LAND EVOLUTION IN ALPINE INLAND RIVER BASIN FROM 1980 TO 2020 ON THE NORTHEASTERN TIBETAN PLATEAU, CHINA

XU, R. H.[1,2,3,4] – WANG, Z. G.[1,2,3,4*] – ZHU, J. F.[5*]

[1]College of Geographic Science, Qinghai Normal University, Xining 810008, China

[2]Academy of Plateau Science and Sustainability, People's Government of Qinghai Province & Beijing Normal University, Qinghai Normal University, Xining 810008, China

[3]Key Laboratory of Tibetan Plateau Land Surface Processes and Ecological Conservation (Ministry of Education), Qinghai Normal University, Xining 810008, China

[4]Qinghai Province Key Laboratory of Physical Geography and Environmental Process, Qinghai Normal University, Xining 810008, China

[5]College of Life Science, Qinghai Normal University, Xining 810008, China

*Corresponding authors
e-mail: wzg_gis@163.com – Z. G. Wang; 1192387826@qq.com – J. F. Zhu

Abstract. Based on GIS and remote sensing technology, land use change in the northeastern Qinghai-Tibet Plateau was analyzed. The results showed that the grassland area in the Qinghai Lake Basin increased significantly and the barren land area decreased significantly from 1980 to 2020. In the past 40 years, the area of grassland in the Qinghai Lake Basin has increased by 3094 km^2, and the area of barren land in the basin has decreased by 3058 km^2. From the land transfer matrix, the change in the area was mainly due to the transfer of water area to barren land from 1980 to 2000, which its area was about 327 km^2, and the rest of the land types did not change much. However, from 2000 to 2020, the land use type shift proceeded to change significantly, among which the shift of grassland and barren land is the most significant, showing a shift from barren land to grassland.
Keywords: land use change, Qinghai Lake Basin, Qinghai-Tibet Plateau, GIS and RS

Introduction

Land use change reflects the effect of human activities on the terrestrial surface system, and it is an important factor leading to global environmental changes, which can cause ecological and environmental problems such as ecosystem health damage, climate change, and biodiversity loss (Foley et al., 2005; Meyfroidt et al., 2022). In-depth study of land use change can provide scientific guidance for grasping regional ecological environmental changes and sustainable development of regional ecological environments.

The Qinghai-Tibet Plateau, known as the "third pole" of the earth (Wang et al., 2021, 2022a), has been affected by climate change and human activities, which have accelerated land use changes on the Qinghai-Tibet Plateau (Wang et al., 2019; Yang et al., 2020; Zhou et al., 2021). The land use pattern of the Qinghai-Tibet Plateau is an important basis for supporting the structure and function of the plateau ecological barrier (Yu et al., 2022). It not only affects the ecological environment of the plateau itself and regional development, but also has huge environmental effects on the region and the world (Zhang et al., 2019). As the contradiction between resources and the

environment intensifies and the change of the ecological environment accelerates, the Qinghai-Tibet Plateau becomes an important ecological barrier in China, and it is of great significance to explore its land use change (Cui et al., 2022). The study on land use change on the Qinghai-Tibet Plateau includes its spatial pattern, influencing factors and adaptation (Yan et al., 2005; Liu et al., 2006; Song et al., 2009; Zhang et al., 2019). At present, the research on the spatial and temporal characteristics of land use in the Qinghai-Tibet Plateau focuses on typical regions, and the research on the basin scale of alpine inland rivers is relatively weak. Further knowledge is needed in terms of the ecological environment's changes at the basin scale and the sustainable development of future ecological security.

Qinghai Lake, the largest saltwater lake in China, is an important ecological security barrier for maintaining the northeastern part of the Qinghai-Tibet Plateau (Wang et al., 2021, 2022a, b, c). Land use change in Qinghai Lake Basin plays an important role in its ecological quality and the construction of Qinghai Lake Basin National Park. Previous studies have mainly focused on landscape pattern and ecological environment quality changes in the Qinghai Lake Basin (Han et al., 2021; Wang et al., 2022d), and less attention has been paid to changes in land use transfer in long-term sequences. To this end, this study is based on 40 years of land use type data, combined with GIS and RS technology, to reveal land use changes in the Qinghai Lake Basin and provide a theoretical reference for its ecological environment protection and national park construction.

