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Full Length Research Paper

Limnology wetland change trends and perspectives in arid Yinchuan plain, China

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In this paper, the distribution area of limnology wetland in Yinchuan plain at different times was obtained through literature analysis and remote sensing techniques. This study analyzed the evolution process of limnology wetland in Yinchuan plain under environmental change and human socio-economic activities interference. In its long geological period, limnology wetland in Yinchuan plain has experienced the process of area reduction from lake to lake. In the history of mankind and as a result of poor irrigation and drainage water with formation of low-lying land, limnology wetland area has increased in a period of time. In the last 60 years, limnology wetland shrunk rapidly because of excessive exploration of agriculture and extraction of groundwater for industrial development. The results show that the temperature and precipitation changes in environmental factors play a decisive impact on the evolution of limnology wetland in Yinchuan plain. Human activities have accelerated the trend of limnology wetland area reduction. Currently, wetland ecosystems and wetland landscape pattern still develop in a deteriorate way, but the pace of deterioration is obviously slowing down.

Key words: Yinchuan plain, limnology wetland, change trends, impact analysis, arid environment.

INTRODUCTION

Wetlands are a major feature of the landscape in almost all parts of the world. Wetlands are sometimes described as “the kidneys of the landscape” because they function as the downstream receivers of water and waste from both natural and human sources (William et al., 2000). Although many cultures have lived among and even depended on wetlands for centuries, the modern history of wetlands is fraught with misunderstanding and fear. The first protection legislation of wetlands, streams and other waters were enacted in the U.S. (Clean Water Act, 1972). Wetlands protection is a concern in the world including developed and poor countries (Mwakaje, 2009; Kabumbuli, 2009). To conserve and manage wetland resources, it is important to do an inventory of and monitor wetlands and their adjacent uplands. Satellite remote sensing has several advantages for monitoring wetland resources, especially for large geographic areas (Stacy et al., 2002). Obtaining history land cover status is feasible by using history material (Browning et al., 2009). It is important for detecting land cover change. Wetland landscape change is studied by using multi-temporal remote sensing image dataset. In the arid region, water stress is becoming more and more outstanding as global warming and economic development (Karadeniz et al., 2009; Lioubimtseva et al., 2009). The local residents considered that soil salinization is caused by the higher underground water level. Wetland in arid and semi-arid areas is the basis of the maintenance of agriculture and oasis ecosystems. It is important to monitor and analyze wetlands change and impact.

The first national survey of wetlands was executed in January 2004. The survey results show that the total area of wetlands in China was 8.5×10^{7} hm^{2} (excluding rice paddies) in 2004. 3.6×10^{7} hm^{2} of part of the area is nature while the rest is artificial. The total area of wetlands in China ranks the highest in Asia and fourth in the world (behind Canada, Russia and the United States). Currently, the serious threat to the wetlands is mainly wetland area reduction caused by over-exploitation in China (Qiguo and Junfeng, 2007). However, in arid and semi-arid Yinchuan plain, wetland management is facing both global climate change and the initiative of “reclaiming” wetlands through activities

