Analysis on Lake Change and Its Cause in Qaidam Basin

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Abstract. Plateau lakes are sensitive indicators of climate change. This study used multi-source satellite data to monitor the temporal and spatial dynamics of the lake area in the Qaidam Basin. Results showed that the lakes in Qaidam Basin were in different conditions. The lakes in the core area of the basin were affected by human activities and the lake area changes drastically. The lakes around the basin were less affected by human activities and could better reflect the climate change. In the past 50 years, the climate of the Qaidam Basin has generally been warm and humid. The annual mean temperature increases from east to west tends to decrease; the precipitation was just opposite to the temperature, and the rate of increase decreases from east to west. In the eastern part of the basin, there was a significant increase in Delingha; the area of Lake Hala in the east has increased by 18.59 km² over the past 52 years, and the area of Xiaodan Lake in the middle has expanded by 19.87 km² compared with the same period in the past 13 years, while the west of the Muse the overall trend of Lake Kule Lake decreased after the increase; overall, the shallow lakes in the Qaidam Basin were shallow, and the flatness of the lake bottom and the significant increase in precipitation were the main reasons for the significant expansion of its area, while the area of lakes in the western part of the basin decreases. The temperature was obviously higher, and the increase in precipitation is not obvious.

1. Introduction

The Qinghai-Tibet Plateau is a sensitive area of global climate change and a fragile area of ecosystem, and it also produces strong feedback on global climate change [1-3]. Qaidam Basin, located in the northern part of the Qinghai-Tibet Plateau, is one of the most densely distributed lakes in China and the most concentrated salt lakes in the world. At present, there are as many as 47 saline lakes in the Qaidam Basin, more than 1 km² in the West and north of the basin. The Qaidam Basin is one of the famous inland dry basins in China. Its climate is dry and rainfall is scarce. The precipitation decreases from the surrounding area to the center of the basin. The annual precipitation in the surrounding mountainous area ranges from 150 mm to 300 mm. The annual precipitation in the center of the basin is less than 50 mm. The precipitation in the northwest is only 25 mm. The evaporation capacity of the basin is over 1800 mm. The lakes around Qaidam Basin are less affected by human activities. The shrinkage or expansion of lakes can truly reflect the changes of regional climate and environment. They are sensitive indicators of global climate change.
The development of remote sensing technology has become an indispensable means to quickly and accurately obtain the dynamic changes of lakes and reservoirs, and multi-source satellite data has become an important data source for lake change research. In addition, the combination of remote sensing (RS) and geographic information system (GIS) can greatly save manpower and financial resources [4]. Most of the lakes in Qaidam Basin are flat, the lake area recharged by precipitation varies sharply, and the lake area recharged by glaciers is relatively stable[5]. Water resources play an irreplaceable role in resource development of Qaidam Basin [6]. According to statistics, the area of the alpine desert snow area around the basin is more than 44,000 km. The glacier area alone is 1,565.45 km, accounting for 0.6% of the total area of the Qaidam Basin. The ice reserves are 11.35 billion m3, and the annual melting water is about 900 million m3. Mountain snowmelt water flows into the river in accordance with the topography, then flows to the low-lying part of the basin, and finally forms a lake. Most of the lakes in Qaidam Basin are salt lakes, mainly concentrated in the middle of the basin, that is, the tail of river system and the convergence area of surface and underground runoff.

