LONG-TERM REMOTE MONITORING OF THREE TYPICAL LAKE AREA VARIATIONS IN THE NORTHWEST CHINA OVER THE PAST 40 YEARS

Y. Liu [1], Y. Lu [1], Y. Li [1], H. Yue [1]*

[1] College of Geomatics, Xi'an University of Science and Technology, Xi'an, Shaanxi 710054, China – liuying712100@163.com, 823554110@qq.com, 865736425@qq.com, yue_hui@live.com

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ABSTRACT:

In the context of global warming, study on the change of inland lakes in Northwest China not only has great significance in inland water resources management and sustainable development strategy, but also provide reference for assessing the impact of climate change and human activities. This paper selects three inland lakes in Northwest China, using Landsat MSS/TM/ETM+/OLI data from 1970 to 2015, Normalized Difference Water Index (NDWI) and Modified Normalized Difference Water Index (MNDWI) were used to extract lake area and analysed the dynamic trends. Meteorological station rainfall, evaporation and other meteorological data of the lakes were used to analyse reasons for the area change. The results showed that area of Hongjiannao Lake in the past 40a was reduced, the groundwater impoundment and underground coal mining are the main cause of area reduction; the area of Bosten Lake in recent 40a showed a decreasing trend after the first increase, the area was mainly affected by the surface runoff and snowmelt; the area of Qinghai Lake in the past 40a shows a trend of decreasing first and then increasing, the change of its area is mainly affected by regional precipitation and the inflow.

1. INTRODUCTION

Inland lake is an important part of water resources in arid or semi-arid regions. In recent years, due to the climate warming coupled with irrational exploitation and utilization of human beings, a number of inland lakes are on the verge of drying up, such as Manasi Lake and Ebinur Lake in Northwest China (Wang, 1998; Qin 1999). In the past 30 years, the inland temperature in north-western China showed an upward trend. The precipitation in and around the plateau increased and decreased, while the wind speed, solar radiation, sensible heat, and latent heat flux all showed a decreasing trend. The amount of lake water in inland areas was increased (Ma et al., 2011). With the decline of lake water level and the shrinking of lake area, the development of desert and water quality deterioration in lake shore have worsened the fish growing environment, causing serious impacts on the local residents' life and industrial and agricultural production (Yang el al., 2011). Developing the change and cause analysis of arid and semi-arid area of inland lakes, assessing the impacts of climate change and human activities on lakes, is a very important and prospective work which has guiding significance for rational exploitation and utilization of lake resources in arid and semi-arid areas. Many scholars have made relevant researches on the changes in the area of inland lakes, studied the dynamic changes of lakes in various remote sensing images, and made a systematic summary, and then conducted a detailed analysis of the research methods on the current lakes (Lu et al., 2011; Zhang et al., 2013; Feyisa et al., 2014). In this paper, Landsat MSS/TM/ETM+/OLI images from 1970 to 2015 were used as data sources to extract water body boundaries and calculate water area using Normalized Difference Water Index and Modified Normalized Difference Water Index. We choose three typical lakes in the inland to analyse the area change. The dynamic change trend of the area of three typical lakes in the Northwest inland in recent 40 years, such as Hongjiangnao Lake, Qinghai Lake and Bosten Lake, the characteristics and laws of lake area changes were primarily analysed based on the net annual evaporation and temperature as the main influencing factors, through the above-mentioned to provide hydrological monitoring and management of lakes data and reference.

2. DATA AND METHODS

2.1 Data

Landsat MSS/TM/ETM+/OLI images from 1970 to 2015 were chosen as data sources, area extraction was select at cloudless coverage time and concentrated in the May-August image. The data of evaporation, rainfall and temperature of lakes come from the meteorological data centre of China Meteorological Administration (http://data.cma.cn), the method is to select the data from multiple weather stations around the lake to find the average value. The Hongjiannao Lake is selected from Yijinhuoluo (53545) and Shenmu (53651); Bosten Lake is selected by yanqi (51567) and Korla (51656); Qinghai Lake selected Gangcha (52754) and Chaka (52842).

2.2 Methods

Data processing includes atmospheric correction, image mosaic, Landsat-7 ETM+ band restoration, etc. The method of Lake Boundary extraction adopts Normalized Differences Water Index (NDWI) and Modified Normalized Differences Water Inde (MNDWI), the formula is:

$$NDWI = (Green-NIR)/(Green+NIR) \quad (1)$$

In equation (1), Green and NIR represent the reflectivity of the green and NIR bands respectively. For example, Green

* Corresponding author

corresponds to Band 4 of Landsat MSS image and NIR corresponds to Band 6 of Landsat MSS image.

$$MNDWI= (Green-MIR)/ (Green+MIR) \quad (2)$$

In equation (2), Green and MIR represent the reflectivity of the green and mid-infrared bands respectively, for example, Green corresponds to band 2 of the TM/ETM+ image and band 3 of the OLI image respectively; and MIR corresponds to band 5 of the TM/ETM+ image and band 6 of the OLI image respectively. In order to extract the lake boundary more accurately, this paper uses the maximum between-class variance method for dynamic extraction of water body threshold.