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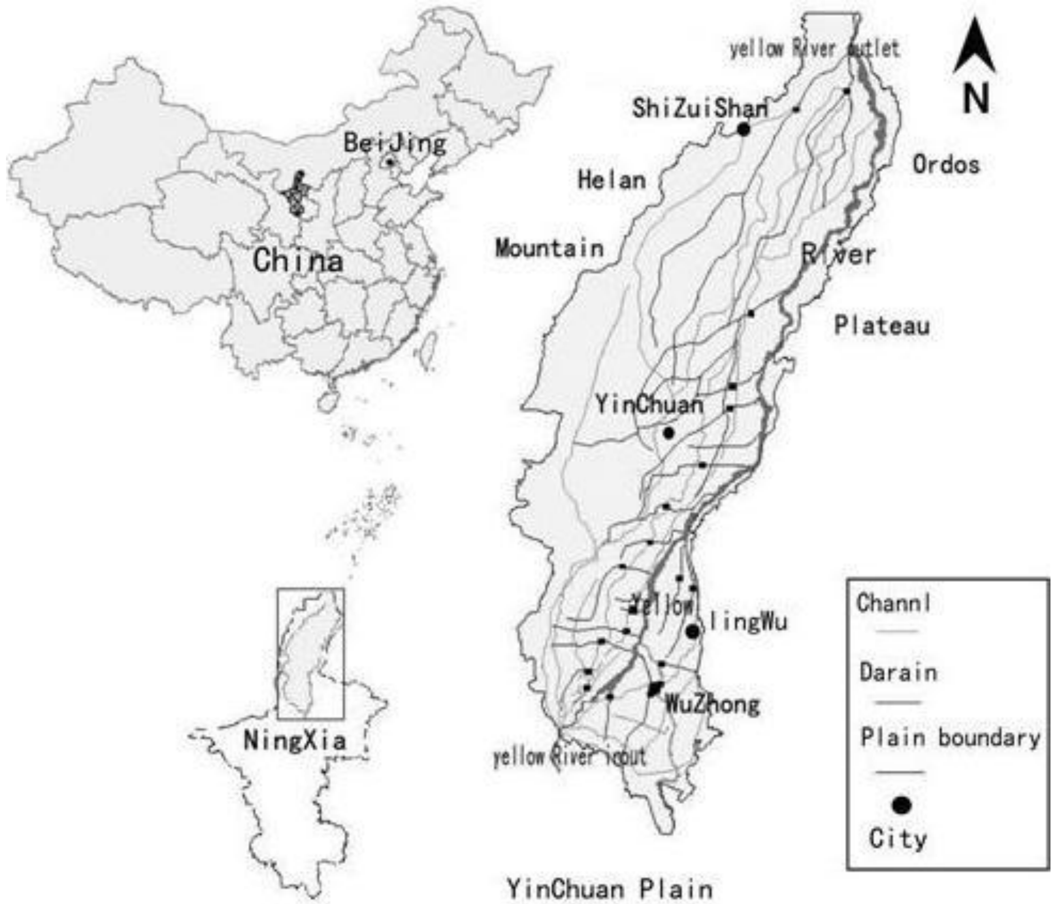

Figure 1. Location map of the study area.

such as levee construction and drainage. In this paper, we studied limnology wetlands change trends located in the arid climate hinterland environment Yinchuan Plain, and analyzed underlying causes. This research objective is to provide theoretical reference for the Yinchuan plain wetlands management and protection.

MATERIALS AND METHODS

Study areas

Yinchuan Plain is located in the arid portion of Western China (Figure 1). The plain is approximately 165 km from south to north and 50 km from east to west, covering an area of about 7793 km^2. The elevation of the study area ranges from approximately 1000 to 1200 m, with a generally flat terrain that slopes from southwest to northeast. The Yellow River runs through Yinchuan Plain from south to north. The study area is subject to a temperate continental climate and has an annual average rainfall of 180 to 220 mm and an annual average evaporation of 1800 to 2200 mm. Some water is supplied to Yinchuan Plain wetland from the Yellow River. Water is also provided by lateral groundwater infiltration, farmland water (runoff), torrent, and precipitation recharge (De Zhou et al., 2009).

One hundred and two million years ago, the Yinchuan plain is a vast lake formed by fault basins. A lot of the sand and gravel diluvium accumulated peripherally in the closed basin. Before the original channel of the Yellow River was formed, the closed basin was outflow basin. The Yellow River swung in this basin, with sediment being silted continuously; while the limnology Wetland distribution became narrowed gradually, until the Yinchuan alluvial plain was gradually formed (Guobang et al., 1995).

