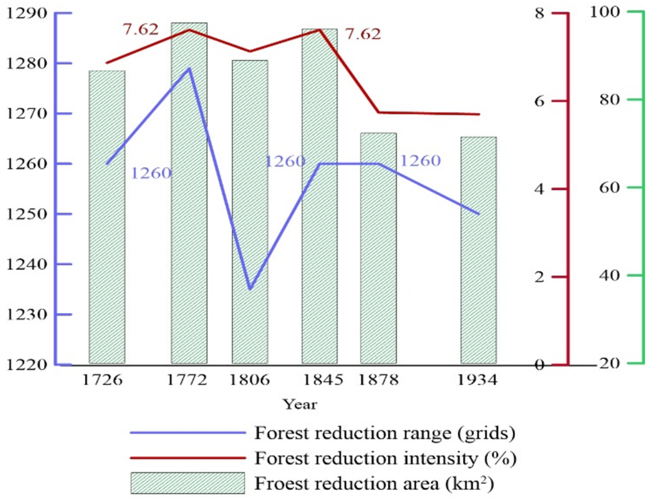

Fig. 3. Comparison of the forest reduction range, intensity, and area

Changes in the range of forest reduction was indicated by the human-reclaimed forest grid numbers. Between 1726 and 1772, the range of forest reduction expanded and reached their highest value in the entire research period. In 1726, approximately 46% of the forest grids in the Hehuang Valley were damaged to different degrees due to the reclamation cropland, the range of forest reduction reached an historical peak (about 1,260 forest grids were reclaimed), and the average percentage of human-reclaimed forest grids was about 6.87%. In 1772, the range of forest reduction to the maximum value during the Qing dynasty and the Republic of China, with a total of 1,279 grids (Figure 3). As a result of reclaiming cropland, the forest area was reduced by about 97.45 km^2. Between 1772 and 1806, the range of forest reduction sharply dropped and fell to a minimum value. In 1806, 1,235 forest grids were reclaimed as cropland, reducing the range of human reclamation of forests by 2% compared with the previous period. This study showed that the forest area was reduced by 88.9 km^2. From 1772 to 1845, the range of forest reduction rebounded to the same level as in 1726 and continued largely unchanged until 1878. In 1845, range of forest reduction was 1,260, and the area of forest reduction was 96 km^2. In 1878, because of the drastic reduction in cropland, the average percentage of human-reclaimed forest fell to 5.7%, and the forest area decreased by 72.34 km^2. Between 1878 and 1934, the range of forest reduction began to declined once again. There were 1,250 forest grids that reclaimed by human, and the total forest area decreased by 71.5 km^2.

The change in the intensity of forest reduction. In 1726, the average percentage of human-reclaimed forest grids was 6.87%. In 1772 the average percentage of human-reclaimed forest grids was 7.6%, and the highest was 32.24%. From 1806, the the average percentage of human-reclaimed forest decreased, and the average percentage of human-reclaimed forest 7%, which increased to 7.62% in 1845. The average percentage of human-reclaimed forest decreased both in the two time period of 1845–1878 and 1878–1934.

4.1.2 Changes in Shrub Coverage from the Qing Dynasty to the Republic of China. The area of shrub coverage in the Hehuang Valley was reduced to 279.36, 283.85, 273.1, 285.82, 220.13, and 208.22 km^2 as a result of human reclamation in 1726, 1772, 1806, 1845, 1878, and 1934 respectively. The region with the most substantial reductions in the range of the shrub mainly distributed in the transition zone between grassland and shrub, meanwhile, the change areas in shrub with the most drastic fluctuations distributed almost in the transition zone between shrub and forest. Overall, the reclaimed shrub grids approximately accounted for 35% of total shrub grids, and the average percentage of human-reclaimed shrub grids was about 8 % during the research period.

