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Original Research Paper

The Spatio-temporal Changes and Driving Factors of the Wetlands in Madoi, China

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ABSTRACT

The first county along the Yellow river, Madoi is the key region of the state natural protective source regions of Yangtze River, Lantsang River and Yellow River, its eco-environment and function in widespread attention. In support of the hardware and software system, based on GIS and remote sensing technology, this paper combined field investigation and laboratory analysis. Around 1990, 2000 and 2010, ten-phase remote sensing images are interpreted, and it is continuously monitored that Madoi wetlands have changed in the 20 years. Using wetland interpretation results and the area of the wetland types transfer matrix, it evaluates the changes of wetland area in the 20 years. With the meteorological and statistical data, this paper discussed the reason of the wetland changing in recent 20 years. The results of remote sensing monitoring and field investigation show that the overall trend of the wetland area changing increased after the first reducing in three times. In the first 10 years, swamp changes were the largest, followed by lakes and rivers; in the next 10 years, lake changes were the largest, followed by swamps and rivers. Natural factors which resulted in wetland changes of Madoi are climate changes, the permafrost environment changes, rodent rampant; man-made factors are overgrazing, irrational mining, fishing, hunting and development of tourism.

INTRODUCTION

Wetland, a special kind of natural complex, has the multi-function of unique ecosystems, regarded as “kidney of the earth” (Liu 2005). In recent years, the wetlands have become an important research field of global concern, and China has begun to carry out all kinds of wetland protection since the 1980s. Due to human irrational development and utilization of grasslands, the wetland resources were destroyed, and the wetland ecosystems obviously resulted into degradation. Therefore, it is important to grasp the changes of wetlands.

Madoi is the first county of the Yellow River, and one of the biggest headwater of the river source. It is also one of the most concentrated area of biodiversity and the most sensitive area of ecological changes in Tibetan Plateau. Influenced by topography and climate, plateau ecosystem is very fragile, very sensitive to human interference. Since 1990, the influences of overgrazing, overload, rodent damages and man-made destruction, have caused the regional wetland degradation and eco-environmental problems. It was mainly displaying in grassland degradation and desertification, wetland atrophy and biodiversity loss, etc. It influenced the development of the local society and economy, also endangered the healthy development and people’s life of the middle and lower reaches.

In this paper, based on remote sensing data as the main data source, combined with the data of terrains and statistics, the wetland information was extracted. Using of wetland interpretation results and wetland area transfer matrix, it is evaluated that the wetlands have changed nearly 20 years. Combined with the meteorological data, this paper analysed the causes of wetland changes, and provided certain scientific basis for the sustainable development and comprehensive treatment of degradation in Madoi.

STUDY AREA

Madoi, the word in the Tibetan language, is “the Yellow River source”. It was a relay station to enter Tibet and an ancient ferry in history (Zhu 2006). Madoi County is located in the south of Qinghai province, the north of Bayan Har Mountains and the west of Amne Mountains, and its geographic range is between 33°50’-35°40’N and 96°55’-99°20’E, from north to south about 207 km and from east to west about 228 km, with a total area of 26,210km^2. Madoi belongs to Golog Tibetan Autonomous Prefecture in Qinghai Province, and consists of Heihe, Huanghe, Zaling and Huashixia,

Heihai and Qingshui townships, with a population of 11,000, mainly belong to the Tibetan, accounting for 85.7%. Madoi belongs to the high plains, the average altitude is 4200-4800m, and the topographic is undulating. There are flat valleys, deserts and swamps between mountains. The alpine steppe climate is cold, dry, no distinct seasons, strong radiation and rich light resources. Drought, snow, frost, wind, hail and other natural disasters are frequent. The annual average temperature is -3.98°C, the annual average rainfall is 309.63mm, the annual average evaporation is 1,333.9mm, and the maximum wind speed is 26m/s. Wild medicinal plants have *Cordyceps sinensis*, *Fritillaria*, snow lotus, and so on; wild animals have wild ass, bear, antelope, Shiyang, snow leopard, marmot, red fox, and so on; and there are 38 kinds of birds.