According to the earliest record of the literature recorded in the book of Shiji written in 200 B.C., there are a lot of lakes and seasonal depression storage, and soil salinization widely distributed in the Yinchuan plain. A massive land development was implemented from 140 B.C. A lot of irrigation channels were built on reference water from Yellow River. Irrigation system and drainage system were not matching. And not all the irrigation water returned to the Yellow River, leading to flooding in the low lands and forming limnology wetland in the central and northern region of Yinchuan plain. The situation was consistent and it continued till the early 1950s. Some natural disasters caused the increasing of limnology wetland distribution area, for example, Yellow River floods and river diversions and the Yinchuan earthquake in 1739. The Yinchuan earthquake caused ground subsidence in Man area and Baofeng area. Until today, there are still wide ranges of limnology wetland distribution in Man area and Baofeng area. After Yellow River diversions, abandoned watercourse formed limnology wetland Wang. Thus, limnology wetland that once appeared in the distribution area increased in the history of mankind (Guoshun, 1989; Yiming, 2005). However, due to global warming, population growth, industrial and agricultural development that led to a large consumption of water resources in the Yinchuan Plain, the stability

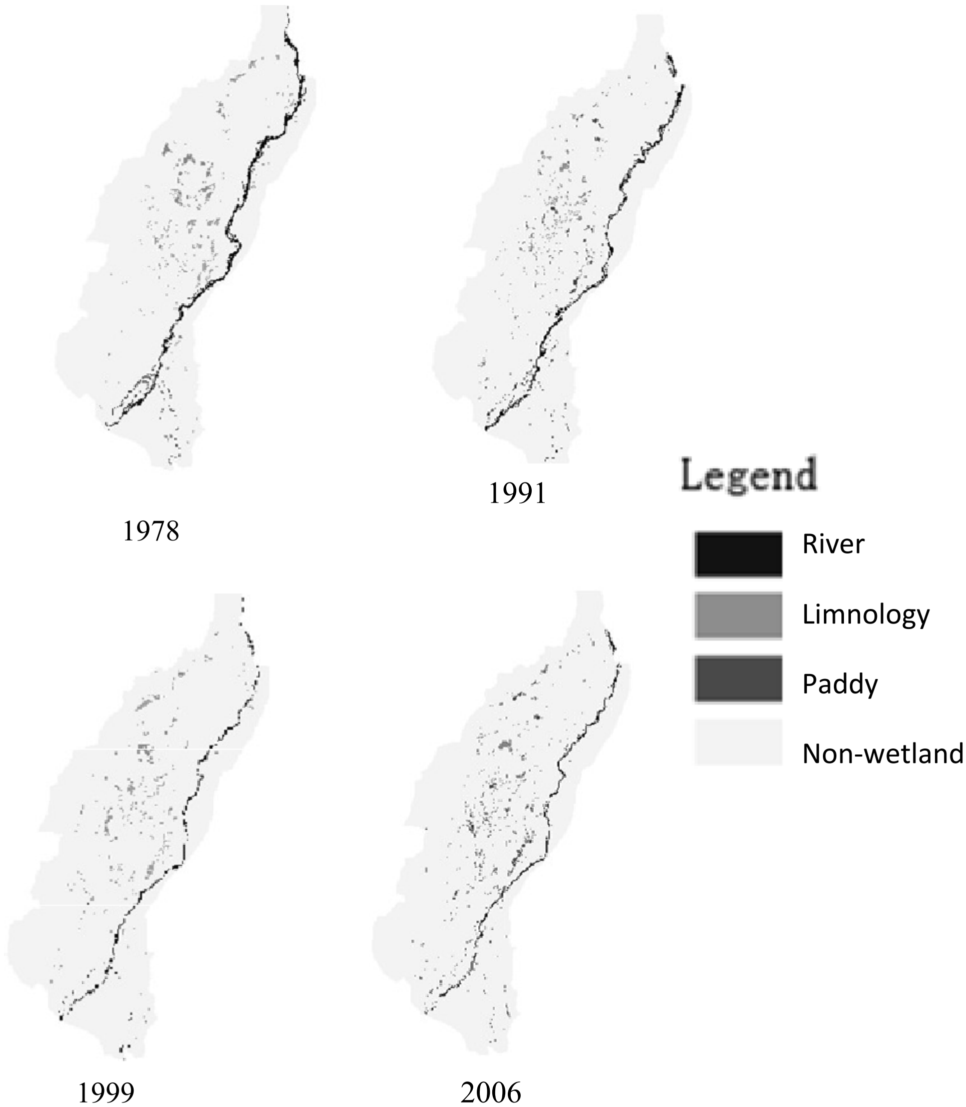

Figure 2. The wetland landscape distribution maps from 1978 to 2006.

of the wetland ecosystem has been threatened over the past 50 years.