3. RESULTS AND ANALYSIS

3.1 Hongjiannao

Hongjiannao is praised as the Pearl of the Desert, the largest desert freshwater lake in China, and is the world’s largest and most endangered bird—the relict gull breeding and habitat. It is located in the relatively low-lying area of the wind-sand area on the eastern edge of the Mu Us Desert. It plays an important role in the local ecological, economic and social development. In recent years, related research reports pointed out that the surface area of the Hongjiannao Lake has continuously shrunk, and the water depth and water storage volume have continuously declined, making the already fragile ecological environment further deteriorated (Ma et al., 2014). The change trend of the area of Hongjiannao Lake can be divided into two stages (Figure 1): the lake area changed little from 1988 to 1997, basically in a stable stage, and the area remained at about 55.00 km^2; from 1997 to 2015, the area of Hongjiannao is drastically reduced and constantly shrinking, by 2014, its area has been reduced to 33.32 km^2. There was a significant negative correlation between the area of Hongjiannao and annual average temperature ($P < 0.01$, $r = 0.661$) (Figure 2).

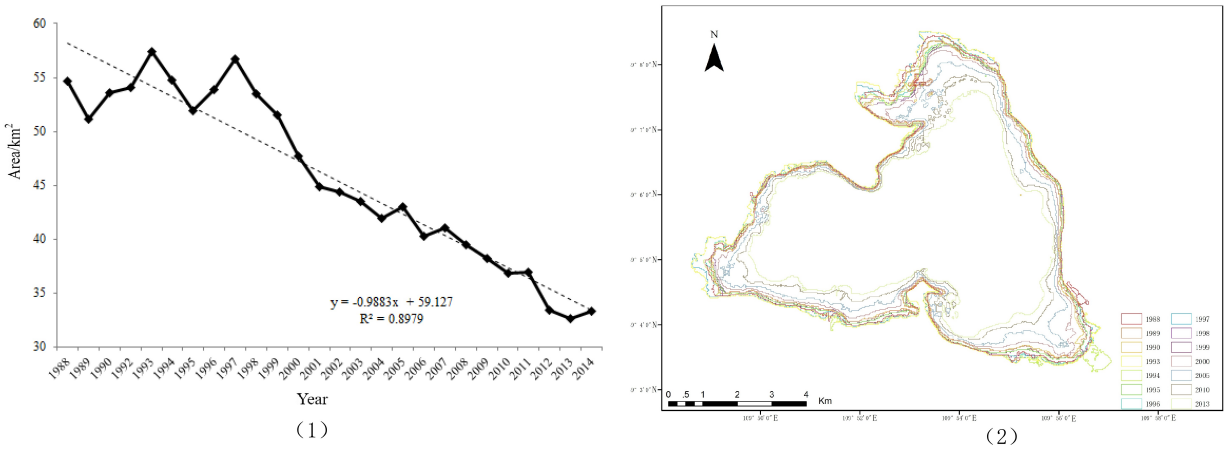

Figure 1. Dynamic map of Hongjiannao Lake area (1) Lake area trend map (2) Lake Boundary map

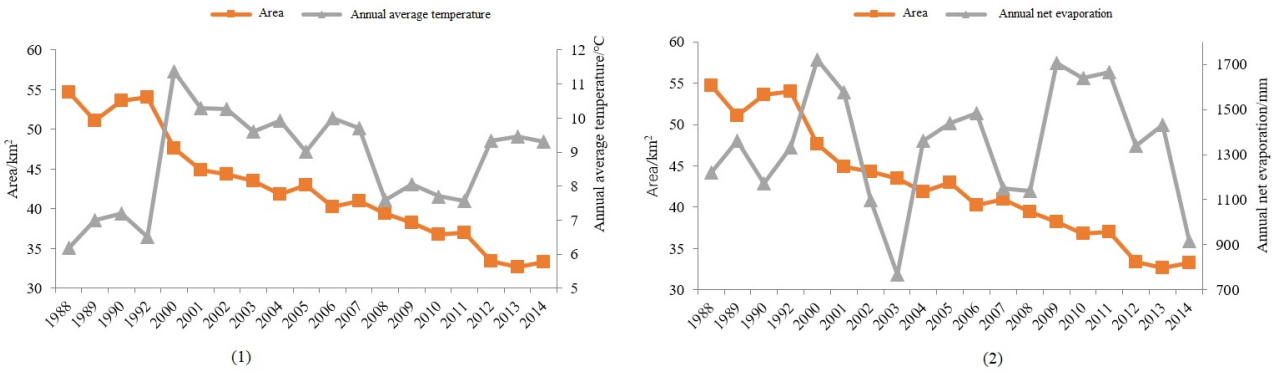

Figure 2. Comparison of area of Hongjiannao Lake and (1) annual average temperature (2) annual net evaporation