Natural grasslands are the main land types in Madoi with a total area of 229.91×10^4 ha, accounting for 87.53%; followed by alpine wetlands, a total area of 18.62×10^4ha, accounting for 7.09%; the third is rock hills, a total area of 8.77×10^4ha, accounting for 3.34%; the fourth is beaches and dunes, a total area of 5.37×10^4ha, accounting for 2.04%. Natural grasslands include alpine meadows and alpine grasslands. Alpine meadows containing *Kobresia pygmaea*, *K. capillif olia*, *Deschampsis*, *Poa*, etc. have degraded, forming secondary vegetation which is distributed in *Artemisia*, *Saussurea*, etc. Alpine grasslands with *Stipapurpurea* have degraded, forming secondary vegetation distributed in *Thermopsis salsula*, *Artemisa arenaria*, *Pedicularis*, *Potentilla*, etc. Alpine wetlands include rivers, lakes and swamps. Madoi has many rivers, 4,077 large and small lakes, having the reputation as "the county of thousand lakes". There are the famous sister lakes (Zaling Lake and Eling Lake), Donggecuonahe Lake, Longre Lake, Hajiang Salt Lake and other large lakes.

DATA AND METHODS

Data sources: The data of wetland degradation are from remote sensing image interpretation. The remote sensing images include: around 1990, four US Landsat TM images were obtained on August 21, 1990, August 30, 1990, July 24, 1991 and July 31, 1991; around 2000, four American Landsat ETM+ images were obtained on August 8, 2000, July 3, 2001, July 12, 2001 and August 13, 2001. Around 2010, two domestic environmental mitigation HJ-1A/B satellite images were obtained on August 12, 2010 and August 30, 2010. The spatial resolution of the images is 30m × 30m. In July and August, 2011, the researchers conducted a field survey in Madoi, collecting the samples of ground GPS data for image classification. Comparing Landsat TM/ETM+ multi-band remote sensing images with field measured data, indoor interpretations were classified.

In order to confirm the accuracy of the classification results, as well as the relevance of the classification results and actual land types, the researchers went to Madoi for field investigation in July and August, 2012, and the test samples were randomly established in the regions. In fact, each random point around the rectangular area of 1km^2 was verified.

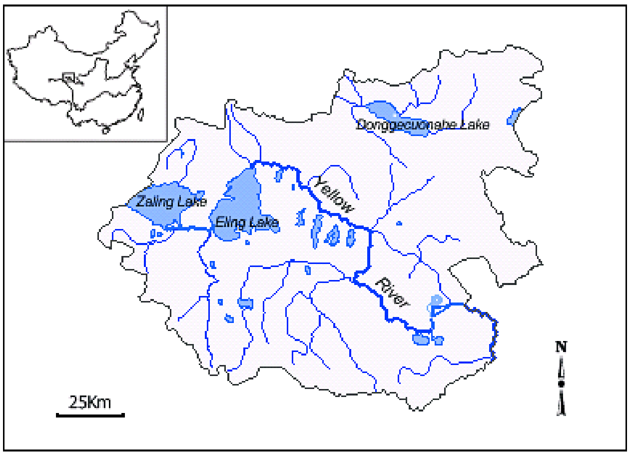

Fig. 1: Geographic location of Madoi in China.

Image preprocessing of remote sensing: This paper used the ENVI4.5 software to check the under corrected remote sensing images and the reference images; used ERDAS IMAGING9.2 software for geometric correction of the remote sensing images; used the quadratic polynomial fitting; chosen ten control points from each image, and used the nearest neighbour method for images resampling. Then, the images were embedded in ERDAS IMAGING9.2 software, cutting the Madoi boundaries, and using the method of Optimum Index Factor (OIF) (Xu et al. 2007) to choose the best band combination.