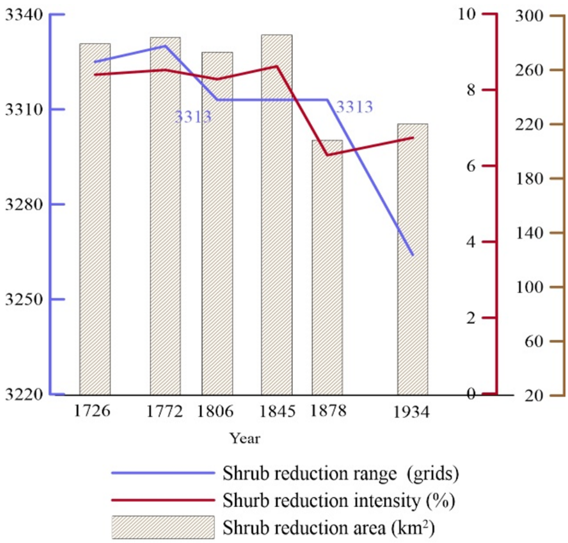

Fig. 4. Comparison of the shrub reduction range, intensity, and area.

Changes in the range of shrub reduction was indicated by the number of human-reclaimed shrub grids. Between 1726 and 1772, the number of human-reclaimed shrub grids was 3,330, which was the largest range of being destructed shrub by human during the research period. In 1726, the shrub area decreased by 297 km^2, and the reclaimed shrub grids totally were 3,325 in the study area. In 1772, the area of shrub decreased by 283.85 km^2, and the number of human-reclaimed shrub grids was 3,330, which reached the maximum value in the research period. From 1772 to 1806, the number of human-reclaimed shrub grids was reduced to 3,313, the range of destructed shrub was reduced, and it was maintained until 1878. By 1934, the reclaimed shrub grid numbers was reduced to 3,200, and the range of destructed shrub was reduced further (Figure 4).

The change in the intensity of shrub reduction. In these six time periods, the average percentage of human-reclaimed shrub did not significantly change for the first three time periods, and then peaked at 8.62% in 1845. From 1878, it decreased to 6.28%, and then rose again in 1934, but did not exceed 7% (Figure 4). In 1726, the average percentage of human-reclaimed shrub was 8.4%, and the highest was 33.25%. In 1772 and

1806, the average percentage of human-reclaimed shrub was 8.6% and 8.28%, respectively. By 1845, the average percentage human-reclaimed shrub was 8.7%, and the highest was approximately 41%. In 1878 and 1934, the average percentage human-reclaimed shrub was 6.28%, and 6.74%, respectively.

4.1.3 Changes in Grassland from the Qing Dynasty to the Republic of China. From the Qing dynasty to the Republic of China in the study area, grassland was the natural vegetation which was most affected by human reclamation activities. In the Hehuang Valley, totally 52% of the grassland grid was damaged to varying degrees as a result of reclaiming cropland, and the average percentage of human-reclaimed grassland grid was approximately 9%. By further comparing "grassland reduction intensity" and "grassland reduction range" (Figure 5), we found that the intensity and range of the grassland reduction in the Hehuang Valley were somewhat different because of the human's reclamation activities.

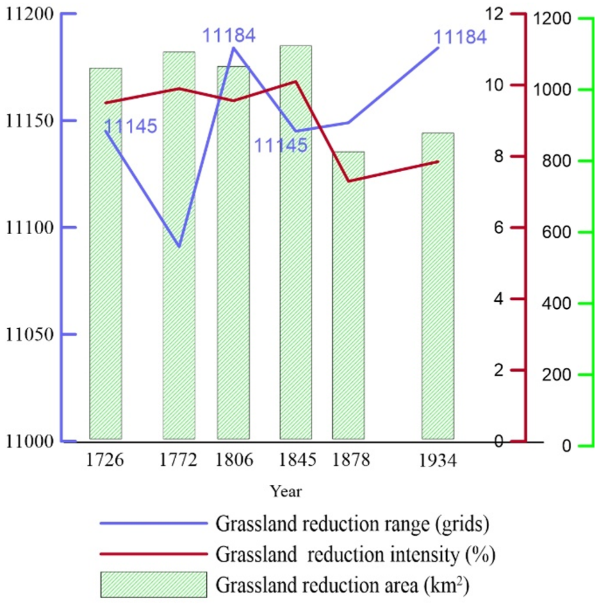

Fig. 5. Comparison of grassland reduction range, intensity, and area.