Data

We used other researchers' findings as Yinchuan Plain limnology wetlands distribution area in history. Limnology wetland distribution area was at least 167 000 hm^2 in Late Pleistocene Quaternary from soils census data (Jiezhi et al., 1990). Researchers calculated the limnology wetland distribution area based-on the distribution area of the soil types under the forming conditions of long-term lakes and swamps (including marsh land, swamps saline soil, some soil in irrigation, etc.).

According to the Yinchuan plain water conservancy survey map in 1936, some researchers calculated limnology wetland distribution area as 53 000hm^2. After 1949, when the complete drainage system was built and after draining some low-lying water, limnology wetland distribution area decreased to 16 000 hm^2 until 1958 (NXACET, 1963).

Remote sensing wetlands mapping

In this study, we used multi-temporal remote sensing image dataset to obtain the limnology wetland distribution area. One Land-sat Multispectral Scanner (MSS) image consisting of four spectral bands in1978 and two Land-sat 5 Thematic Mapper (TM) imagery containing six bands in 1991 and 1999, with a pixel resolution of 57 and 28.5 m, respectively were acquired from Geographical Science and Natural Resources Research, Chinese Academy of Sciences. The last one was the China-Brazil Earth Resources Satellite (CBERS)-02B image in 2006 at a pixel resolution of 19.5 m provided by China Resources Satellite Application Center. All the images covered the area of Yinchuan plain.

The limnology wetland distribution maps in 1978 were obtained by modifying limnology wetland information from the interpreted data of remote sensing image. Limnology wetland in 1991 and 1999 used decision tree classification. And we combined supervised and unsupervised classifications together to obtain the distribution map of wetland types in 2006. At last, we got four distribution maps of limnology wetland in Yinchuan plain (Figure 2). Limnology wetland

Table 1. Dynamical degree lake wetland area change.

Time interval	1958-1978	1978-1991	1991-1999	1999-2006	1958-2006
Total reduced area(−) (hm^2)	−4906.29	−2082.93	−1567.40	−669.19	−9255.81
average reduction area (hm^2/a)	-245.31	-160.23	-195.93	-99.88	-192.83

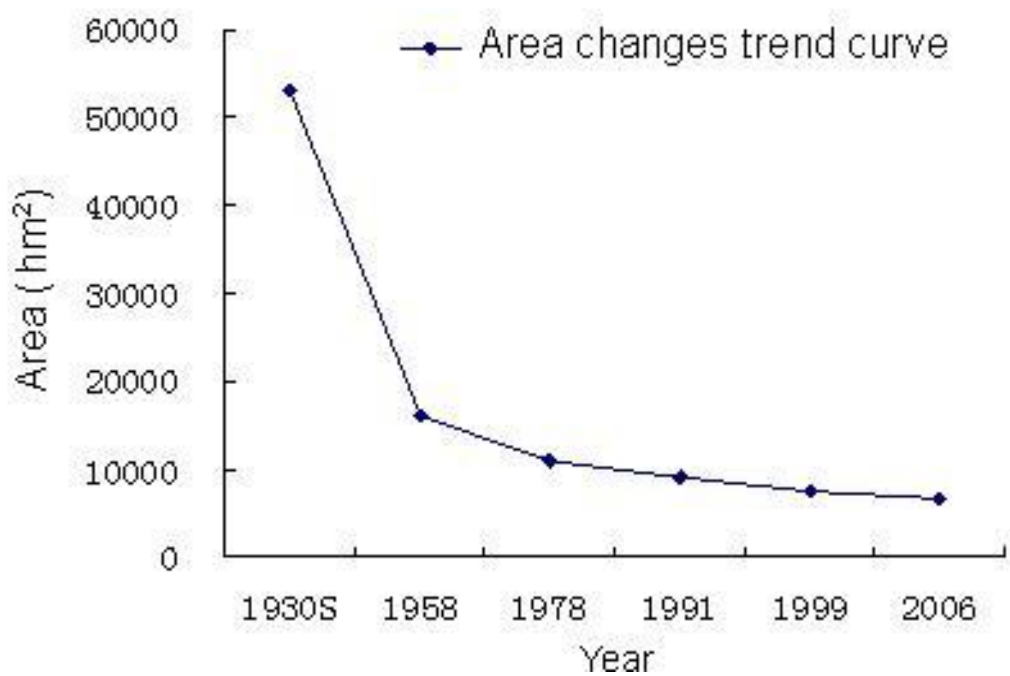

Figure 3. Limnology wetland area changes trend curve.