Band information was Statistics in ENVI 4.5 software, and OIF index was calculated in Excel software. Considering OIF index and actual characteristics of the spectrum in Madoi wetland, the best combination was determined. Finally, after TM images 5-band, 4-band and 3-band, ETM+ image 7-band, 5-band and 1-band, HJ-1 image 3-band, 4-band and 1-band given RGB respectively, we got the composite false colour images. Those closed to the colour of the real object, colour bright, level clear, easy to interpret, and being the best band combination.

Finally, after performing enhancement, brightness and contrast stretching in ERDAS IMAGING9.2 software, the images were compared to the original images, brightness expanded, and clarity improved.

Wetland information extraction: By reference to the convention on wetlands and national wetland classification system, Madoi wetland was divided into two major categories of inland natural wetlands and artificial wetlands, then, divided into five subclasses including rivers, lakes, swamps, floodplains and reservoirs. Among them, the reservoirs were artificial wetlands, and the others were natural wetlands.

With the aid of 1:700,000 topographic maps and Google-Earth images in Madoi, based on the spectral and geometric characteristics of the various types of wetland landscapes in Madoi, we obtained 150 GPS recording points and geographical landscape information fieldwork through field investigation, and established the classification interpretation signs of Madoi wetland. With the support of ArcGIS10.2, the remote sensing images were implemented the interactive visual interpretation. The screen dimensions were from 1:30,000 to 1:60,000. Based on the images of 30m resolution, wetland information was extracted. The width of rivers was not less than 3 pixels (90m), and the area of lakes was not less than 3×3 pixels ($0.09km^2$). Floodplains were interpreting with gradient data. When the images of phase 2 and phase 3 interpreted, we referenced to the result of phase 1, and carried out contrast examination.

Interpretation of results quality inspection: According to relevant data and field survey, wetlands in Qinghai Province were divided into four categories, including rivers, lakes, swamps and man-made lacks. This paper established wetland classification system covering all of the wetlands in Madoi. The system could completely meet the requirements of wetland dynamic evaluation, and the integrity of interpretation was very good.

This paper used ETM+ image of 15 m resolution to test the accuracy of interpretation. With the support of ERDAS IMAGING 9.1 software, each issue image was evenly chosen 150 samples to test. Correct rate of test results of TM image was 97%, ETM+ image was 90%; and environmental satellite image was 93%. Overall, the accuracy of interpretation of wetlands was above 90%, and could meet the evaluation of wetland changes.

This paper selected three remote sensing images, and the recent was environmental mitigation satellite image in August 2010. The results of interpreting could reflect the dynamic developments of the wetlands in Madoi, and the timeliness was good.

RESULTS AND ANALYSIS

Changes of wetland distribution: Based on the ArcGIS10.2 software, we produced three distribution maps of wetlands around 1990, 2000 and 2010.

Comparing the three-period distribution of wetlands, it can be seen that the overall changes of wetlands were not big, but the changes of each type were different. Comparing with status of wetlands around 1990, some rivers were shrinking around 2000, whose width narrowing, area reducing and channel drying up. Such as, from 1998-10-20 to 1999-6-3, the Yellow River between Zaling Lake and Eling Lake had first appeared drying up for nearly eight months. Changes of large lakes were not obvious, but a lot of small lakes were shrinking or even disappearing. According to statistics of remote sensing data, between 1990 and 2000, the lakes of more than 6 hm^2 reduced from 405 to 261; the lakes of which area with 1-10km^2 reduced from 27 to 18; and the lakes of more than 10km^2 reduced from 13 to 10. Swamps shrunk or disappeared in many places. Especially in south-east of Madoi, the swamps being complete became fragmented, obviously degrading. In the process of interpretation, it is found that the regions have very serious desertification, and the swamps in the early 1990s have degenerated into deserts.

