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Analyzing qualitative and quantitative changes in coastal wetland associated to the effects of natural and anthropogenic factors in a part of Tianjin, China

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ABSTRACT

Natural and anthropogenic factors in coastal wetland changes are widely discussed in wetland studies. Previous literatures have demonstrated that many factors may cause wetland change and argued that the global climate change and nutrient enrichment may become the most important ones in the next 50 years. Through field investigation, with the help of remote sensing technology and geographic information system, this research discusses the wetland change in Tianjin under the great pressure of rapid economic development, population growth, and sea-level rising. These findings include: (1) the wetland area expanded from 466.50 km^2 to 658.38 km^2 between 1987 and 1998, but it shrank to 550.5 km^2 by the year of 2006. (2) The results show that the groundwater has not been contaminated while the surface water has been polluted. (3) The questionnaire survey shows that the social environment in some specific ways impedes the protection of natural reserve. In order to achieve the harmony between human and nature, feasible countermeasures on how to keep ecological balance should be immediately taken. Consequently, natural conservation and sustainable economic development will be realized.

1. Introduction

Natural wetland, occupying 3.8% of China's territory and providing 54.9% of ecosystem services, is unevenly distributed in China. Coastal wetland is an important kind of wetland and natural landscape with abundant natural resources and unique environmental effect (An et al., 2007). Human activities have changed the environment and caused a series of ecological changes in natural estuarine communities, prolonging dry seasons, altering groundwater levels, and decreasing connectivity and habitat heterogeneity (Brock et al., 1999; Bunn and Arthington, 2002; Ivan et al., 2008). Along with the rapid economic development in coastal area, the damage caused by the interference of human activities in coastal wetland is becoming more and more obvious. Large areas of wetland are disappearing, and those remaining areas become vulnerable under anthropogenic impacts from industry, agriculture, aquaculture, urban development and domestic waste (Casabianca et al., 1997; Junk, 2002; Charpentier et al., 2005; Bernard et al., 2007; Vela et al., 2008). Therefore, the conflict between protection and exploitation is getting more and more irreconcilable. The wetland area greatly decreased in the past 50 years due to wetland reclamation, population pressure, water diversion, dam construction, pollution, resource over-excavation, biological invasion, desertification, climate change, and the misguiding policies. Therefore, the study of qualitative and quantitative changes in wetland patterns and the reasons behind has become hotspot in wetland studies in recent years (Augusteijn and Warrender, 1998; Chen, 2002; Liu et al., 2004a, 2004b; Marieke et al., 2008; Wang et al., 2008).

Satellite imagery has been well utilized in natural science to measure qualitative and quantitative terrestrial land-cover changes (Seto et al., 2002; Vela et al., 2008). Qualitative changes in landscapes can be attributed to either natural or human factors (Paula and William, 2000; Lan and Zhang, 2006). Lunetta and Barlogh (1999) have evaluated the application of moderate spatial (30 m) and spectral resolution satellite imagery and digital image analysis technology in ensuring the potential jurisdictional wetlands. Remote sensing technology has been extensively used in wetland studies (Noriega and Lozano-García, 2000; Wright and Gallant, 2007), such as the analysis of hydrology and wetland cover changes (McHugh et al., 2007). Carreño et al. (2008) used Landsat images to draw the land-cover maps and to analyze the change of wetland area during the period of 1984–2000. Landsat MSS, TM, and SPOT-XS are common data types for wetland classification and its temporal-spatial dynamic change (Munyati, 2000; Paula and William, 2000).

By analyzing the dynamic changes of wetland achieved by case study, we find the relationship between the reasons of wetland

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change and the change of wetland use. The combination of natural and anthropogenic factors evokes a deep understanding of the mechanism of wetland change (Zhao and Lai, 2007). The factors that contribute to the operation of wetland change reveal the change rules in different temporal-spatial conditions and the function of their mechanism in typical areas (Zhao and Lai, 2007). Meanwhile, they show the main aspects in wetland change and give further implication of environmental effects of wetland change from a global perspective (Liu et al., 2004a, 2004b). Many researches of coastal wetland focus on its status and characteristics (Xiao et al., 1996; Robert et al., 2005). However, so far, few researches have been carried out in Tianjin coastal area to study its wetland change and the reasons. Through field investigation, this paper, by adopting remote sensing data, reveals the qualitative and quantitative process of wetland change during the past decades and analyzes the underlying causes, which are also the specific purposes of this research.