distribution areas in the four periods were 11093.71 hm^2 in 1978; 9010.78 hm^2 in 1991; 7443.38 hm^2 in 1999; and 6744.19 hm^2 in 2006.

RESULTS AND ANALYSIS

By analyzing the literature of other researchers' findings on limnology wetlands distribution area in Yinchuan Plain, we proposed that the distribution area of different periods are at least 167 000 hm^2 in Late Pleistocene Quaternary, about 53 000 hm^2 in 1930S and 16 000 hm^2 in 1958. By remote sensing wetland mapping, we obtained that the four period limnology wetland distribution areas were 11093.71 hm^2 in 1978; 9010.78 hm^2 in 1991; 7443.38 hm^2 in 1999; and 6744.19 hm^2 in 2006. The total reduction area was 9255.81 hm^2 from 1958 to 2006, and the annual average reduction area was 192.83 during the same period. We can find that the area decreased rapidly annually, from 1958 to 1978 and from 1991 to 1999; but it also decreased slowly annually, in the remaining time interval (Table 1).

We can find that the limnology wetlands change trends when the distribution area is reducing, and it reduced very quickly from the 1930s to the late 20th century. Limnology wetland distribution area dropped sharply from 1958 to1999, and dropped trend slowly from 1999 to 2006 (Figure 3). With existing limnology wetland distribution area reducing, the water depth of limnology wetland is greatly reducing (Yiming, 2004). It shows that limnology wetland has be in declining stage. Limnology wetlands have been changing into salinity-alkalinity land.

DISCUSSION

Temperature and precipitation influence

The late Quaternary environmental research shows that the local climate passes the change process from warm-wet, cold-wet, cold-dry, warm-dry, and the local climate in the warm-dry period currently (Guobang et al., 1998). In this study, we used the meteorological observation data of four meteorological stations in the Yinchuan plain from 1961 to 2006 to analyze climate time series change. The annual average temperature is rising in recent 46 years (Figure 4), but the annual precipitation is reducing (Figure 5). Limnology wetland decreasing trends is consistent