Changes in the range of grassland reduction was indicated by the number of human-reclaimed grassland grids. Between 1726 and 1772, the number of human-reclaimed grassland grids in the Hehuang Valley was reduced from a high value to the lowest value of the six time periods, meanwhile, the range of grassland reduction also declined. In 1726, the area of grassland decreased by 1060.74 km^2, and the number of human-reclaimed grassland grids was 11,145. By 1772, the grassland area decreased by 1105.74 km^2, and the number of human-reclaimed grassland grids decreased by about 50 compared with 1726. In 1806, the grassland area decreased by 1065.37 km^2, the number of human-reclaimed grassland grids was 11,184, which reached its highest value of the six time periods. In 1845, the grassland area decreased by 1122.88 km^2, and the number of human-reclaimed grassland grids was the same as that of 1726 in the early Qing dynasty, with an average percentage of human-reclaimed grassland of 10.2% and a highest percentage of human-reclaimed grassland of 43.7%. By 1878, the area of grassland reduced by 825.68 km^2, the number of human-reclaimed grassland grids was the same as that of the previous year, and the average percentage of human-reclaimed grassland decreased to 7.3%. In 1934, the area of grassland decreased by 878.25 km^2, and the range of human-reclaimed grassland was the largest it had been. Meanwhile, the highest percentage of human-reclaimed grassland was 57.64%, and the average percentage of human-reclaimed grassland grids was 7.85% (Figure 5).

The change in the intensity of grassland reduction. Between 1726 and 1806 in the early Qing dynasty, the average percentage of human-reclaimed grassland fluctuated around 9.5% and was basically stable. In 1845, the average percentage of human-reclaimed grassland increased to 10.2%, which was reached highest value of the six time periods, indicating that the intensity of human reclamation of grassland was the greatest in that year. By 1878, the average percentage of human-reclaimed grassland decreased to 7.3%, and the intensity of human reclamation of grassland fell to a minimum. In 1934, the average percentage of human-reclaimed grassland was 7.85%, which was relatively higher than in the previous period. However, compared with the early (1726) and middle (1845) periods of the Qing dynasty, the human reclamation intensity of grassland was significantly reduced (Figure 5).

4.2 Human Factors in the Change of Natural Vegetation from the Qing Dynasty to the Republic of China

4.2.1 The Natural Vegetation was Unprecedentedly Destroyed Because of the Agricultural Development in a Stable Social Environment Between 1726 and 1772. Between 1726 and 1772, with rapidly developed of agriculture in the Hehuang Valley, the cropland was drastically increased in the region where near the river. However, constrained by the fragile natural environment, there were little land available for cultivating in the study area. Hence, with increases in population, a phenomenon of "too many people and too little cropland" appeared in the Hehuang Valley.

To solve the contradiction between human and land, the governor of the Qing dynasty promulgated the agricultural cultivation policy that human could reclaimed cropland in where natural environment was fragile in 1740, such as slope areas [36]. In order to consolidate its effects, the importance of this policy was re-emphasized in 1766. This policy revealed that the cropland in this stage expanded to slope areas in the Hehuang Valley, because all of the region where closed to the river in the previous stage of the river valley had been farmed. From then on, in much historical literature of Qinghai Province the words, such as dry land, were recorded, marking a significant turning point for human reclamation activities in the Hehuang Valley. The range of shrub and forest destroyed by the cultivation of cropland increased during this period, because cropland was expanded to reach the hillsides (Figure 6). The forest and shrub reduction area significantly decreased, with the forest reduction area decreased by about 98 km^2, and the range of shrub being reclaimed as cropland reaching its maximum in the research period.

4.2.2 Destruction of the Environment Caused by Excessive Reclamation, Resulting in a Large Number of Cropland was Abandoned Between 1772 and 1806. In the previous stage, forest and shrub in slope areas which are very fragile and sensitive to human activities were reclaimed, causing a series of problems, such as the soil erosion, the increase of natural disasters, and the destruction of the environment in study area [37]. Because land desertification caused by soil erosion, a large amount of cropland was abandoned. Thus, the number of human-reclaimed forest and shrub grids drastically declined. As a result, in 1806, the cropland area decreased and the range of human-reclaimed forest and shrub was reduced. The range of human-reclaimed forest was reduced by 4% compared to the previous period.