In recent years, many domestic and foreign scholars have made use of multi-source data to analyze the dynamic change of Lake area. Aerial photographs, topographic maps and NOAA satellite data were mainly used during the 1970s and 1990s. The early data or resolution was low. It was difficult to distinguish lake shoreline changes below 200KM2, or the transit period was long. In addition, due to the influence of clouds, the amount of data was very limited, which affected the analysis of Lake dynamic characteristics. Serwan et al. used Landsat TM remote sensing data to extract and classify the ecological information of lake and river basin[7]; Birket used multi-temporal radar and NOAA/AVHRR remote sensing data from 1992 to 1998 to analyze and predict the interannual and seasonal water surface changes of Lake Chad in Africa and the law of flood changes in the basin[8]; Based on the topographic maps, aerial photographs and multi-temporal TM satellite remote sensing data from 1970 to 2000, a comprehensive remote sensing analysis method for lake changes has been established, and the changes of Yang zhuoyong Lake and Shencuo Lake in the south of Qinghai-Tibet Plateau have been analyzed [9]. Li Junli and others have used Landsat TM long time series remote sensing data for more than 30 years. The temporal and spatial characteristics of lake changes in the closed inland watershed [10]; Han Fang and others used NOAA/AVHHR remote sensing data of polar orbiting meteorological satellites to analyze the interannual variability of Lake Darinor [11]; Ma Mingguo and other high-resolution remote sensing data such as 1973-2006 foreign satellite data and China-Brazil satellite data and MODIS data to monitor lakes. Shao Zhaogang and others[12-14] analyzed the changes of key lakes in the Qinghai-Tibet Plateau in the past 25 years. Some scholars have studied lake changes in Qaidam Basin in recent years. Using MODIS satellite data for 9 consecutive years from 2000 to 2008, Zhang Chao et al. combined with local meteorological data, analyzed the changes of Lake area in Qaidam Basin. The results show that the lake water area in the middle of the basin has an obvious increasing trend with the increase of temperature in recent years, while the other lakes such as Dulan Lake in the southeastern part of the basin are less affected by temperature and have no obvious change for many years. The Lake area in the central plain area of Qaidam Basin was taken to analyze its changing trend and driving mechanism [15]; Xu Haojie and others studied the area change of Tuosho Lake in Qaidam Basin and Tsongna Lake in winter through Landsat TM and Landsat ETM + images from 1985 to 2010; Wu Juanjuan studied 40 remote sensing images of TM and ETM + in five periods from 1992 to 2013. On the basis of field investigation and indoor remote sensing interpretation, the dynamic change trend of water area of main salt lakes in Qaidam Basin in the past 20 years was studied, and the causes of dynamic change of salt lake water were analyzed with the environmental data in the basin [16]; the normalized water index method NDWI of MODIS09 data was used by Wei Shanrong and others. The Lake area change and its response to climate change in the Qaidam Basin during 2001-2014 for 14 consecutive years have been studied [17]. The water intensity of the section has been systematically studied by using Landsat satellite remote sensing data from 1976-2015 for 40 years. Some of the lakes are based on earlier aerial photographs. Map data, area data can be traced back to the end of 1950s. Combined with the investigation of water resources development and utilization, the lake change characteristics and its response to climate and human activities in the Qaidam Basin are analyzed comprehensively [18].
However, most of the above-mentioned studies use foreign land resources satellite data, and the data are generally discontinuous or the data sequence is short. It is difficult to reflect the long-term persistent changes of the lake [19]. Therefore, the purpose of this paper is to analyze the long-term changes of the lake area around Qaidam Basin and the continuous changes since 2001 by using Multi-source Satellite data, and to analyze the causes, so as to provide theoretical and decision-making basis for the comprehensive management of the ecological environment and the construction of ecological civilization by government departments at all levels.

2. Methods and Sources

2.1 Overview of Research Area

The Qaidam Basin is a huge intermontane basin on the northeastern margin of the Qinghai-Tibet Plateau. It lies between 34 41 39 20 N and 87 48 99 18 E. It is one of the four major basins in China. The basin is slightly triangular and extends northwest-west-southeast-east. The northwest, northeast and south of the basin are surrounded by Altyn, Qilian and Kunlun Mountains respectively. It is a closed inland basin with a total area of 26.5 104KM2. Among them, the mountainous area around the basin is 13.7 104KM2, and the plain area of the bottom basin is 12.8 104KM From the margin to the center of the basin, the geomorphic types are alpine, Gobi, fixed and semi-fixed dunes, wind-eroded hills, fine-soil plains, swamps, salt marshes and lakes. The southern part of the basin is a piedmont alluvial plain, with a long Gobi belt in East and west. There are large areas of sand dunes on it. The "Yadan" topography in the western part of the basin is widely distributed.

The precipitation in Qaidam Basin is scarce, the distribution of river network is very uneven, the southern river network is dense, and the runoff is relatively abundant; the Northwest River is sparse. There are 39 rivers in the whole basin, of which 10 annual runoff exceeds 100 million m3. These rivers originate from the surrounding mountains and converge to the center of the basin. The river flows through the surface or underground runoff and eventually flows into the respective catchment centers to form the tail lake.

The central lakes in Qaidam Basin are complex and variable in size, while the surrounding lakes are relatively small. The original Koko Salt Lake and Cooperative Lake area have become large artificial salt fields, and the natural form of the salt lake has changed seriously or no longer exists. Under the dual influence of human activities and natural inflow, the Saline Lake in Chaidamu basin is the most changeable. Therefore, this study focuses on the area and shoreline changes of the peripheral lakes of the basin which are less affected by human activities.