Materials and methods

Study area

The Qinghai Lake Basin is located in the north-eastern part of the Qinghai-Tibet Plateau (36°15′ to 38°20′N, 97°50′ to 101°20′E) and it is a sensitive region for global climate change (*Fig. 1*). The altitude rangs from 3169 m to 5268 m, and the total area is about 2.96×10^4 km^2. The annual average temperature and precipitation in the basin range from -1.1 ℃ to 4.0 ℃ and from 290 to 580 mm, respectively (Wang et al., 2021, 2022a). The watershed had relatively low precipitation, the difference between day and night temperatures was drastic. The main land types include cropland, grass land, and barren land (Wang et al., 2021, 2022a).
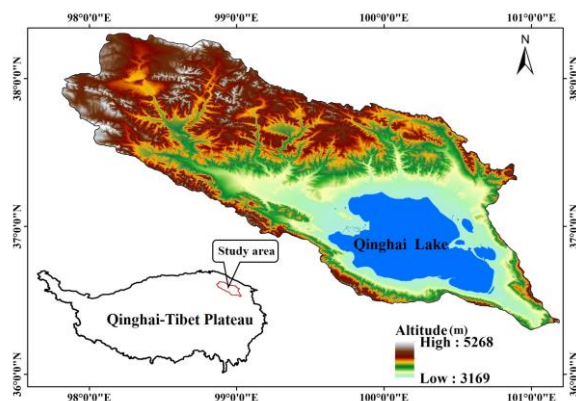

Figure 1. Map of the study area

Data sources

The data on the status quo of land use comes from the Data Center of Resource and Environmental Sciences, Chinese Academy of Sciences (https://www.resdc.cn/). The data is constructed by manual visual interpretation using Landsat remote sensing images as the main information source. The time range is 1980-2020, with a spatial resolution of 1 km. The primary types of land use in the study area include 6 types of cropland, shrub land, grassland, water area, construction land and barren land (Liu et al., 2014). In this study, according to the actual situation of the Qinghai Lake basin combined with the land use classification standard, land use is divided into six categories, namely, cropland, shrub land, grassland, water area, construction land and barren land. The land use classification is shown in *Table 1*.

Table 1. Land use classification

First-class classification	Secondary classification	Meanings
Cropland	Water field Dryland	Land for growing crops
Shrub land	With forest land Shrubland Open woodland Other forest land	Forestry land such as growing trees, shrubs, bamboo, and coastal mangrove land
Grassland	High-coverage grass (＞50%) Medium-coverage grassland (20~50%) Low-coverage grassland (5~20%)	Various types of grasslands with herbaceous plants growing mainly and covering at least 5% of the area
Water area	Rivers and canals Lakes Reservoirs Permanent glacial snow land Mudflats Beachland	Refers to land with natural land waters and water facilities
Construction land	Urban land Rural settlements Other construction land (industrial and mining, oilfield, transportation, etc.)	Urban and rural settlements and other industrial and mining, transportation and other land
Barren land	Sandy Gobi Saline land Marshland Bare land Bare rock texture Others	Land that is currently unused, including hard-to-use land

Land use transfer matrix

The land use transition matrix can quantitatively describe the system state and transition state between land use types in a certain time series unit. It can comprehensively reflect the direction and structural characteristics of land use change (Liang et al., 2018).

$$S_{ij} = \begin{pmatrix} S_{11}S_{12} \cdots S_{1m} \\ S_{21}S_{22} \cdots S_{2m} \\ \cdots\cdots\cdots \\ S_{11}S_{m2} \cdots S_{mm} \end{pmatrix} \quad\quad\quad (Eq.1)$$

In the formula: S_{ij} represents the area of the i-th land use type at the initial stage to the j-th type of land use at the end stage. i and j are the land use types at the beginning and end of the study, respectively. m is the number of land use types. In the transition matrix, the row represents the i-th land use type at the initial stage, and the column represents the j-th land use type at the end stage.

Data analysis

In this study, ArcGIS 10.2 was used to reclassify the raw land use data, calculate the transfer matrix, and visualize the analysis. The data were pre-processed and analyzed using Excel. Mapping was done using Origin 2021 and ArcGIS 10.2.