2. Study area

The studied area, Ninghe County and Hangu District, is located at 117°18′40″E to 118°03′47″E, 38°05′43″N to 39°35′57″N in the north-east of Tianjin, covering an area of 1908 km^2 (Fig. 1). The climate is cold and moist with an annual average temperature of 11.3 °C, total evaporation about 1500 mm, precipitation in total about 600 mm, most of which falls between June and September.

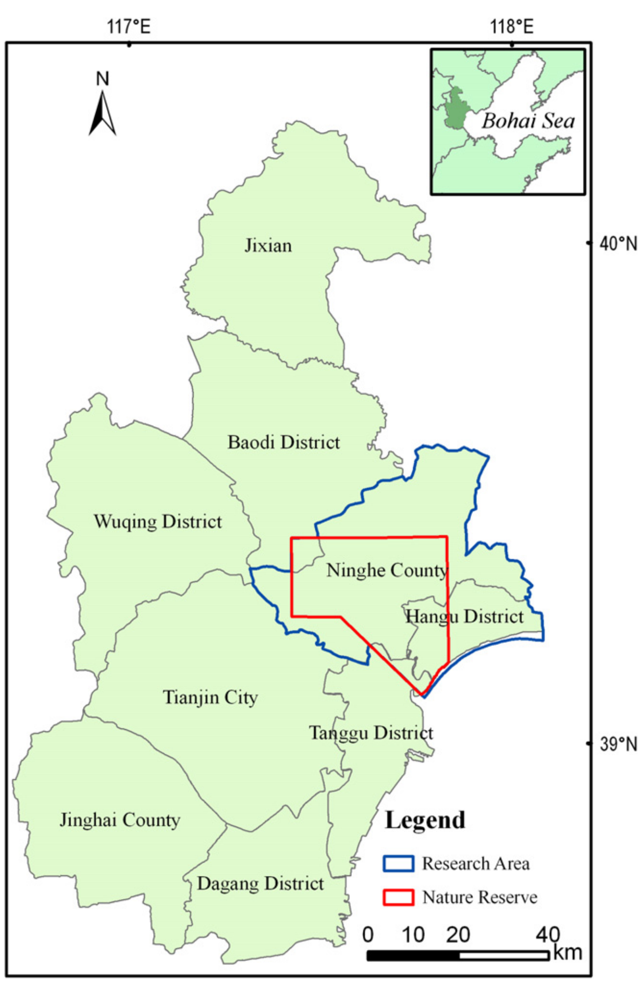

Fig. 1. Location of the study area.

The terrain has an elevation between 0 m and 30 m above the sea level. The area is comparatively dense in population, with an average of 316 persons per km^2 and its main industry is agriculture and industry.

National natural reserve, established in 1992 approved by the central government of China, lies in the research area. This natural reserve is a marine one which occupies 990 km^2, making up 52% of the total studied area. From Fig. 1, we can see that the natural reserve is situated to the west of Bohai Bay and in the east of Tianjin, China. A total of 196 species belonging to 121 generas and 46 families are found in the national reserve, most of which are herbaceous plants with few woody plants and shrubs. Most of the trees and shrubs are cultivated tree species. The characteristics of vegetation are simple vegetation species, many dominant species, and high degree of vegetation coverage and herbaceous plants dominates the floristic elements in this region. The main tree species of salt resistance are *Ailanthus altissima*, *Robinia pseudoacacia*, *Ulmus pumila*, *Fraxinus velutina*. Most of the species aggregate together and grow into cluster, which become dominant and subdominant species of different communities. The phenomenon of cultivating wetland in the natural reserve is very prevalent, continuously diminishing the habitat of wild animals. The serious damage of habitat inflicted by human activities can lead to the inevitable decrease of wild animals. Owing to the enduring human activities, the species of plants are more complex than that in modern coastal zone. The main types of wild animals are *birds*, *mannalia*, *reptiles*, *amphibian*, *fishes*, *crustacea*, *archigastropoda*, *annelids*, *insects*.