![Figure 1. geographical location of Qaidam Basin](image-url)
2.2 Data Sources

The environmental disaster reduction satellite data and Gao Fen-1 data used by this research institute are from the Land Observation Satellite Data Service Platform of China Resources Satellite Application Center (http://218.247.138.121/DSSPlatform/index.html). The CCD data of the Qaidam Basin region (Table 2) were selected. Before 2001, the satellite data came from NASA. All types of satellite data sensors, transit time, resolution and data sources are shown in Table 1.

| Data Source          | Time                                      | Resolution | Resolution Type                           |
|----------------------|-------------------------------------------|------------|------------------------------------------|
| Landsat TM/ETM+      | 1976.07.07,1976.11.08,1976.11.13,1988.06.28,1989.05.13 | 5m         | USGS/NASA                                |
|                      | 1990.11.05,1995.08.19,1999.09.23,2000.01.28,2001.10.21 |            |                                          |
| HJ1A/B CCD           | 2010.09.06,2011.09.18,2012.08.19,2014.09.24,2015.09.30 | 30m        | China Center for Resources Satellite Data and application |
| GF-1 CCD             | 2016.09.16,2016.10.02,2017.09.24             | 16m        |                                          |
| MODIS                | 2001.09.21,2002.10.01,2003.10.06,2004.10.01,2005.09.17,2006.09.30,2007.09.20,2008.10.05,2009.09.28,2010.09.12,2011.09.11,2012.09.21,2013.09.24,2014.09.25 | 250m       | NASA                                     |

The MODIS-MOD13Q product data comes from the United States Geological Survey (NASA) (http://glovis.usgs.gov), the spatial and temporal resolutions are 16d (from the first day of each year to 353 days) 250m, the product track numbers of the study area are h25v05, h26v05, and the corresponding products of June, July and August from 2002 to 2015 (Table 2), the total is 8.4 scenery.

| Month | Days of the month | Days of the month |
|-------|-------------------|-------------------|
| 1     | 1,17              | 7                 |
| 2     | 33,49             | 8                 |
| 3     | 65,81             | 9                 |
| 4     | 97,113            | 10                |
| 5     | 129,145           | 11                |
| 6     | 161,177           | 12                |

The climate data of Qaidam Basin are collected from 8 stations, including Delingha, Ulan, Golmud, Dachaidan, Lenghu, Mangya, Normuhong and Xiaozaohua. The time period is 1961-2016, and the time period of Ulan is 1980-2016. The climate data are provided by Qinghai Meteorological Bureau.

2.3 Method

2.3.1 High Score Satellite Image Processing Method

Loading the image data under ENVI 5.4, according to the spectral characteristics of different ground objects in each band of the CCD data of the environmental disaster reduction satellite and the high-resolution satellite, channel 4, channel 3 and channel 2 are respectively given three colors of red, green and blue for false color synthesis, and the water boundary position is observed qualitatively. Secondly, radiometric correction, Flash atmospheric correction and ortho-rectification are carried out in turn, and the geometric correction of the pseudo-color composite image is performed using the corrected LANDSAT TM image. The corrected RMSE is less than 0.5 pixels. Finally, the empirical threshold model is used to extract the lake water area. The model is B4/B2<1-B4<0.05, in which B2
and B4 represent the reflectivity of the 2nd and 4th channels of the environmental disaster reduction satellite or high-resolution CCD data (Fig. 2).

![Figure 2](image_url)

**Figure 2.** data processing flow of environmental disaster reduction satellite or high score 1 satellite

### 2.3.2 Vegetation Index Processing Method

1) projection transformation and data mosaic. MOD13Q1 data can be programmed using the MODIS special data processing tool MRT software, ENVI software or IDL programming language provided by NASA website. The output data can be converted to isolongitude and latitude projection or Albers projection in IMG or Geotiff format, and the ellipsoid is selected as Xi'an 80, and the nearest neighbor method is selected as resampling method. 2) The monthly vegetation index is synthesized. The grid calculator under the spatial analysis module of ArcGIS 10.2 was used to process the NDVI data of 2 phases per month according to the maximum synthesis method (MVC). The monthly maximum NDVI from June to August was used to synthesize the maximum composite value images of vegetation growth season; 3) cropping images. The maximum NDVI images from June to August and the vector boundaries of Qaidam Basin are opened in ArcGIS 10.2 software. Then, the monthly NDVI raster maps and the maximum NDVI images of all growing seasons in Qaidam Basin are cut in batches with MASK tools under the spatial analysis module of ArcGIS 10.2 software.