3.2 Bosten Lake

Bosten Lake belongs to the lake between the mountains and is the largest inland fresh water-handling lake in China. The lake is surrounded by state-level nature reserves and Xinjiang important agricultural bases. Bosten Lake plays an important role in local economic development and ecological environment protection. The area of Bosten Lake can be roughly divided into three stages: during 1973-1988 were decreasing; the area showed an overall upward trend during the 1988-2002, except slight decreasing in 2001, the area has increased about 286.50 km^2 over the past 15a; during 2002-2014, the lake area showed a rapid downward trend which the area has been reduced by 281.22 km^2. The location where the boundary has changed considerably over the years is located in the lakeside wetland northwest of Lake Bosten (Figure 3). The lake area is not significantly related to annual average net evaporation and annual average temperature (Figure 4).

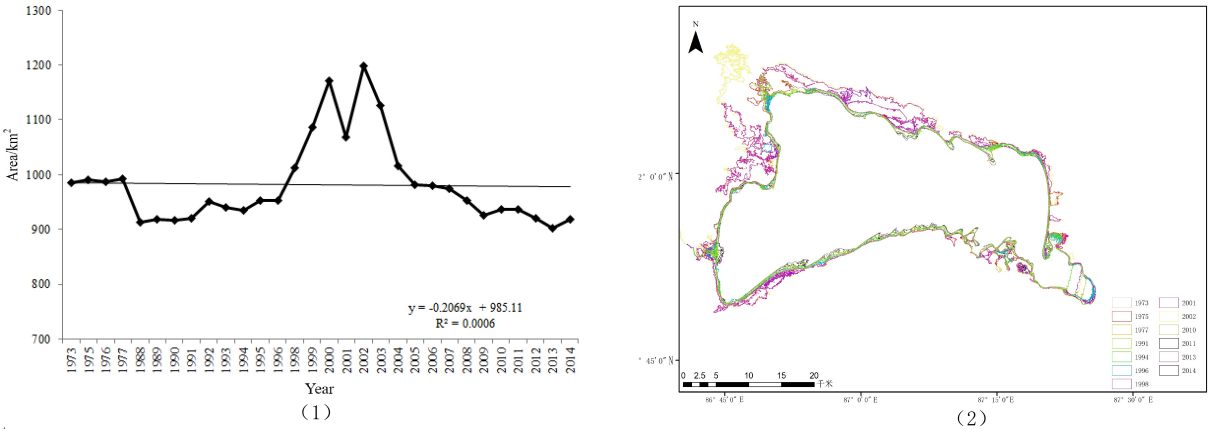

Figure 3. Dynamic map of Bositeng Lake area (1) Lake area trend map (2) Lake Boundary map

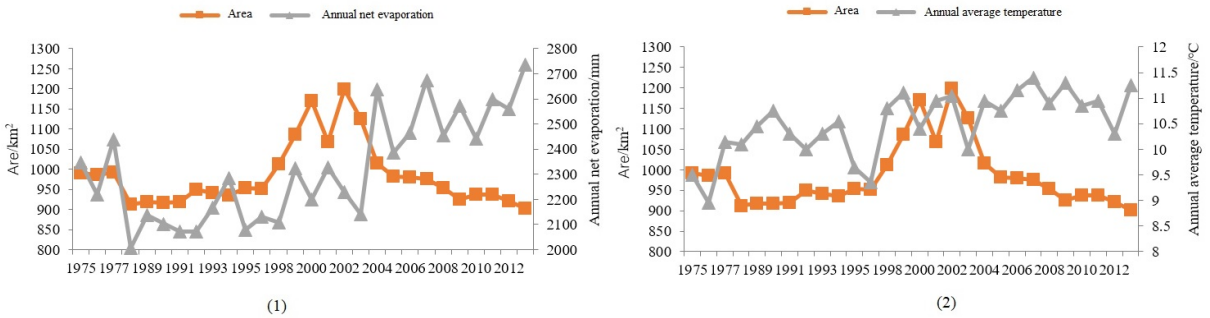

Figure 4. Comparison of area of Bositeng Lake and (2) annual average temperature (1) annual net evaporation