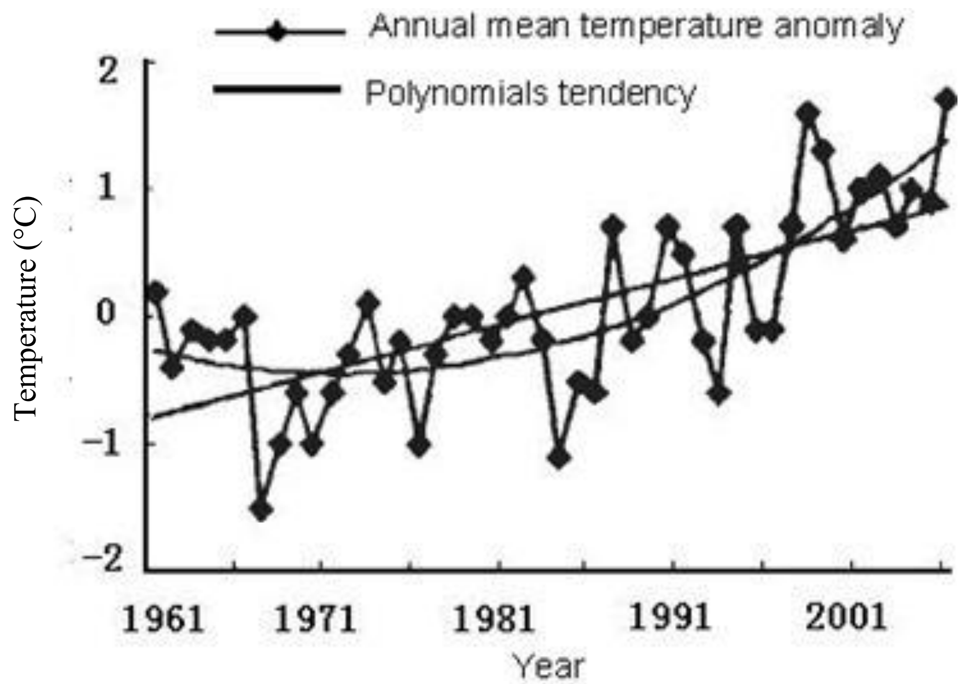

Figure 4. The change of the annual mean temperature anomaly and polynomials tendency.

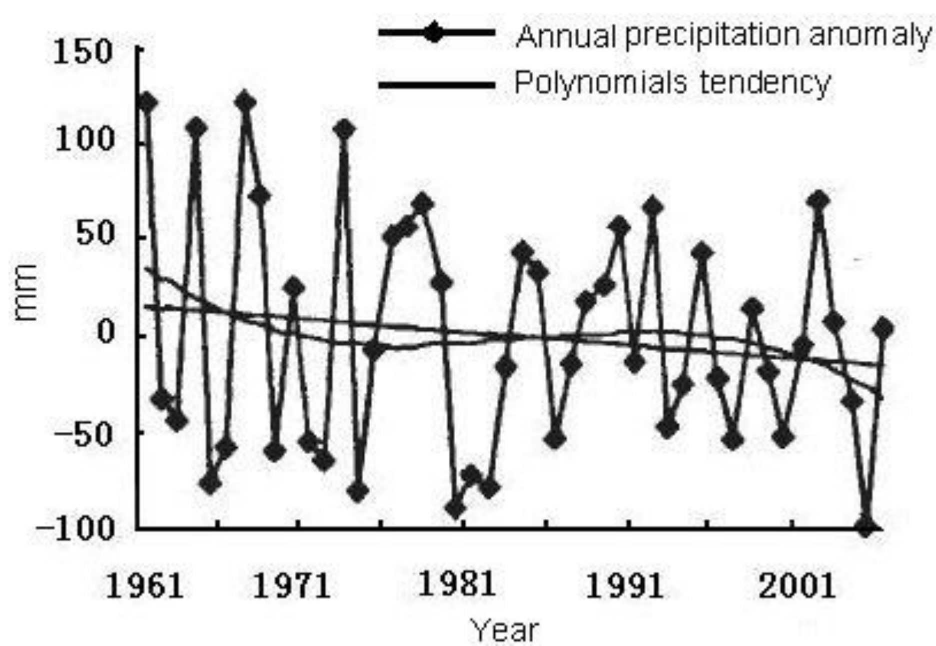

Figure 5. The changes of annual precipitation anomaly and polynomials tendency.

with the annual precipitation that declines.

Human activities influence

In Yinchuan plain, population growth increased from 149 to 255 million, and GDP growth from 9.3 to 636 billion RMB, in the last 28 years from 1978 to 2006. Firstly, both population growth and economic development consume large amounts of water resources, and cause the groundwater levels to fall. Secondly, high population needs more food production, and local residents drained

Table 2. The landscape pattern indices of Yinchuan plain limnology wetland in 1978-2006.

Indices	1978	1991	1999	2006
Area	11093.71	9010.78	7443.38	6744.19
Plaques density(PD)	0.0504	0.0854	0.1477	0.0650
Landscape shape index (LSI)	30.9514	53.5952	66.8531	40.8960

limnology wetland for expanding cultivated area. Thirdly, in arid and semi-arid regions, groundwater levels that are shallow easily cause soil salinization (Guobang et al., 1995). And so, from the 1950s, people left no stone unturned while draining limnology wetland in order to control soil salinization that caused loss of many wetlands.