### 2.3.3 Meteorological Data Processing Method

The meteorological data of the Qaidam Basin were obtained by arithmetic averaging from 1961 to 1979 at seven meteorological stations, including Delingha, Golmud, Dachaidan, Lenghu, Mangya, Normuhong and Xiaozaozuo, while from 1980 to 2016, there were 8 Meteorological stations, including Delingha, Ulan, Gelmud, Dachaidan, Lenghu, Mangya, Normuhong and Xiaozaozuo. The meteorological data of meteorological stations represent the whole Qaidam Basin. The interannual variations of temperature and precipitation are analyzed by using SAS 10.0 and OFFICE 2013 statistical software, correlation analysis and linear trend method.

### 3. Lake Change Characteristics in Qaidam Basin

#### 3.1 Major Lake Area Changes

##### 3.1.1 Lake changes in the eastern part of Basin

Torsu Lake is the only saline lake in the basin, belonging to Tailu Lake. The annual precipitation of the lake area is about 80 mm, and the evaporation capacity of saline water is about 1300 mm. The supply of lakes to lakes is weak, and the area of lakes is mainly affected by the amount of upstream water.
During the period from 1956 to 2017, the lake experienced a process of decreasing, enlarging, stabilizing and enlarging, and showed a weak decreasing trend, slowing down to 0.41 km²/a. Among them, from 1956 to 2004, the area of Torsu Lake decreased continuously, and the area of Torsu Lake shrank 60.31 km² in 48 years; from 2005 to 2010, the area of Torsu Lake showed an obvious expansion trend, with an area of 146.31 km² in 2010, which was 14.56 km² larger than that of 2005; from 2011 to 2016, the area of Torsu Lake was relatively stable, with an increase or decrease range of 1.70 to 4.95 km²; from 2017 to 2017. The annual area of Lake Torso is 7.79 km² larger than the average value of 2011-2016, and 10.45 km² larger than that of 2016, reaching the maximum in nearly 30 years (Figure 3).

**Figure 3.** 1956–2017 area change of Tuosu Lake

From 1956 to 2017, the lake experienced a process of decrease enlargement stabilization, and showed a significant trend of expansion, with an increase rate of 0.35 km²/a. Among them, from 1976 to 1999, the area of Cahai Lake shrank by 2.36 km²; from 2004 to 2010, the area of the lake expanded by 35.25 km² in 2010, which was 5.44 km² larger than that of 2004; from 2011 to 2017, the area of Cahai Lake was relatively stable, and the increase or decrease range was between 0.06 km² and 0.62 km²; from 2011 to 2016, the area of Tuosu Lake was flat. The average value increased by 7.79 km², 10.45 km² over 2016, reaching the highest level in nearly 30 years (Fig. 4).

**Figure 4.** 1976–2017 Lake area change

### 3.1.2 Changes of lakes in central and Northern Basin

Xiao Chaidan Lake, also known as Baga Chaidamu Lake, is located in the north-central Qaidam Basin, about 35 km from Da Chaidan Town, near rhombic surface, belonging to sodium chloride brine. The Lake area is rich in boron and lithium salt deposits of industrial value, with the deposits of stone salt, mirabilite and borate, and the coexistence of solid and liquid phases. The Tata river is the largest river in the basin, with annual runoff of about 1.26 x 108m³ from NW to lake.
From 1976 to 2017, the area of Xiaochaidan Lake experienced a process of stability expansion-reduction expansion. Among them, from 1976 to 2001, the area of Xiaochaidan Lake remained basically stable, with an area of 42.4-49.8 km$^2$. From 2004 to 2010, the lake surface showed an obvious expansion trend, with an area of 97.41 km$^2$ in 2010. From 2011 to 2017, the area of Xiaochaidan Lake first decreased and then expanded. In 2017, the area of Xiaochaidan Lake reached its maximum in nearly 42 years (Fig. 5). The tartaron River expanded 4 to 6km outward into Hukou, and the east coast line of the lake expanded 0.7 to 2km.