3.3 Qinghai Lake

Qinghai Lake is a structural faulted lake. The edges of the lake basin are fractured and connected to the surrounding mountains. Qinghai Lake is now the largest inland lake and saltwater lake in China. The change in the area of Qinghai Lake over the past 40a shows a tendency of first decreasing and then becoming stable and then increasing. In 1974, the lake area of Qinghai Lake was 4479.72 km^2 which is the maximum during the monitoring period (Figure 5). The lowest value of the area is 4240.19 km^2 in 2005; during the 1994 to 2005 the area of Qinghai Lake decreased gradually; from 2005 to 2015, the lake area of Qinghai Lake has been increasing gradually. The area of Qinghai Lake Area has reached 4424.96 km^2 in 2015, reaching its peak in recent years. Qinghai Lake is the largest lake in China. Its lake water supply is mainly rainfall and surface runoff. In the past 40 years, the area with the most significant changes in the lake boundary is on the east bank and west bank of the lake. The driving distance is between 100 and 630 m (Liu et al., 2013). The lake area is not significantly related to average net evaporation and annual average temperature (Figure 6).

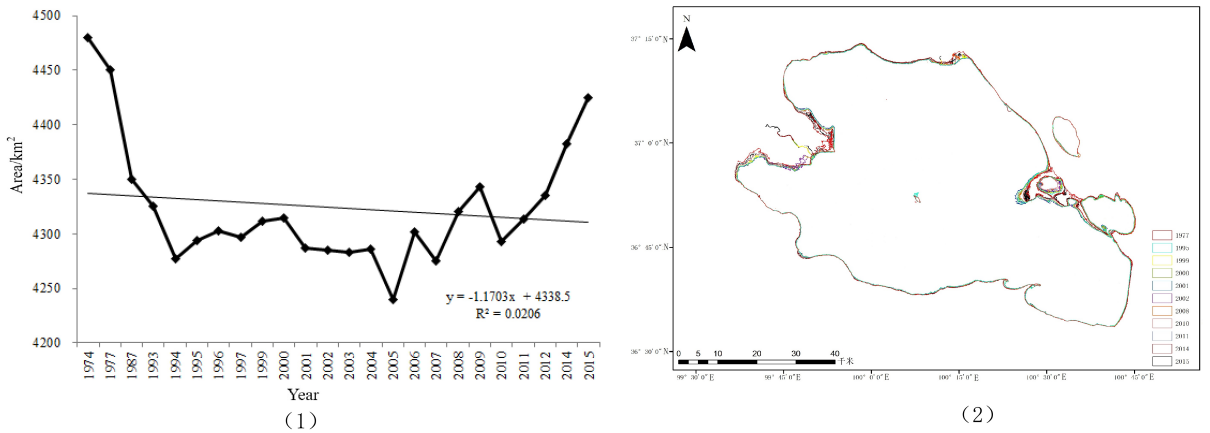

Figure 5. Dynamic map of Qinghai Lake area (1) Lake area trend map (2) Lake Boundary map

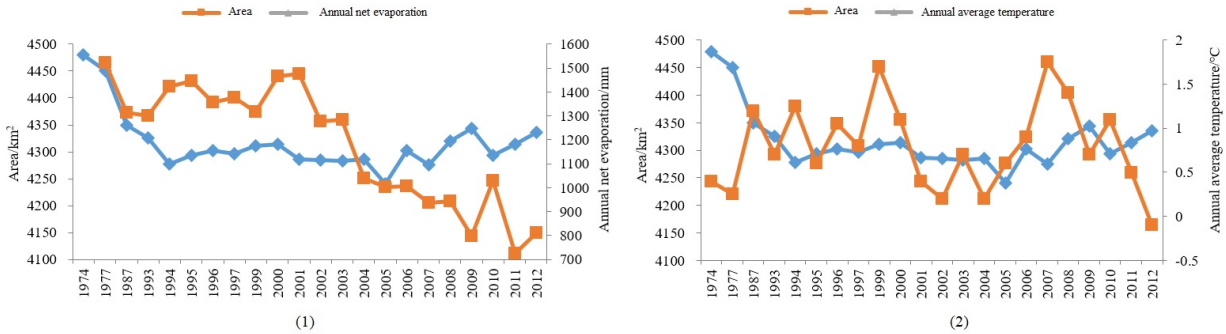

Figure 6. Comparison of area of Qinghai Lake and (2) annual average temperature (1) annual net evaporation

4. CONCLUSIONS

(1) The decrease in the area of Hongjiannao from 1988 to 2014 as a whole led to a reduction in area mainly due to increased water use in the economy, society, rivers and rivers, and underground coal mining.
(2) The area of Bosten Lake increased from 1973 to 2014 and then decreased. The area change was mainly affected by surface runoff and snow melt water.
(3) The area of Qinghai Lake from 1974 to 2015 showed the trend of decreasing first and then increasing. The area change of Qinghai Lake was mainly affected by regional precipitation and runoff into the lake.

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