In China, people used to think wetland is a cultivated land reserves, including the Yinchuan plain wetlands (Mingju and Chengjie, 2005). More than two hundred drains have built in the Yinchuan plain from mid 1950s; wetland drainage area is almost 1.4×10^{2} hm^{2}. When limnology wetland drained water, people developed it into national commodity grain base. But, it caused a large number of natural limnology wetland disappearance or atrophy, wetland water-holding capacity reduced, adjustable climate ability lowered and birds migrating habitat became less and less.

In recent years, along with the rapid industry development and increasing water consumption, groundwater levels fall obviously in local area forming many groundwater funnel. In the groundwater funnel and its surrounding areas, many wetlands disappear or atrophy. For example, Ningda Lake disappeared in recent years, because of input water reduced and large groundwater was extracted.

Limnology wetland landscape pattern change

We used the method of landscape ecology and a series of landscape index to analyze the landscape pattern change characteristics in the Yinchuan plain. Limnology wetland distribution area, plaques density (PD) and landscape shape index (LSI) from 1978 to 2006 are given in Table 2. At first, we concluded that limnology wetland distribution area has been reduced from 1978 to 2006. Secondly, that limnology wetland landscape pattern plaques density is becoming higher from 1978 to 1999 and reducing from 1999 to 2006. Thirdly, the bigger value of landscape shape index shows that human activities affected limnology wetland very strongly. In the Yinchuan plain, limnology wetland shape index increased from 1978 to 1999 and reduced from 1999 to 2006. It shows that human activities affected limnology wetland strongly in the 1980s and 1990s, and that the interference weakened from 1999. Entering the 21st century, the government improves wetland management and human consciousness of conservation wetland is improving.

Limnology wetland ecosystem degradation

In order to control soil salinization, local residents built drainage system and extraction of groundwater for lowering underground water level. As a result, it made limnology wetland area to reduce and atrophy; wetland climate adjustment function weakened and biodiversity threatened. For example, in the Shabotou Nature Reserve located in the Yinchuan plain edge, the local residents extracted groundwater in order to develop horticulture and forestry. This behavior caused some lakes disappearance and grassland degradation around lakes, extinction of rare wetland species in Shabotou Nature Reserve (Jianlin, 2002). Many natural lakes disappear, the flood storage capacity of limnology wetland is decreasing, and the flood that occurred in the Yinchuan plain caused an economic loss of 2 billion Yuan RMB in 1998 (Wenbao et al., 2001).

Wetland pollution is very serious. The wastewater from urban life and industries is directly discharged into rivers and lakes wetlands without treatment. According to the monitoring, limnology wetland water with its quality was classified as No.5 (in China's water quality standard, No.5 class represents serious pollution and cannot have direct contact with the human body). For example in Sha Lake, ammonia nitrogen content increased nearly 12 times, total phosphorus was added nearly 1.9 times, the cadmium content increased twenty times and other indexes increased at different level. We compared the water monitoring values of 2000 with 1990. Sha Lake water is clean in 1990 but has light pollution in 2000. The reasons for the deterioration of water quality are: one, the quantity of water supplies is being decreased and two, polluted water enters into the lake directly (Yanxia et al., 2002).

Conclusions

Limnology wetland distribution areas changed from low to high, and from high to low in geological periods and human history in the Yinchuan plain. This change was caused by the ground subsidence, Yellow River floods, dry climate and other natural factors. The limnology wetland distribution area changed according with agriculture and industrial development in the Yinchuan plain. Since 60 years now, and due to productive technology development, the ability to transform nature and the awareness of humans to protect wetland are insufficient. Limnology wetland area reduces rapidly from 1950s to 1970s. In the 1990s, as people started having wetland protection consciousness, wetland area reduction trend is been controlled. But, limnology wetland area is still decreasing with its ecosystems getting worse in the Yinchuan plain.

Limnology wetland is precious resource and important ecological system in arid and semi-arid area. Evaporation is 7 to 10 times precipitation in Yinchuan plain. To realize wetland resources sustainable utilization is very difficult in arid environment. Local governments should establish the legal rules and regulations of wetland resources protection to restore protection and control its natural dying process. It is a must that local governments increase more economic investment to protect wetland, in order to meet the livelihood of local residents.

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