3.1.3 Lake changes in Western Basin

The northwestern part of the basin is Lake garsell. From 1976 to 2017, the area of Gaskool Lake experienced a process of enlargement-decrease-stability-enlargement-decrease. From 1976 to 2000, the area of Gaskool Lake was expanding continuously, ranging from 106.44 km$^2$ to 119.51 km$^2$. It decreased significantly in 2001. From 2002 to 2009, the lake surface was relatively stable, with an area of 130.69km$^2$ in 2010, which was the largest in recent 42 years. During 2011 to 2017, the area of Gaskool Lake expanded significantly except in 2012 and 2013. The area of Guskulle Lake was basically stable, with a reduction rate of 2.59 km$^2$/a and 15.9% in 2017 compared with 2010, but an increase of 5.4% compared with the smallest area in 2001 (Fig. 6). In 2010, 2012 and 2013, the area was significantly enlarged due to the significant increase in the surrounding rainfall.

4. Lake Change Cause Analysis

4.1 Climate Change
In the past 50 years, the annual average temperature of Qaidam Basin has been rising significantly, and the temperature of the basin has been rising significantly from east to west. The heating rate ranges from 0.44 0.84 / 10a from east to west. The heating rates of small stove fires and cliffs in the West are 0.66 / 10a and 0.84 / 10a, respectively. The heating rates of Harbin Lake were 0.44 / 10a, 0.47 / 10a and 0.49 / 10a, respectively. The heating rates of the northern cold lake were the smallest, 0.27 / 10a, which passed the significance level test of P < 0.01 (Table 2 and Figure 7).

**Figure 7.** Temperature and Precipitation Variations (a) and Delingha temperature and Precipitation Variations (b) in the Qaidam Basin from 1961 to 2016, Dachaidan temperature and Precipitation Variations (c) in the outskirts of the basin, and Mangya temperature and Precipitation Variations (d) in the outskirts of the basin.

Rainfall and air temperature showed an increasing trend, but the increasing trend was not obvious except Delingha, and the growth rate of precipitation and air temperature was opposite, and increased from west to east. In the eastern part of the basin, the precipitation of Ulan and Delingha increased significantly with the increasing rates of 26.1mm/10a and 31.1mm/10a, respectively. The precipitation in the rest of the basin showed a weak increasing trend, and did not pass the P=0.05 significance test (Table 4).

**Table 4.** 1961~2015 annual climatic trend rate and correlation coefficient of meteorological stations in Qaidam Basin

| Category | numuHong | Ulan | LengHu | Delingha | DaChaiDan | Golmud | XiaoChaidan | Mangya |
|----------|----------|------|--------|----------|-----------|--------|-------------|--------|
| Propensity rate(℃/10a) | 0.44 | 0.47 | 0.27 | 0.49 | 0.55 | 0.62 | 0.66 | 0.84 |
| Correlation coefficient | 0.71 | 0.55 | 0.47 | 0.72 | 0.78 | 0.81 | 0.85 | 0.85 |
Since the beginning of the 21st century, precipitation and runoff have changed from dry to rich, indicating that the climate tends to warm and humid in the near future. Chen Bishan [18]'s research also shows that the climate in the basin has developed towards warm humidification in the past 50 years.

4.2 vegetation restoration
Vegetation not only has an important impact on regional climate change, but also can reduce the reflectivity of surface to solar shortwave radiation and the effect of near-surface warming, thus reducing the turbulence exchange and water evaporation. At the same time, vegetation restoration is also conducive to the increase and decrease of surface water conservation function. The ineffective infiltration and dissipation of precipitation contribute to runoff generation and continuous replenishment of [20].

As shown in Fig. 8a, the vegetation area of Qaidam Basin increased significantly from 2002 to 2015 ($R^2 = 0.4919$, $P < 0.01$). The total area of the basin was positively correlated with the total area of Tossel Lake, Xiaochaidan Lake, Dachaidan Lake, Keluke Lake, Dulan Lake, Black Sea, Arak Lake and Gaskule Lake (Fig. 8b), and the total vegetation area of the basin increased significantly with the increase of the total area of the lake ($R^2 = 0.5055$, $P < 0.01$). Under the joint influence of engineering construction, watershed ecology tends to recover, showing a benign evolution. The restoration of vegetation in the basin effectively promotes precipitation to form runoff and recharge into rivers, which in turn contributes to the rise of lake levels (Fig. 8).