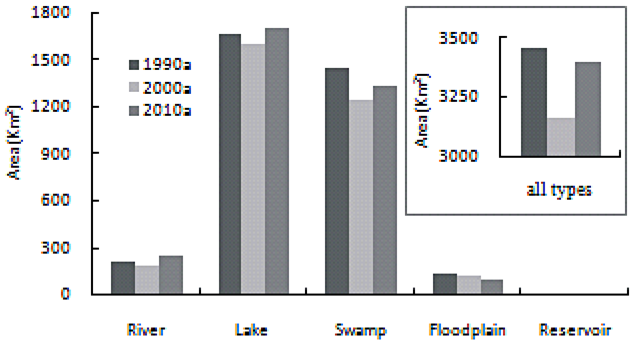

Fig. 2: The area of various types of wetlands in Madoi for three periods.

Comparing with the wetlands around 2000, the situations of Yellow River drying up decreased around 2010, especially in south-east of Madoi; a lot of lakes having disappeared reappeared, especially in central location of Madoi and downstream of reservoirs; the area of swamps increased, and the situations of swampy fragmented degradation also improved.

Wetland area changes: Three periods of the wetland area are 3,460.250km^2, 3,158.223km^2 and 3,398.597km^2. Over the past 20 years, the wetland area and wetland rate have shown a trend of increasing after first decreasing. Between 1990 and 2000, the wetlands decreased by 8.728%, and the wetland rate decreased from 13.702% to 12.506%, a decrease of 1.196%. Between 1990 and 2000, the wetland area increased by 7.611%, and wetland rate increased by 0.952%. Fig. 2 shows, from 1990 to 2000, in the various types of wetlands, the marsh area decreased most, a net decrease of 7.74%, followed by lakes and rivers; from 2000 to 2010, all types of wetland area increased, and reservoir area increased most, followed by lakes.

Since 2000, both the natural wetlands and artificial wetlands have increased greatly, and the total area of the wetlands has increased by 240.374km^2. The lake area increased most, a net increase of 101.832km^2, and the area in 2010 was even more than 1990; followed by swamps and rivers. The floodplain area decreased, the reason could be two images with different time, and part regions of the environmental mitigation images obscured by clouds; in addition, the river islands were an important part of floodplains, their area decreased because of the river area increasing. The reservoir area increased 16.469km^2, on the one hand due to runoff and water storage of the Yellow River increasing, and on the other hand due to the situations of evaporation and seepage improving after the hydropower station normal working.

Since 2000, Madoi has carried out the eco-environmental control engineering. In 2005, Madoi was included in the state natural protective source regions of Yangtze River, Lantsang River and Yellow River. By 2008, the ecological core area of Madoi has been invested ￥69.333 million in the projects of ecological protection and construction. In recent years, along with the projects of ecological protection and construction carried out, soil erosion and grassland desertification of Madoi were a little contained, and the eco-environment was partly improved. Due to implementation of the projects, the wetland area increased, and some of the original dry lakes restored. Comparing the process of interpretation, it was also found that many shrinking lake areas increased, the water flow of main stream and tributaries in the Yellow River increased, and the situation of river drying up improved significantly.

Overall, in the past 20 years, wetland area in Madoi showed a trend of increasing after first decreasing; and the proportion of each wetland type changed little, lakes and rivers increasing, swamps decreasing. From wetland changes over the past 20 years, it can be seen that effect of ecological engineering is significant.

Wetland conversion: Based on the spatial analysis capabilities of ArcGIS10.2 software, vector images of interpretation were converted to raster images, and pixels of output were 20m×20m. With the support of ENVI4.5 software, this paper detected respectively the changes of three times, two periods (1990-2000, 2000-2010) images, obtaining the transfer matrix of area conversion between types of wetlands and between wetlands and other lands.

As presented in the Table 1 and Table 2, the swamp area decreased, and more than 17.4% of the swamps converted to the other lands in 1990-2000. The floodplain area decreased, about 9% of the floodplains converted to the other lands, and the area conversion between the floodplains and the other types of wetlands was small. Mainly including river deltas flowing into the lakes, piedmont alluvial fans, river flats, river islands, etc., the floodplains converted to the largest area of river, about 3.8%. The lake area decreased, and 4.3% of the lakes converted to the other lands. The area conversion between the lakes and other wetlands was small, and most of the lakes converted to the swamps; river area decreased, approximately 33.4% converted to the other lands, about 3.1% converted to the swamps, and another 2.9% converted to the floodplains. Overall, from 1990 to 2000, the area conversion between different types of wetlands was small, and various types of wetlands converted greatly to the other lands.

