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Shrinking and Drying up of Baiyangdian Lake Wetland: A Natural or Human Cause?

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Abstract: The shrinking and drying up of wetlands in arid and semiarid areas of China have been widely observed in the recent years, but there has been no consensus on whether the aggravation is caused by human activities or by global climate warming. For a better understanding of the cause, this study investigates the dynamic changes of Baiyangdian Lake wetland over the last 40 years. It is shown that since the 1980s, Baiyangdian Lake has suffered from an insufficient water input and shrunk considerably. By using SPSS11.0, this study undertakes a detailed analysis on the significance of the effects of the possible driving factors for the degradation. It is identified that the North China Plain has been warming up significantly in recent years, which causes a significant reduction in the precipitation and inflow to the lake. Although human disturbances such as the irrigation and storage of water in reservoirs do not play a decisive role, they accelerate the degradation and their effects should be minimized.
Keywords: climate change; human activities; Baiyangdian Lake wetland; hydrologic process; North China Plain

1 Introduction

The sensitivity of ecosystems to global climate change is one of important issues for research. Many studies have indicated that wetland ecosystem is one of the most vulnerable systems (Brock and Van, 1992; Vourltis and Oechel, 1997; Burkeet, 2000; Lahmer et al., 2001; Zhang et al., 2001; Deng et al., 2003).

The shrinking and drying up of wetlands in arid and semiarid areas of China have been widely observed in the recent years (Wang, 1990; Wang and Zhang, 1991; Jin, 1993; Zhou et al., 1997), but there has been no consensus on whether the aggravation is caused by human activities or by global climate warming (Wang, 1989; Gu and Mu, 1994; Shi and Zhang, 1995; Kenneth and David, 1997; Patrick and Michael, 1997; Qin, 1999; Lu, 2000; Fu and Li, 2001; Han et al., 2003).

The North China Plain is one of the most fragile zones in the world because of the scarcity of water resources (Liu and Lin, 2004). The population of the region accounts for 34.8% of China's total, GDP for 32.3%, irrigted farmland for 42%. In contrast, the water resources of the region only account for 1.8% of China's total, and the per capita water resources are only 1/6 of the country's total (Xia, 2002). Nowadays, the water scarcity is becoming the biggest environmental problem and the largest barrier for the region to realize sustainable socio-economic development.

Baiyangdian Lake is the only large fresh-water lake in the North China Plain. It plays an important role in providing water resources, controlling floods, and regulating regional climate (Jin, 1993; Zhao et al., 2005). Since the 1980s, Baiyangdian Lake wetland has shrunk and dried up frequently. Hence, this study focuses on the dynamic change of the wetland over the past 40 years and aims at: 1) analyzing the dynamic changes of Baiyangdian Lake wetland over the last 40 years; 2) recognizing the possible driving factors for the changes; and 3) identifying the main driving factors for the wetland's degradation.

2 Study Area

Baiyangdian Lake wetland, with an area of 366km^2, being an alluvial lowland of the Yongding River and the Hutuo River, is located in the North China Plain. It is in the range of 115º38′–116º07′E and 38º43′–39º02′N. It is in the semiarid monsoon climate zone and the average annual precipitation is 563.9mm, which generally occurs

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during July–August, furthermore, interannual precipitation varies considerably. There are eight rivers in the upstream of Baiyangdian Lake drainage area (Fig. 1). These rivers have become seasonal in the recent years. The average annual evaporation in the region is 1369mm, which is far higher than the average annual precipitation.

The area of water bodies accounts for 50% of the total area of Baiyangdian Lake drainage area, which are generally distributed below the elevation of 7.5m. Reed and moss lands account for 36%, which are distributed in the elevation from 6.5m to 7.5m. In contrast, the cropland, shallow lake and coastal area occupy 14%, which are distributed in the transitional area in the elevation from 7.5m to 9.0m[①]. When the water level falls below 6.5m, Baiyangdian Lake will dry up and the whole wetland will disappear when the water level falls below 5.5m.