Results

Spatial and temporal change of land use in Qinghai Lake Basin

The spatial change of land use in the Qinghai Lake Basin from 1980 to 2020 showed that cropland was mainly concentrated on the north bank of the Qinghai Lake (*Fig. 2*). Shrub land was mainly distributed in the middle reaches of the Shaliu River, the Buha River Valley and the southwest of the Qinghai Lake. Grassland was mainly distributed in the north and northwest of the Qinghai Lake. Barren land was mainly distributed in the northwest of the Qinghai Lake Basin. The area changes of various land types in the Qinghai Lake Basin from 1980 to 2020 showed that the land types that have changed the most in the past 40 years were the significant increase in the area of grassland and the significant decrease in the area of barren land. In 1980 and 2020, the grassland area in the Qinghai Lake Basin was 14539 km^2 and 17633 km^2, respectively (*Fig. 3*). In the past 40 years, the grassland area in the Qinghai Lake Basin has increased by 3094 km^2. In 1980 and 2020, the barren land areas in the Qinghai Lake Basin were 8089 km^2 and 5031 km^2, respectively. In the past 40 years, the area of barren land in the Qinghai Lake Basin has decreased by 3058 km^2 (*Fig. 3*).

Relative changes of land use types in Qinghai Lake Basin

Calculating the relative rate of change for the area of land use types from 1980 to 2020, the results of the relative change of land use types in the Qinghai Lake Basin showed that from 1980 to 1990, The land use type had a large change in the relative rate of change between 1980 and 1990, 1995 and 2000, and 2010 and 2020 (*Fig. 4*). From 1980 to 1990, the relative change rates of the cropland, shrub land, grassland, water area, construction land and barren land in the Qinghai Lake Basin were -0.2%, 0.07%, 0.2%, -6.5%, 5.5% and 3.7%, respectively. Among them, the land use types with a negative relative change rate were cropland and water area, and the relative change rate of water area was the lowest. Building land and barren land are land use types with a positive relative change rate, and building land was the type with the fastest increase in