As given in the Table 3 and Table 4, the reservoir area increased in 2000-2010, 160.396km^2 of the reservoirs converted from the other lands, and 5.056km^2 converted from the rivers. The swamp area increased, 4,600.52 km^2 of the swamps converted from the other lands, 187.012km^2 converted from the rivers, and 178.916km^2 converted from the lakes. The floodplain area increased, 273.996km^2 of the floodplains converted from the other lands, 86.16km^2 converted from the rivers, and 49.04km^2 converted from the swamps. The lake area increased, 1,690.484km^2 of the lakes converted from the other lands, 286.452km^2 converted from the swamps, and 232.176 km^2 converted from the floodplains. The river area increased, 1,892.72km^2 of the rivers converted from the other lands, 218.796km^2 converted from the swamps, and 207.892km^2 converted from the floodplains. By 2010, the conversion ratio between the various types of wetlands was still relatively small, comparing with the past ten years, and it was not very different. The various types of wetlands converting from the other lands increased, and the various types of wetlands converting to the other lands also increased. The main reason was that the geometry correcting of environmental mitigation satellite was more difficult, its accuracy of geometric correction was relative lower than TM/ETM+ image, and pixels had a certain deviation. As shown in the proportional changes, the wetlands converting from the other lands were the largest proportion in the composition.

DRIVING FORCES OF WETLAND CHANGES

Irrational human activities and climate changes were the major factors for wetland changes. In order to better understand the degrading mechanism of wetlands, the author has analysed the environmental changes and human activities of Madoi in the past 20 years.

Climatic factors: Madoi is located in the hinterland of the Qinghai-Tibet Plateau. Because of the special geographical position, it formed a special climate. According to meteoro-

Table 1: Transfer Matrix of area conversion between types of wetlands and between wetlands and other lands in Madoi from 1990 to 2000 (unit: km^2).

1990a	2000a						
	Lake	Reservoir	River	Swamp	Floodplain	Other land	Total
Lake	15,704.592	0	0.364	24.148	3.08	713.304	16,445.488
Reservoir	0	0	0	0	0	0	0
River	3.472	1.68	1,233.972	63.528	60.104	682.332	2,045.088
Swamp	63.228	0	74.74	11,698.648	22.496	2,497.132	14,356.244
Floodplain	9.656	0	51.828	2.968	1,168.088	122.612	1,355.152
Other land	91.088	5.912	399.14	536.804	70.172	229,600.48	230,703.596
Total	15,872.036	7.592	1,760.044	12,326.096	1,323.94	233,615.868	264,905.576

Table 2: Transfer Matrix of area convertible rate between various types of wetlands and between wetlands and other lands in Madoi from 1990 to 2000 (%).

1990a	2000a					
	Lake	Reservoir	River	Swamp	Floodplain	Other land
Lake	95.495	0	0.002	0.147	0.019	4.337
Reservoir	0	0	0	0	0	0
River	0.17	0.082	60.388	3.106	2.939	33.365
Swamp	0.44	0	0.521	81.488	0.157	17.394
Floodplain	0.713	0	3.825	0.219	86.196	9.048
Other land	0.039	0.003	0.173	0.233	0.03	99.522

Table 3: Transfer Matrix of area conversion between types of wetlands and between wetlands and other lands in Madoi from 2000 to 2010 (unit: km^2).