| Tendencia (mm/10a) | 3.8 | 26.1 | 5.5 | 31.1 | 3.2 | 1.7 | 1.7 | 1.7 |
|--------------------|-----|------|-----|------|-----|-----|-----|-----|
| Correlación r       | 0.07| 0.21 | 0.10| 0.32 | 0.02| 0.02| 0.02| 0.02|

**Figure 8.** Changes of vegetation area in Qaidam Basin from 2002 to 2015 (a) Relationship between total area of main lakes and total vegetation area in Qaidam Basin (b)

4.3 Lake Runoff
Runoff into the lake refers to the amount of water flowing into the lake, which determines the change of the lake water level and is the main source of Lake recharge. The Bayin River in the eastern part of Qaidam Basin flows through Heishishan Reservoir and Keluke Lake successively, and finally flows into Tuosu Lake through Jianxiao River. Therefore, the flow of Bayin River represents the runoff of Lake Creek and ho Tuo su. From 1955 to 2017, the runoff of Bayin River, which entered Lake Keluke, showed an overall upward trend with an upward rate of 0.066 m³/s a 1. The upward rate of Bayin River runoff was 0.0074 m³/s a 1 from 1955 to 2000, and the upward trend was not obvious ($P > 0.05$); however, the upward rate of Bayin River runoff was 0.1455 M from 2001 to 2017. 3/s A-1 increased significantly. The main reason is that the precipitation increases with the warming and humidifying of
the basin climate in the past 10 years, which eventually leads to the increase of the Bayin River flow, resulting in the significant expansion of the area of Lake Torsu in the Tailu Lake in the lower reaches of the Bayin River in the past 10 years, and the variation trend of the Bayin river runoff and the water area of Lake Torsu is very similar (Fig. 9).

**Figure 9.** deep range variation of runoff in Bayin River

### 4.4 Human Factors

(1) population factor

The Qaidam Basin is a vast and sparsely populated inland area with extremely uneven population distribution. The population distribution in the lower reaches of the Ger River and the Nomu River and the eastern part of the basin is relatively dense, mainly because the terrain is flat and the soil is black soil with high organic matter content, which is relatively fertile, has abundant water resources, and has convenient transportation, thus concentrating the whole flow. Over 90% of the population, towns and transportation infrastructure. In recent years, the rapid development of local economy, trade, transportation and tourism has brought local economic prosperity, but also aggravated the local environmental pollution and ecological damage. In 1949, the total population of the Chaidamu basin was only $1.6 \times 10^4$, and the cultivated land area was $2 \times 10^3$ha. After the founding of the people's Republic of China, with the establishment of state-operated farms, the planting industry has been developed. The reclamation area reached $8.6 \times 10^4$ha at the end of 50s. Since the 1980s, oil and gas, Salt Lake resources, metal and coal mining industries in the basin have developed rapidly, and the population has also increased dramatically. In 2010, the permanent population reached $4.54 \times 10^5$, the agricultural irrigation area was $4.95 \times 10^4$ha, the grain output was $9.33 \times 10^4$t, and the livestock stock stock was $1.56 \times 10^6$ (only). The GDP of the whole year was $3.21 \times 10^{10}$ yuan, and the added value of the first, second and third industries accounted for 2.7:78.0:19.3 of GDP. By 2011, the total population of eight cities and counties in Qaidam Basin had reached $5.72 \times 10^5$, of which $3.72 \times 10^4$ were resident population and $5.51 \times 10^3$ha were cultivated land except $1.99 \times 10^5$ floating population. According to statistics, the total population of villages and towns in Qaidam Basin increased linearly from 1982 to 2010, with an average annual increase of $1.4 \times 10^3$ people.

(2) social and economic development

Bayin river is the main river in the basin, and also the main source of water supply for the lakes and wetlands. From the 1950s to the 1980s, with the gradual increase of runoff (Table 5), Lake Tossel experienced a significant shrinkage. Area is negatively correlated with precipitation and runoff, but positively correlated with evaporation capacity (Fig. 10), which can not be explained physically. Obviously, the atrophy of the Tuo lake has nothing to do with changes in climatic and hydrological factors.

| Year | Lake Area (km²) | Layout (m) |
|------|----------------|------------|
| 1956 | 100            | 10         |
| 1980 | 200            | 20         |
| 2005 | 300            | 30         |

**Table 5.** Comparison of area and climatic and hydrological factors of Tuo Su Lake area
The shrinkage of Tuosi Lake can be found from the social and economic development in Delingha. Before liberation, Delingha had only a few settlements of Bayin River, Gobi and Zongwulong, with more than 40 families and more than 300 people. The water conservancy facilities only have a long 10km of Guo Li Mu canal, and the irrigated area is only 48.87ha. Delingha farm was established in 1954, and water conservancy facilities were built in 1956. In 1959, the irrigation area reached 1104ha. In 1960s, the highest cultivated area reached 1.33 *104ha. Agricultural irrigation increased from nearly zero or one to nearly 1.9 * 108m3. In 2010, the total socio-economic water consumption in the Bayin River Basin was 2.6 *1010m3, and the utilization rate of water resources reached 54%.