relative change rate. From 1995 to 2000, the relative change rates of the cropland, shrub land, grassland, water area, construction land and barren land in the Qinghai Lake Basin were 6.9%, -1.9%, -0.3%, -0.7%, 10.5% and 0.06%, respectively. Among them, the land use types with a negative relative change rate were shrub land, grassland and water area, and the relative area of shrub land shrinks greatly. Cropland and construction land were land use types with a positive relative change rate, and construction land was still the type with the fastest relative change rate increase. From 2010 to 2015, the relative change rates of the cropland, shrub land, grassland, water area, construction land and barren land in the Qinghai Lake Basin were -0.18%, 0%, -0.01%, 1.3%, 52.3% and -0.7%, respectively. Among them, the land use types with a negative relative change rate were cropland, grassland and barren land, and the relative area of cropland has decreased greatly. Water area and construction land were the land use types with a positive relative change rate, and construction land was still the type with the fastest relative change rate increase. From 2015 to 2020, the relative change rates of the cropland, shrub land, grassland, water area, construction land and barren land in the Qinghai Lake Basin were 0%, -2.1%, 21.53%, 4.17%, 50% and -39.7%, respectively. Among them, the land use types with a negative relative change rate were shrub land and barren land, and the relative area of barren land was greatly reduced. Grassland and construction land were land use types with a positive relative change rate, and construction land was still the type with the fastest relative change rate increase.
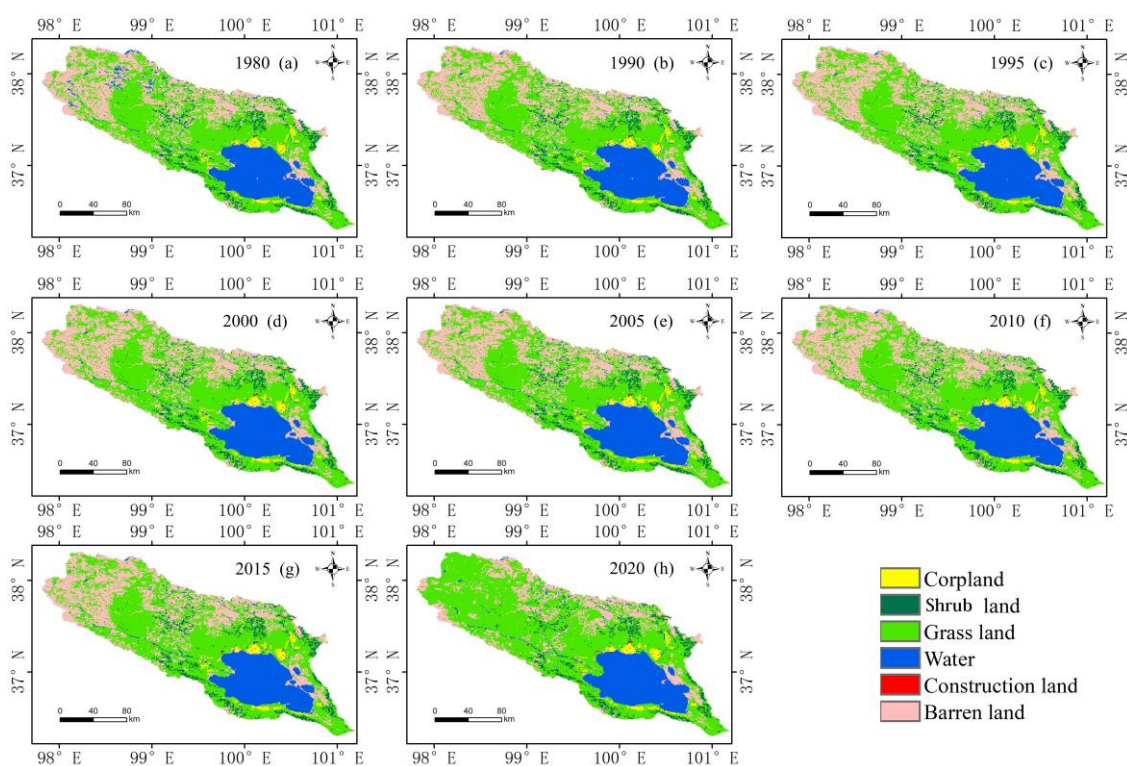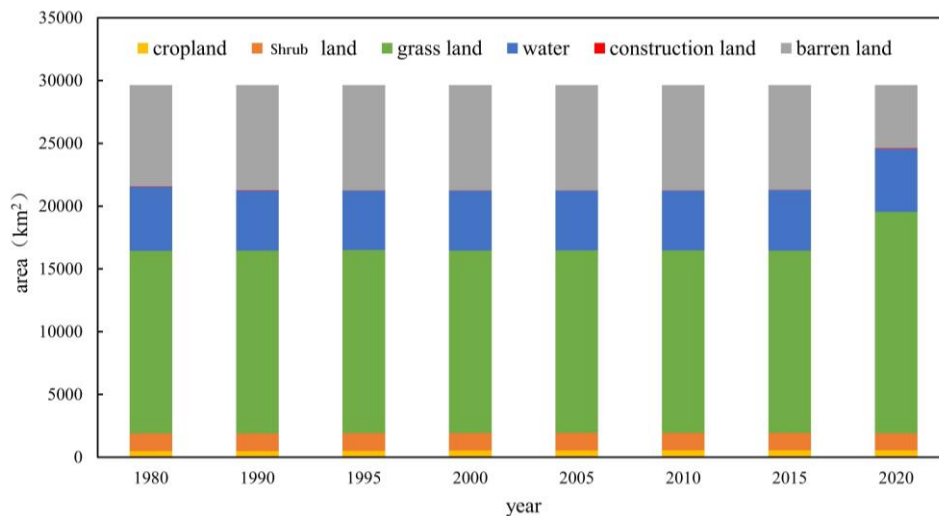

Figure 2. Spatial changes of each land use type in the Qinghai Lake Basin from 1980 to 2020

Changes in land type transfer in Qinghai Lake Basin

The transfer matrix calculation of land use types in the Qinghai Lake Basin for nearly 40 years showed that the changes in land use in the Qinghai Lake Basin from

1980 to 2000 were small, mainly due to the transfer of water to barren land, with an area of about 327 km^2, and the rest of the land types changed little (*Fig. 5*). From 2000 to 2020, the types of land use began to change significantly. On the whole, the changes in grassland and barren land were the most significant, which was reflected in the transfer of barren land to grassland. From 2000 to 2020, about 4333 km^2 of barren land was transferred to grassland, and about 1178 km^2 of grassland was transferred to barren land. The second was the mutual transfer of grassland and shrub land, in the past 20 years, about 473 km^2 of grassland has been converted to shrub land, and the area of shrub land converted to grassland was about 527 km^2. The transfer between water and grassland has also changed from before. The water area generally showed an increasing trend. From 2000 to 2020, the area of the water area transferred to grassland was about 174 km^2, the area of grassland transferred to water area was about 253 km^2, and about 269 km^2 of barren land was transferred to water area, increasing the water area. Cropland and construction land were smaller and had less change. The area of cropland has not changed much, and the construction land was mainly transferred from other land use types, among which the area of grassland transferred was the largest, about 25 km^2.