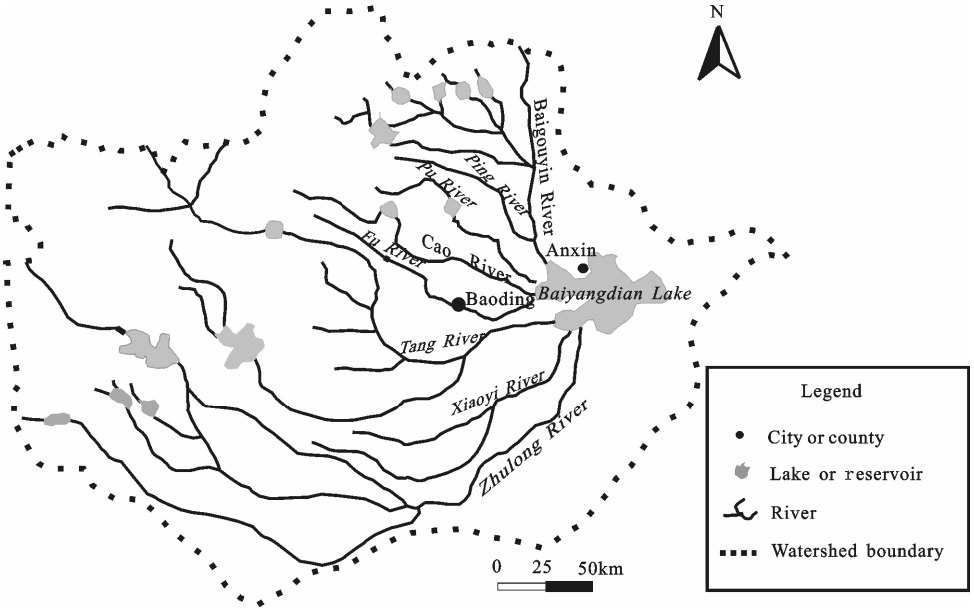

Fig. 1 Water system in Baiyangdian Lake drainage area

3 Data and Methods

3.1 Indicator selection and data sources

Hydrological conditions are the major driving factors of wetland formation, evolvement, even disappearance (Mortsch, 1998; Deng et al., 2003; Song, 2003; Li et al., 2004). On the one hand, dynamics of wetland hydrological character can lead to the changes in the volume and quality of water, and then affect the aquatic biological ecosystem's structure and function; meanwhile, the changes of wetland ecosystem functions counteract the aquatic biological resources and water quality, resulting in the change of wetland hydrological characteristics (Li et al., 2004). For this reason, this study selects precipitation, evaporation, and inflow as indicators to reflect wetland supplies, and then chooses water level (maximum), water volume, wetland area, drying up frequency, and the species and number of wetland living things to reflect wetland eco-environmental conditions. Among these indicators, the meteorological data came from Baoding Weather Station[②], the hydrological data from the Newsletter of Water Resources of Baoding City and the Report of Water Resources of Anxin County[③]. Data on the wetland area are calculated from the Chorography of Baiyangdian[④] according to the corresponding water level.

3.2 Methods

In order to identify major driving factors leading to the wetland's degradation, the correlation coefficents between the dynamic changes of the wetland and the indicators mentioned above were calculated. Before performing such an analysis, it is necessary to transform the data of different dimensions into non-dimension forms. For this reason, we calculate the mean annual value of each indicator for each decade and then compare the mean annual value of the same indicator in different decades with the mean annual value in the 1960s. With

① Office of Chorography of Anxin County, 1996. ② Weather Bureau of Baoding City, 1960–2003. ③ Water Conservancy Bureau of Baoding City, 1960–2003; Office of Water Resource Management of Anxin County, 1994. ④ Office of Chorography of Anxin County, 1996.

the non-dimensional values, we use the SPSS11.0 software to calculate the correlation coefficients between the non-dimensional values of wetland area and the selected indicators in different decades. In this study, we use wetland area as an indicator of the wetland structure and function. From the correlation coefficients we then identify the major driving factor leading to the wetland's degradation.