Under the background of warm and humid climate, the Torsu Lake shrank by 54 km² from 1956 to 1999, and the water consumption in the upper reaches of the lake was the main reason. In 1960s, the highest cultivated area reached 1.33 *105ha. Agricultural irrigation increased from nearly zero or one to nearly 1.9 * 108m³. In 2010, the total socio-economic water consumption in the Bayin River Basin was 2.6 *1010m³, and the utilization rate of water resources reached 54%.

The artificial water consumption in the upper reaches of Torsu Lake reduced the inflow flow and broke the original water balance. Because of the deeper water, the area of the lake changed relatively slowly, but the long-term human impact caused the lake to shrink continuously. Recently, the lake water area has been slightly expanded, which is related to the partial runoff of the Lake since 2002. From 2002 to 2011, the average annual inflow of the Bayin River reached 4.49 6550.

### 5. Conclusion and Discussion

There are many lakes in the Qinghai-Tibet Plateau. The changes of area and water volume are not only sensitive to climate change, but also have an impact on climate change through energy exchange between the earth and atmosphere. Many studies have revealed the change of Lake area and its response to climate change in the Tibetan Plateau. In this study, Multi-source Satellite Data were used to monitor the continuous temporal and spatial dynamics of the lake water area in the Qaidam Basin in the past 40 and 50 years, especially in the past 10 years. The main conclusions are as follows:

1) The changes of lakes in Qaidam Basin are different. The Lake area in the core area of Qaidam Basin varies dramatically because of the influence of human activities. The peripheral lakes of the basin are less affected by human activities, which can better reflect the climate change.
2) in the past 50 years, the climate of the Qaidam Basin is generally warming and humidification. The annual average temperature rising rate increased from east to west, ranging from 0.27 to 0.84 c/10 a, and the precipitation increasing rate decreased from east to west, ranging from 1.7 to 31.1 mm/10 a.

3) From 1956 to 2017, the Torsu Lake in the eastern part of the basin experienced a process of decreasing, enlarging, stabilizing and enlarging, and showed a weak trend of decreasing, slowing down to 0.41km$^2$/a. The area of the small Chaidan Lake in the central and northern part of the basin experienced the process of stabilization, enlargement, decrease and enlargement from 1976 to 2017, and the overall trend of increase was 3.47 km$^2$/a. The area of Lake Lake has gone through the process of enlarging, decreasing, stabilizing, expanding and decreasing. The overall trend is weak, with a growth rate of 0.15km$^2$/a.

4) The main reasons for the increase of Lake area are as follows: the increase of precipitation caused by climate warming and humidification in Qaidam Basin in recent years; the vegetation restoration in Qaidam Basin is remarkable; the vegetation area and Lake area are positively correlated; the population increase and economic and social development in Qaidam Basin are important factors.

With the successful launching of many satellites in China and abroad, and more and more free satellite data, and more clear sky weather in Qaidam Basin, the fine monitoring of lake water area and lake shoreline in a year based on Multi-source Satellite data becomes possible; in order to increase the amount of satellite monitoring data, the water area is greater than 200 km$^2$. The lake can use the polar orbiting satellite data such as MODIS, FY3 series and NPP to assimilate and increase the data of MODIS satellite, FY3B/3C/3D and NPP VIIR. In addition, the length of Lake data sequence can be added. For lakes with small data area and easy to flood, such as Koluk Lake, the monitoring accuracy can be improved by using high-resolution satellite data. If the rainy weather lasts for many days during the flood, the high-resolution radar data can be used to monitor the water area in detail. Dynamic monitoring of Lake area and lakeside line can be carried out by UAV aerial photography.