*Figure 3. Temporal changes of each land use type in the Qinghai Lake Basin from 1980 to 2020*

Spatial dynamic transfer of land use in Qinghai Lake Basin

Spatially, the land use change in the Qinghai Lake Basin was relatively stable as long as it was in the northwestern part and the area around Qinghai Lake from 1980 to 2000, when the land use change was small. The changes during this time period were mainly the transfer of waters to other sites and the reduction of water area. From 2000 to 2020, the land use pattern of the Qinghai Lake Basin has undergone dramatic changes, the most obvious of which is the shift of a large amount of barren land to grassland types, most concentrated in the northwestern part of the Qinghai Lake Basin. This was followed by a reciprocal shift between grassland and shrub land, mainly in the southeastern part of the Qinghai Lake Basin. The area of construction land and cropland accounts for a very small proportion of the area, so the change was also minimal during this period (*Fig. 6*).
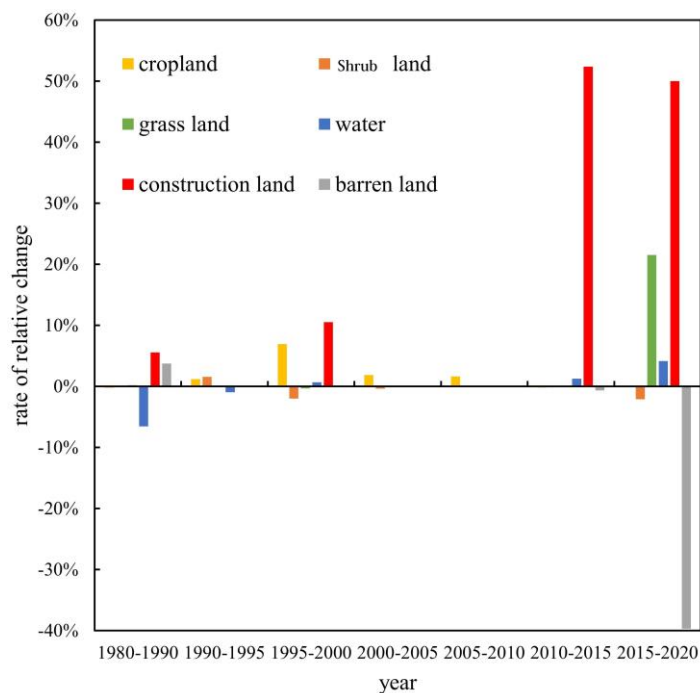
Figure 4. Relative changes of land use types in Qinghai Lake Basin from 1980 to 2020
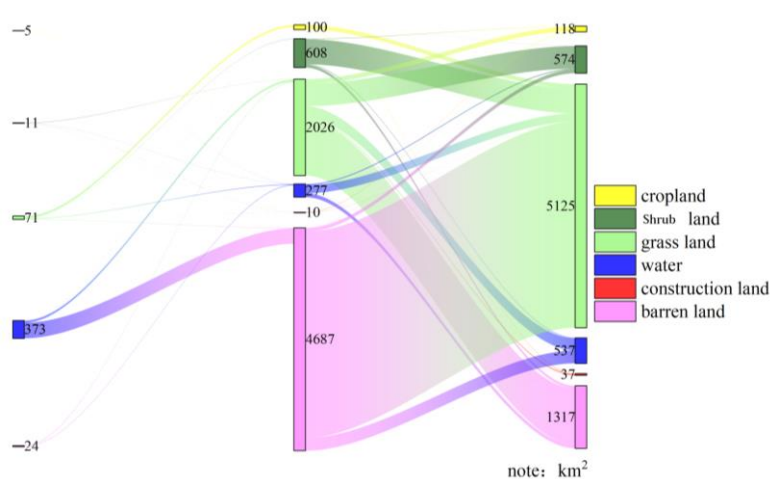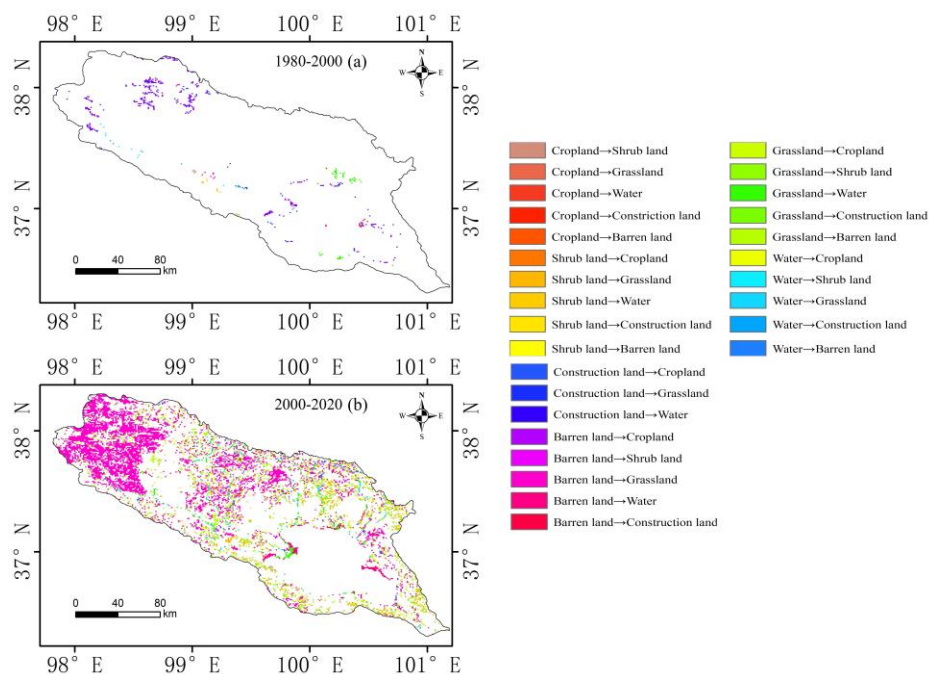