2000a	2010a						
	Lake	Reservoir	River	Swamp	Floodplain	Other land	Total
Lake	14,607.72	0	1.12	178.916	6.152	1,078.2	15,872.108
Reservoir	0	5.84	0	0	0	1.752	7.592
River	24.344	5.056	200.924	187.012	86.16	1,256.548	1,760.044
Swamp	286.452	0	218.796	8,076.228	49.04	3,695.74	12,326.256
Floodplain	232.176	1.016	207.892	24.616	583.072	275.168	1,323.94
Other land	1,690.484	160.396	1,892.72	4,600.52	273.996	224,989.12	233,607.248
Total	16,841.176	172.308	2,521.452	13,067.292	998.42	231,296.552	264,897.188

Table 4: Transfer Matrix of area convertible rate between various types of wetlands and between wetlands and other lands in Madoi from 2000 to 2010 (%)

2000a	2010a					
	Lake	Reservoir	River	Swamp	Floodplain	Other land
Lake	92.034	0	0.007	1.127	0.039	6.793
Reservoir	0	76.923	0	0	0	23.077
River	1.383	0.287	11.416	10.625	4.895	71.393
Swamp	2.324	0	1.775	65.521	0.398	29.983
Floodplain	17.537	0.077	15.703	1.859	44.041	20.784
Other land	0.724	0.069	0.81	1.969	0.117	96.311

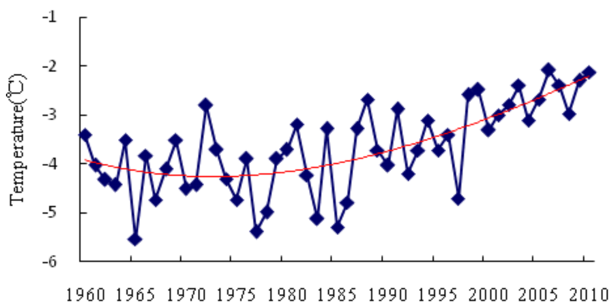

Fig. 3: The changes of annual temperature in Madoi from 1960 to 2010.

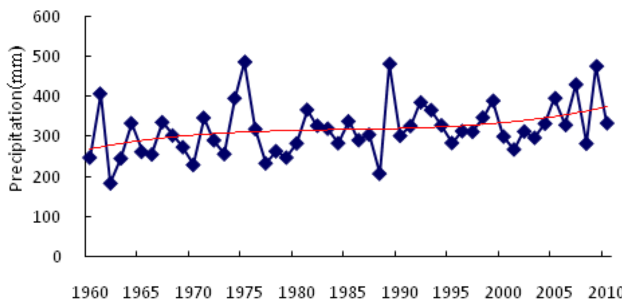

Fig. 4: The changes of annual precipitation in Madoi from 1960 to 2010.

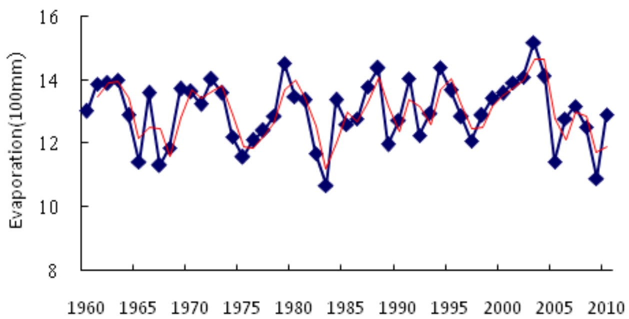

Fig. 5: The changes of annual evaporation in Madoi from 1960 to 2010.

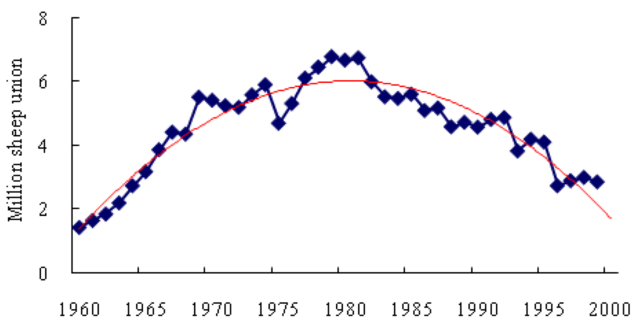

Fig. 6: Changes of livestock numbers in Madoi during 1960-2000.