6. References

1. Zhu Liping, Xie Manping, Wu Yanhong. Quantitative analysis Of lake area variations and the influence factors from 1971 to 2004 in the Nam Co Basin of the Tibetan Plateau[ J]. Chinese Science Bulletin, 2010, 55(13): 1294 - 1303.
2. Li Hui, Xiao Pengfeng, Feng Xuezhi, et al. Lake changes map and area change in the Sanjiangyuan area in the past 30 years [J]. Lake Science, 2010, 22(6): 862-873.
3. Shi Yafeng, Shen Yongping, Li Dongliang, et al. Research on the Characteristics and Trends of Climate Change in Northwest China from Warm-dry to Warm-wet[J]. Fourth Quarterly Studies, 2003, 23(2):154-164.
4. FENG Zhongkui, LI Xiaohui. Remote Sensing Monitoring of the Change of the Water Area and the Evolution of Lakeshore in Qinghai Lake in Recent 20 Years[J]. Acta Palaeonaeologica Sinica, 2006, 8(1): 1–5.
5. CAO Rong-long, LI Cun-jun, LIU Liang-yun, et al. Miyun Reservoir Area Extraction and Change Monitoring Based on Water Index[J]. Surveyor Science, 2008, 3(2): 158–160.
6. Yujin Kang, Huang Yongsheng, Feng Xuezhi et al. Water Extraction Method and Classification of SPOT Satellite Images [J].
7. Han Fang, Li Xinghua, Gao Layun. Remote Sensing Monitoring of Dynamics of Lake Darinor Wet lands in Inner Mongolia. Journal of Inner Mongolia Agricultural University, 2007, 28(1):74-78.
8. Ma Mingguo, Song Yi, Wang Xuemei. Research on dynamic monitoring of lakes in Ruoqiang, Xinjiang from 1973 to 2006. The glacier frozen soil, 2013, 35(5):1237-1246.
9. SHAO Zhao-gang, ZHU Da-gang, MENG Xian-gang, et al. Characteristics of the evolution of major lakes in the Qinghai-Tibet Plateau over the past 25 years[J]. Geological Bulletin, 2007, 26(12): 1633-1645.
10. DUAN Shui-qiang, CAO Guang-chao, LIU Wei, et al. The characteristics and causes of recent lake expansion in the Qiangtang Basin, Qinghai Province [J]. The glacier frozen soil, 2013, 35(5):1237-1246.
11. Jia Lu, Xiao Pengfeng. Study on the Change Detection of Tibetan Plateau Lakes Based on Multi-temporal Atlas. Land and Resources Remote Sensing, 2009, (4): 78-81, 85.
12. LI Jun-li, SHENG Yong-wei, LUO Jian-cheng, et al. Remote Sensing Mapping of Inland Lake Changes over the Tibetan Plateau[J]. Journal of Lake Sciences, 2011, 23(3): 311-320.
13. Zhang Guoqing, Xie Hongjie, Yao Tandong, et al. Monitoring lake level changes on the Tibetan Plateau using ICESat altimetry data (2003–2009)[J]. Remote Sensing of Environment, 2013, 58(26): 2664-2678.
14. Birkett C M. Synergistic remote sensing of Lake Chad: variability of basin inundation [J]. Remote Sensing of Environment, 2000(72):218-236.
15. Medina C E, Gomez-Enri J, Alonso J J, et al. Water level fluctuations derived from ENVISAT Radar Altimeter (RA-2) and in-situ measurements in a subtropical waterbody: Lake Izabal (Guatemala)[J]. Remote Sensing of Environment, 2008, 112(9):3604-3617.
16. Amatya P M. Water Level Fluctuations of Namco Lake in Tibetan Plateau Observed from Radar and Laser Altimetry[D]. Master Thesis. Enschede, the Netherlands: University of Twente, 2011.
17. LIU Bao-kang, WEI Xu-li, FENG Yan-qing, et al. Study on the area dynamics of Qinghai Lake based on environmental mitigation satellites[J]. Pratacultural science, 2013, 30(2): 95-96.
18. Liu Baokang, Li Lin, Du Yu’e, et al. Causes of the outburst of Zonag Lake in Hoh Xil, Tibetan Plateau, and its impact on surrounding environment [J]. Journal of Glaciology and Geocryology, 2016, 38(2):305-311.
19. Du Yu’e, Liu Baokang, He Weiguo, et al. Dynamic change causey analysis Lake and in Hou Xil on Qinghai-Tibet during 1976—2017[J]. Glaciology and Geocryology, 2018, 40(1):47-54.