Figure 5. Changes in land type transfer in Qinghai Lake Basin from 1980 to 2020

Discussion and conclusion

In the past 40 years, grassland in Qinghai Lake Basin has been the most significantly increased land use type, and barren land has been the most reduced land use type. This is consistent with the changing trend of land use types in the entire Qinghai-Tibet Plateau (Zhang et al., 2019, 2021). One of the important reasons for this change is climate change. In the past 40 years, the climate of the Qinghai Lake Basin, including the Qinghai-Tibet Plateau, has shown a trend of warming and humidification (Piao et al., 2019; Wang et al., 2021). This promotes the increase of vegetation coverage in the Qinghai Lake Basin, among which the grassland coverage is the most significant. Another important reason for this result is the influence of the ecological construction

project in the Qinghai Lake Basin. The impact of human activities cannot be ignored for the change of land use types in the Qinghai Lake Basin. The relative change rate of grassland in the Qinghai Lake Basin from 2015 to 2020 was relatively high, indicating that the implementation of ecological protection projects in the Qinghai Lake Basin had a significant effect at this time. This is in general agreement with the results of Han et al. (2021).

Figure 6. Changes in land type transfer in Qinghai Lake Basin from 1980 to 2020

In terms of spatial transfer dynamics, the ecological environment in the northwestern part of Qinghai Lake has improved significantly over the past 40 years, with a large amount of bare land converted to grassland (*Fig. 6*), and a study by Bao et al. (2018) also found a significant increase in vegetation cover in the Qinghai Lake Basin. This result is mainly due to two factors: on the one hand, climate change, which tends to warm and humidify in the Qinghai Lake Basin during the study period, with a maximum temperature increase of about 0.30°C per decade (Yin et al., 2010), and precipitation increasing year by year (Su et al., 2018), which promotes vegetation growth. On the other hand, since the 21st century, Qinghai Province has followed the national strategy of western development and initiated a large number of ecological construction projects, which have significantly improved the ecological environment of the Qinghai Lake Basin (2007). It has also been shown that human-influenced grassland biomass is positively correlated with livestock density and that reasonable grazing can increase grassland biomass (Li et al., 2019).

This study analyzed land use changes and type shifts in the Qinghai Lake basin based on the past 40 years of land use data and came to the following conclusions.

(1) The area of grassland land use types in the Qinghai Lake basin over the past 40 years showed a significant increasing trend and the area of barren land showed a significant decreasing trend, whose grassland area increased by 3094 km^2 and barren land area decreased by 3058 km^2.

(2) From the land transfer matrix, the land use type in the Qinghai Lake basin mainly changed from water area to barren land from 1980 to 2000, and from 2000 to 2020, the land use type mainly changed from grassland to barren land, which showed that the ecological environment in the Qinghai Lake basin tended to develop in a benign way.

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