4 Results and Analysis

4.1 Changes of Baiyangdian Lake wetland

4.1.1 Water level and drying up frequency

An analysis of the historical records indicates that the water level has decreased since the 1960s. For example, the maximum water level has decreased from 11.58m to 6.82m, while the minimum water level has dropped from 6.45m to 5.50m (Table 1). These changes have exerted profound effects on the wetland. It increases the frequency or severity of extremely hydrologic events. Taking the frequency of drying up as an example, there were two times in the 1960s, four times in the 1970s, five times in the 1980s, and three times during the period of 2000–2003.

Table 1 Variation of water level and frequency of drying up in Baiyangdian Lake

Period	Water level (m)		Drying-up frequency
	Max	Min	(times)
1960s	11.58	6.21	2
1970s	10.18	6.45	4
1980s	9.40	5.50	5
1990s	9.80	6.31	1
2001–2003	6.82	5.50	3

4.1.2 Water surface area and volume

Through expanding or shrinking of water body, a wetland can maintain a balance between the input and output of the energy. It is this self-adjusting feedback mechanism that makes a lake adapt to the changes of the physical environment (Qin, 1993). Since the 1960s, the maximum area of water surface in Baiyangdian Lake wetland has reduced by over 50%, and the maximum volume of water body has decreased by 90% (Table 2).

Table 2 Change of tiptop water area and volume

Period	Max water area ($\times10^3$ha) (year)	Max water volume ($\times10^9$m^3) (year)
1960s	– (1963)	7.030 (1963)
1970s	950.4 (1970)	6.550 (1970)
1980s	463.5 (1988)	1.140 (1988)
1990s	459.0 (1996)	0.733 (1996)

Note: "–" indicates that flood occurred in 1963

4.1.3 Biological diversity

Loss of habitat needed for specific species can result in a reduction in biological diversity. For Baiyangdian Lake wetland, the change in biological diversity can be seen from the dynamic change of algae. The species have reduced by 15.5%, and the total number has increased 181.4 times (Table 3). Meanwhile, the species of fish has also decreased by 44.4%.

4.2 Driving factors

4.2.1 Natural factors

The natural factors that may affect wetland hydrology mainly include temperature, precipitation and evaporation.

Table 3 Change of biodiversity in Baiyangdian Lake wetland (Jin, 1993)

Sort	1958		1975		1993	
	Species	Number/L	Species	Number/L	Species	Number/L
Algae	129 genera	75000	–	1302	109 genera	13676000
Protozoa	38 genera	3227	24 genera	2104	76	14123
Rotifer	60	12.9	49	15887	24	2850
Copepod	23.0	8.0	7.0	123.6	17.0	235.7
Fish	54	–	35	–	30	–

(1) Temperature. Since the 1960s, the temperature in Baiyangdian Lake wetland has rose continuously. Especially since the 1980s, the temperature has been much higher than the multi-annual average one (Fig. 2). For example, the average annual temperature of 1996–2000 was 1.13℃ higher than that of 1961–1965.

(2) Precipitation. The decreasing trend of precipitation can be observed in Baiyangdian Lake wetland in the recent years, especially in the 1980s and in the early 2000s. The average annual precipitation in the 1980s and in 2000–2003 had reduced by 69.68mm and 139.68mm respectively in comparison with that in the 1960s (Fig. 3).

(3) Evaporation. The physical morphology of a wetland affects the response of the wetland to climatic change. Shallow and flat basin is sensitive to climatic change, but the deep one may be not sensitive (Qin, 1993). Baiyangdian Lake is a shallow and flat lake with a broad water surface; hence it is sensitive to the dynamic change of temperature. Since the 1980s, the evaporation has risen rapidly. In the 1990s, the average evaporation was 270.15mm higher than that in the 1960s, increasing 21.6%. While it was 348mm higher in 2001–2003 than in the 1960s, increasing 27.8% (Fig. 4). The average evaporation (1369mm) of Baiyangdian Lake wetland is much higher than the average precipitation (563.9mm) over the last 40 years, implying an overall increase in the natural consumption of ecological water.