logical data, the annual temperature in Madoi showed a trend of slow increase in the past 40 years (Fig. 3). The mean annual average temperature was -3.5°C, and the annual temperature increased by approximately 0.24°C every 10 years. In mid and late 1980s, the upward trend in the annual temperature was very obvious. The annual temperature of 1990s than the 1970s and the 1980s was higher 0.7°C and 0.4°C. Under the background of the annual temperature increase, there were seasonal variations in the temperature changes, warming significantly in winter, followed by summer and autumn, and changing gently in spring. Temperatures rising could lead to the eco-environment of wetlands more fragile (Luo 2005), making wetland degradation easier.

As shown in Fig.4, from 1960 to 1975, the annual precipitation of Madoi increased significantly, the eight-year-average precipitation was 278.288 mm from 1960 to 1966, and it was 322.425 mm from 1968 to 1975, a difference of 44.137 mm; from 1976 to 1980, the annual precipitation felled back, and the five-year-average precipitation was 269.36mm; from 1981 to 1988, the annual precipitation showed a decreasing trend, and felled to 207.9mm in 1988. From 1989 to 1995, the annual precipitation showed roughly a decreasing trend, and from 1995 to 2010, the annual precipitation showed an increasing trend. On the seasonal distribution of precipitation, from May to September, the precipitation accounted for 85.4% of the total; since January, with the temperature rising, the precipitation increased gradually, and reached the first peak in July. Next, the precipitation felled back slightly in August, and reached the second peak in September; then, the precipitation decreased dramatically.

In recent 40 years, the changing trend of the annual evaporation of Madoi experienced a relatively wet period from the late 1970s to the mid-1980s; after the mid-1980s, the annual evaporation increased year by year; in the 1990s, the changing trend was obviously drying. As shown in Fig. 5, from 1985 to 2011, the mean annual evaporation of Madoi was 1,299.7mm. The annual evaporation reached the maximum of 1,565.0mm in 2003, and the minimum of 1,121.1mm in 2009.

An important consequence of climate changes was the impact on water environment. According to the survey data of Madoi, the decrease in lake area was 0.54% from 1970s to 1980s, and it was 9.3% from 1980s to 1990s. In general, the lake level fell 2-3m, and the lake area shrank about 20-30m. Since the source regions of Yellow River dried up in 1996, more than 2,800 lakes have dried.

Permafrost environmental changes: Madoi belongs to the permafrost regions, and changes of the permafrost environment have a great influence on the eco-environment. On the one hand, the permafrost can effectively prevent infiltration of surface water and soil moisture, thereby increasing the moisture content of plant roots; on the other hand, the permafrost has the function of gathering the upper nutrients, and the lower soil temperature is advantageous to accumulation of organic matter. Over the past 30 years, with climate warming, the temperature at 20m underground increased by 0.2°C-0.3°C, which affected the temperature changes at above 40m deep, and caused the talik of permafrost expanding, the seasonally thawed layer swelling (Wang et al. 2000, Cheng et al. 2000). The degradation of permafrost and the downward movement of cryogenic aquifuge, caused the groundwater level and the ecological water level in the regions decreasing generally. The soil moisture in the root system of the vegetation reduced, the swamps and the lakes dried up, and soil structure and composition changed (Kang 1996). These caused grasslands degrading, eco-succession of dominant plant population, swamps shrinking, rodent damages aggravating, desertification intensifying and other ecological issues.