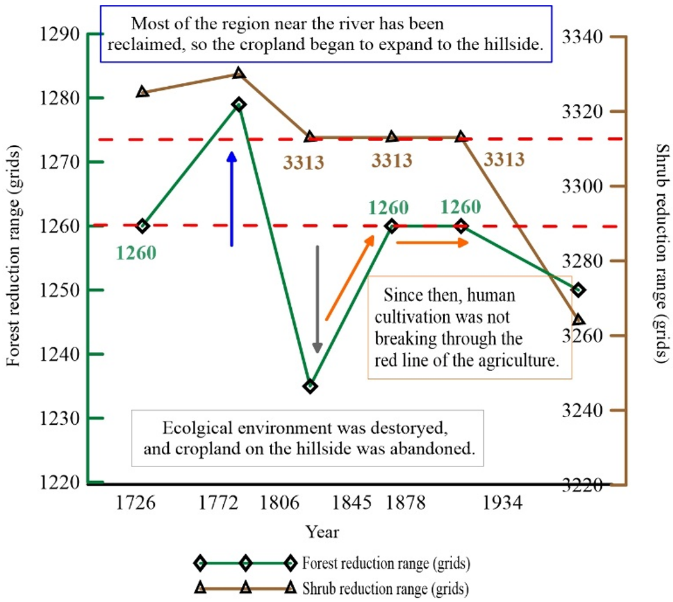

Fig. 6. The comparison of the shrub and forest reduction range (This two types of vegetation in the higher hillside than grassland in the Hehuang Valley)

4.2.3 Following the Restoration of Reclamation, the Range of Reclaimed Natural Vegetation was Reduced, but the Reclamation Intensity Increased between 1806 and 1845. Between 1806 and 1845, the agriculture of the Hehuang Valley was developed again after the extreme deterioration of the ecological environment. By 1845, the cropland area was approximately 1504.72 km^2, which reached its highest value during the Qing dynasty. As a result of cropland reclamation, the forest and shrub areas of Hehuang Valley for 1806 and 1845 decreased by 96 and 286 km^2, respectively. In addition, the number of human-reclaimed forest grids for 1845 was larger than that of 1806, but it did not exceed that of 1726. The reclamation intensity increased, even so, the range of these three types of natural vegetation was reclaimed by human declined.

4.2.4 Agricultural Development Fell into a Trough because of Ongoing Wars. The Hehuang Valley falls within China's farming–pastoral transitional zone where contemporary land uses is half farming and half animal husbandry. Hence, the study area is very sensitive to climate change and human activities. Alternations between agricultural period and pastoral period have occurred many times throughout the history of the study area, because of the alternate domination between the agricultural groups and nomadic groups as well as climate change. During the reclamation period between 1806 and 1845, the cropland area increased rapidly to the highest value during the Qing dynasty, which stimulated regional ethnic conflicts. In addition, since the outbreak of the First Opium War in 1840, China had become a semi-colonial and semi-feudal society. In 1862, a large-scale anti-Qing struggle by the Hui people broke out in the northwestern China, affecting the Hehuang Valley. In 1878 the reclaimed cropland area plummeted to a lowest value during the Qing dynasty, because many people were massacred, cropland was destroyed. Therefore, by this period, the reduction area of forest, grassland and shrub was at its lowest due to human reclamation. Compared with the previous period (from 1806 to 1845), the range of human-reclaimed grassland had increased, but the range of human-reclaimed shrub and forests had remained relatively stable.

4.2.5 Government-led Afforestation Activities Gradually Emerged. In the early Republic of China, agricultural development of the Hehuang Valley experienced a brief recovery period. Compared with 1878, in 1934 the cropland area increased but only 6 %. In the middle and late periods of the Republic of China, as a result of an increase in taxes and a reduction in the labor force engaged in agricultural production, a large amount of cropland was abandoned. During this period, the range of human-reclaimed forests and shrub was reduced but the reclamation intensity of forests, grasslands, and shrub increased. Furthermore, as people's awareness of ecological protection increased, afforestation activities were carried out in the Hehuang Valley.