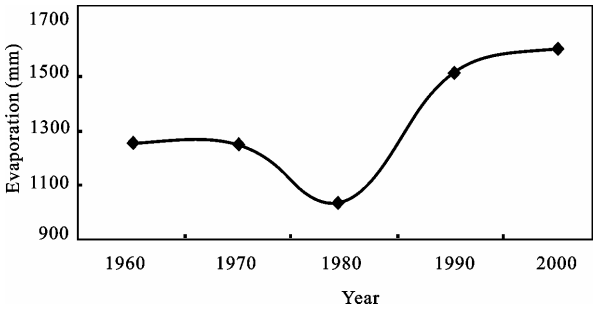

Fig. 4 Variation of 10-year average evaporation in Baiyangdian Lake wetland

4.2.2 Human factors

The human factors affecting Baiyangdian Lake wetland are mainly the construction of reservoirs and domestic and agricultural water consumption, which significantly change the inflow to the lake.

(1) Construction of reservoirs. Various water conservancy projects have been built in the upstream of Baiyangdian Lake drainage area since 1958 (Fig. 1). This has resulted in a temporal and spatial dynamic change in water resources distribution and reduced the inflow to the lake. As shown in Table 4, there was a remarkable difference in the inflow before and after the construction of reservoirs under the similar precipitation conditions. The precipitation was similar in 1957, 1968 and 1986, while the ratio of actual inflows turned to be 1∶0.298∶0 and the ratio of outflows 1∶0.225∶0. In 1988, the inflow of about $1.251\times10^9 m^3$ was yielded from the precipitation of 819mm; while in 1957, the similar inflow ($1.165\times10^9 m^3$) was yielded from the precipitation of only 433.8mm. The ratio of precipitation between 1957 and 1988 was 1∶1.89, but the ratio of inflows between the two years was just 1∶1.07.

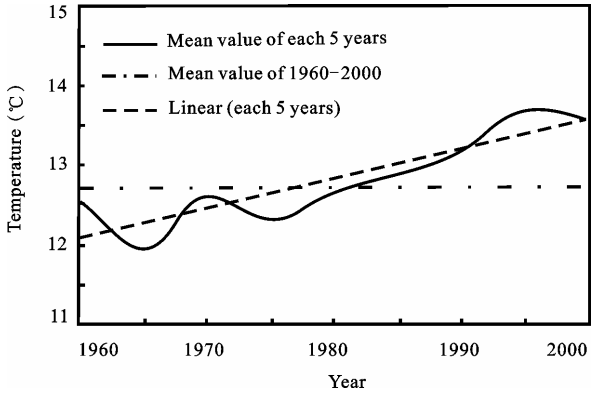

Fig. 2 Changes of average temperature of Baiyangdian Lake wetland

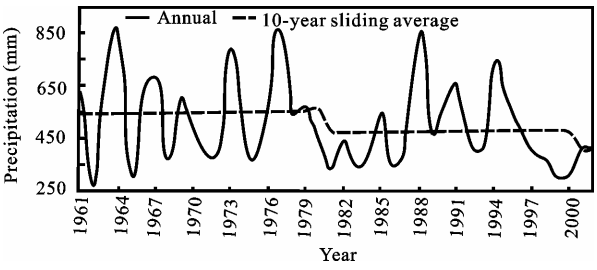

Fig. 3 Changes of annual precipitation and 10-year sliding average precipitation in Baiyangdian Lake wetland

Table 4 Variation of inflow and discharge of Baiyangdian Lake before and after constructing reservoirs (Gu and Mu, 1994)

Phase	Year	Precipitation (mm/yr)	Inflow ($\times10^9 m^3$/yr)	Discharge ($\times10^6 m^3$/yr)
Before	1957	433.8	1.165	941
	1968	436.9	0.347	212
After	1986	431.6	0	0
	1988	819.3	1.251	651

(2) Domestic and agricultural water consumption. Owning to the rapid development of economy in the upstream of the wetland, the water demand has increased sharply, especially in Baoding City and Anxin County. The Baoding City, with a total area of $126 km^2$ and a population of 692×10^3, is about 45km away from Baiyangdian Lake. Anxin County, with a population of 11×10^3, is the closest neighbor of Baiyangdian Lake wetland①. There are 39 pure water villages in Baiyang-

① Office of Chorography of Anxin County, 1996.

dian Lake wetland, with a population of 100×10^3. Statistical data indicate that the annual water consumption of Baiyangdian Lake drainage area amounts to 5.05×10^9 m^3/yr (Jin, 1993). This, especially in arid years, has made the imbalance between water supply and demand much more intense.