Rodent damages: Rodent damages in Madoi were longstanding, particularly serious since 1985. In the regions of grasslands, rodents are mainly *Myospalax baileyi* and *Ochotona curzoniae*, and the *Ochotona curzoniae* has wider distribution and more harmful. According to statistics, the existing rodent damages of grasslands reached 149.95×10^4hm^2, accounting for 65.20%, and the density of the rodent holes was 3,750-7,050/hm^2, serious areas up to 19,860/hm^2. Rodents gnaw the stems and leaves, digging the roots, so that the plants shrivell and die, accelerating the degradation and desertification of grasslands. In Madoi, more than 50% of "back-soil flats" is caused by the rodents. According to determination, in the shady and sunny secondary bare areas suffering rodent damages, the water content of the surface soil was respectively 22.18% and 29.27% less than the native grasslands. Rodent damages mainly concentrate in the areas of Zaling township, Huanghe township and Heihe township. In swamps and floodplains, the functions of water conservation and purification are relying on the role of marsh vegetation, but rodent damages have great influence on the two types of wetlands.

Overgrazing: Madoi is a pure animal husbandry county, and its income mainly depends on animal husbandry. Therefore, expanding the number of livestock is the main way of economic growth. Since the late 1960s, the animal husbandry of Madoi has got fast development, and the number of livestock has grown exponentially; the grasslands have been in a state of overload, leading to the continuing degradation of grasslands (Fig. 6). In winter and spring, due to the smaller grasslands and the longer grazing time, overgrazing was much more serious. Especially in the beaches near water source, in the valley sides and in the lower part of hillsides, the grasslands were frequently in a state of overload, exacerbating the load of the winter and spring grasslands. According to the survey on Madoi grasslands from 1994 to 1996 (Wang et al. 2001), the theoretical carrying capacity of the winter pastures was 667,000 sheep units, and the summer pastures was 3,048,900 units. Therefore, the summer and autumn pastures were better in quantity and quality than the winter and spring pastures, which led to the livestock in a vicious cycle of autumn fat, winter thin, and spring death.

Irrational exploitation: There are abundant natural resources in Madoi. Alluvial gold, salt and other minerals, as well as Huang fish, fox, sand fox and other wild animals, are always the main objects of farmers and herdsmen who engaged in sideline. Since 1980, tens of thousands of foreigners have come to Madoi and engaged in gold mining, fishing salt, fishing, hunting rodent predators. Due to the long-term indiscriminate digging, a large number of grasslands were destroyed, rodent predators reduction, ecosystem destruction, soil erosion and desertification (Dong et al. 2002). The grasslands of riversides were under desertification, the functions of water conservation were declining, and these artificially accelerated the wetland degradation.

Tourism development: Madoi is located in the Yellow River source, with numerous lakes, and is the holy lands of tourism. The famous tourist attractions are the Yellow River source, Zaling Lake, Eling Lake, Bayan Har Mountain and others. To bring economic benefits to the local, at the same time, tourism brought great pressure to the eco-environment. Tourists and buses moving in the wetlands, not only damaged the vegetation, but also changed the habitat of animals and plants. With the development of tourism, the pressures on the eco-environment of wetlands continue to increase. Especially in swamps, tourism is one serious factor of wetland degradation.

Ecological protection and construction: Madoi is one key region of the state natural protective source regions of Yangtze, Lantsang River and Yellow River. In 2005, Madoi was officially launched the ecological protection and construction projects of grasslands. The projects mainly included the ecological construction, the infrastructure construction of farmers and herdsmen, and the ecological protection. The implementation of the projects made the eco-environment greatly improve, and made some shrinking lakes to restore. From 2000 to 2010, the projects were the most important reason of the wetland area and the ecological functions changing.

DISCUSSION AND CONCLUSIONS

Comparing with the Landsat TM images around 1990, the Landsat ETM+ images around 2000, and the HJ-1A/B satellite images around 2010 in Madoi: from 1990 to 2000, the wetland area decreased by 8.728%, and the rate of wetlands has decreased by 1.196%; from 2000 to 2010, as a result of the implementation of the ecological protection and construction projects, the wetland area increased by 7.611%, with the rate of 0.952%.

The results show that over the past 20 years, the reasons of wetland degradation in Madoi were climate warming and drying, human irrational development and utilization of grasslands, and contributing to the eco-environment problems. Under the combined effects of natural factors and human factors, the area of wetlands reduced, and even dried, causing a series of ecological deterioration such as grassland degradation and soil erosion.

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