The Hehuang Valley is located in the hilly grassland area of the Qilian Mountains and has few forests. Although given a long history of afforestation, the scale of afforestation before the Qing dynasty was small [38]. Between 1929 and 1947, the government the Republic of China abroad organized afforestation in the Hehuang Valley, especially after the establishment of the Qinghai Province in 1938. To sum up, afforestation in the Republic of China had a significant impact for nearly 20 years, and the main types of trees planted were poplar and willow. The range of afforestation expanded from the Huangshui Basin to the Datong River Basin, and in 1938 it developed to the Yellow River Basin of the study area. By 1938, afforestation activities covered the whole Hehuang Valley, and mainly distributed within the town, or on both sides of the main road. Before the founding of the People's Republic of China in 1947, a total of 9.196 million trees were planted in the Hehuang Valley (Qinghai Provincial Government in the Republic of China, 1929). During the Republic of China, the scale of tree planting was considerable, and the idea of "planting trees and afforestation" was deeply rooted in the hearts of the people. Therefore, since the founding of the People's Republic of China, the tradition of afforestation has been maintained in Qinghai Province.

5 Conclusions

Based on the reconstructed historical LULCC data of cropland, forest, shrub, and grassland, this study is combined with the changes of cropland representing human activities during the corresponding period, an analysis of how human activities have impacted on the natural vegetation and a description of the land cover changes resulting from human activities at the regional scale. Our major conclusions are as follows:

To better depict the land cover changes resulting from human activities in the historical period at typical region of the Qinghai-Tibet Plateau, we designed three intensity index of human activities affecting natural vegetation that are the area of natural vegetation reduction, the natural vegetation reduction range, and the natural vegetation reduction intensity.

Combing with using the three intensity index and the leading human factors, the natural vegetation changes in the Hehuang Valley in corresponding period can be divided into five main periods. The high tide of agricultural development period (1726–1772): the natural vegetation was unprecedentedly destructed by reclamation activities; the trough of agricultural development period (1772–1806): the cropland in the hillside was abandoned due to the destruction of the ecological environment; the agriculture recovery period (1806–1845): human-reclaimed range of natural vegetation reduced, and reclamation intensity increased; the period of agricultural development affected by external factors (1845–1878), compared with period of 1806–1845, human-reclaimed range of natural vegetation almost unchanged; and the maintenance of agricultural development period (1878–1934): Humanity's awareness of ecological protection has increased, and government-led afforestation activities have taken place.

The different types of natural vegetation reclaimed by humans were not only affected by the natural environment and policy factors but also by the degree of human understanding of the ecological environment. From the Qing dynasty to the Republic of China, the human–earth relationship tended to a more complex one based on mutual influence, with the gradual deepening of that understanding. The concept of land development from the initial changing the nature environment to adapting the ecological environment as a result of land reclamation, which was an historical manifestation of the concept of sustainable development in which humans were in harmony with nature. For example, from 1726 to 1772, because of an increase in population and the lack of agricultural technology, humans beings could only produce more food by continually expanding the available cropland, that is, "increase production by increasing area". In addition, cropland was constantly expanded to the area with higher elevation, leading to the destruction of the ecological environment and affecting the development of subsequent agriculture. Between 1772 and 1806, the ecological environment damage resulting from excessive cultivation cropland further forced a large amount of cropland to be abandoned. Learning from the experiences from 1772 to 1806, in the next period (1806–1845), the humans increased the reclamation intensity of the three types of vegetation instead of expanding the range of reclamation cropland.

In the Hehuang Valley, the range and intensity of human reclaimed different natural vegetation types may had threshold throughout the history. Within this threshold, the agriculture could normally develop, otherwise the ecological environment will be damaged. The threshold for human-reclaimed forests grids was 1,260, accounting for 46% of the total number of forest grids, and the threshold of the average percentage of human-reclaimed forest was 7.62%. The threshold for human-reclaimed shrub grids was 3313, accounting for about 30% of the shrub grids. The threshold for human-reclaimed grassland grids was 11,145, accounting for about 50% of the grassland grid.

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Conflicts of Interest: The authors declare no conflict of interest.

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