4.3 Correlation analysis of wetland changes and driving factors

In order to identify the main factors responsible for the wetland's degeneration, the paper calculates the correlation coefficients between the driving factors (both natural and human factors) and the wetland's structure and function (taking the area of the wetland as indicator). Among the driving factors, the temperature, evaporation and precipitation are natural factors reflecting climatic change, while the inflow reflects the result of human disturbances, including irrigation, reservoir construction, productive and domestic water consumption of upstream and peripheral areas. These analytical results are presented in Table 5, showing that the correlation coefficient between precipitation and wetland area is the highest (R=0.979), following with the correlation coefficients of wetland area with inflow (R=0.878), temperature (R=–0.674), and evaporation (R=–0.632).

River flow into Baiyangdian Lake wetland fluctuates considerably with seasons, especially the Cao River and the Pu River, so there is almost no inflow from the upstream except in the rainy season. Therefore, the wetland area has a close relationship with the precipitation in the study area. This implies that it is the climatic change especially the precipitation that is the main driving factor for Baiyangdian's degeneration. Human disturbances such as irrigation and reservoirs construction increase the water demand of the wetland, and all the other factors intensify the degradation but none of them plays a decisive role. As a whole, Baiyangdian Lake wetland has been threatened by the shortage of water resources, descent of water level, shrink of water area and degeneration of wetland ecosystem.

5 Conclusions

The sensitivity of ecosystems to global climate change is one of important issues for research. Many studies have indicated that wetland ecosystem is one of the most vulnerable systems. This study analyzes the main causes for the eco-environmental degradation in Baiyangdian Lake wetland of the North China Plain through examining the temporal changes of climate, hydroloy and wetland ecosystems over the past 40 years and calculating the correlation coefficients wetland ecology and driving factors. This study has reached following conclusions:

Table 5 Correlation coefficient between wetland area and driving factors

	Temperature	Evaporation	Precipitation	Inflow	Wetland area
Temperature	1	0.772	–0.802	–0.893*	–0.674
Evaporation	0.772	1	–0.735	–0.695	–0.632
Precipitation	–0.802	–0.735	1	0.947*	0.979**
Inflow	–0.893*	–0.695	0.947*	1	0.878*
Wetland area	–0.674	–0.632	0.979**	0.878*	1

Notes: * Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

(1) The eco-environment of Baiyangdian Lake wetland has degenerated seriously since the 1960s, and its ecosystem's structure and function have been damaged. The maximum water level has dropped from 11.58m to 6.82m; the frequency of drought has increased considerably (two times in the 1960s, four times in the 1970s, five times in the 1980s, and three times in 2001–2003). The largest reduction in water area reaches over 50%, and water volume has reduced by 90% in comparison with that in the 1960s. Biodiversity has decreased sharply, algae species have reduced by 15.5%, while the number of algae is 181.4 times of that in the 1960s and fish species has reduced by 44.4%.

(2) The average annual temperature during 1996–2000 has increased by 1.13℃ in comparison with that in the 1960s. While the precipitation has decreased by 13.1%, and the evaporation has increased by 27.8% in 2000–2003 compared with that in the 1960s.

(3) Climatic change is the main driving factor for the degeneration of Baiyangdian Lake wetland ecosystem because the correlation coefficient between wetland area and precipitation is the highest (0.979). Through decreasing water supply and increasing the demand, climate change has altered the hydrological characteristics of the wetland. Human activities such as water conser-

vancy projects have intensified the degradation. Although human disturbances such as the irrigation and storage of water in reservoirs do not play a decisive role, they accelerate the degradation and their effects should be minimized.

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