We choose this region to study because it is located in the coastal area and near the Binhai New Area of Tianjin, one of the areas with fastest economic development in Northern China which has emerged as the prominent commercial, industrial and shipping centre. There are national natural reserves, industrial areas, coastal wetland and dense population. The area also risks sea-level rising, which may inundate coastal areas some day. Exploring of causes of wetland change in coastal areas may help decision-makers to know how to keep the balance between wetland protection and economic development.

3. Data and method

3.1. Data

In this research, three remote sensing images are used to examine wetland change. A full scene Landsat ETM+ (Enhance Thematic Mapper plus) recorded on September 1st, 1998, was acquired from the Global Land Cover Facility (http://www.glcf.umiacs.umd.edu). Landsat images of March 27, 1987 and July 21, 2006 were purchased from China Remote Sensing Satellite Ground Station. Both images, which have six bands and 30 m spatial resolution, are predominantly cloud-free. Meteorological data were collected from Climate Data Center of China Meteorological Bureau.

3.2. Methods

Remote sensing data processing, including preprocessing and false color composite, was carried out by means of the software package of ENVI 4.2(the Environment for Visualizing Images). To deal with the unsystematically geometric errors, geometric rectification is, therefore, needed before classification (Yu, 2006). After finishing all above, the ISODATA algorithm is firstly used to perform unsupervised classification to obtain different wetland clusters by using different color composites. The preliminary interpretation can maximally reduce the man-made errors and select the most appropriate clusters for further processing (Yu, 2006). Furthermore, the Maximum Likelihood algorithm is used to improve the accuracy of the wetland classification. The traditional pixel-based classification above will result in a pixelized (salt and pepper) representation. Many patches with only one or two pixels will sharply increase the number of total patches and decrease the mean area of each wetland class. This will further lead to the fragmentation of wetland on the one hand, and decrease of the overall accuracy on the other hand. Thus, patches smaller than a certain number of pixels should be eliminated to avoid the 'salt and pepper' phenomena. This process involves a sequence of SIEVE and ELIMINATES functions. Change detection and monitoring involve the use of multi-date images to evaluate differences in wetland cover due to environmental status and human activities (Green et al., 1994; Stewart, 2001; Yang and Lo, 2002; Seto et al., 2002). The classification and post-comparison method were applied in the research, with the help of Change Detect Statistics of ENVI to analyze the changing condition of wetland. The Kappa parameter of the three images on different dates was computed in the process of accuracy assessment, and the results are 0.75, 0.74, and 0.85, respectively.

Groundwater and surface water quality has adopted the common methods in monitoring applied the Class V of Surface Water Environment Quality Standard. The water quality analyzing methods of pH, DO, COD_{Mn}, BOD_5, Cr^{6+}, Cd, As, Pb, TP, Hg, TN are relatively glass electrode method, iodometric method, potassimu permanganate method, dilution and inoculation method, diphenylcarbohydrazide spectrophotometric method, atomic absorption spectrophotometry, silver diethyldithiocarbamate spectrophotometry, atomic absorption spectrophotometry, tin chloride reduction spectrophotometry, cold vapour atomic absorption spectroscopy, persulfate oxidation method.

A questionnaire survey on their attitude about wetland protection was also carried out among local residents in the natural reserve. Firstly, the questionnaire survey took the form of face-to-face interviews of residents, and we took notes of their answers. Secondly, these interviews mainly focus on their education degree, annual income, their perceptual knowledge on the change and causes of wetland vegetation and wild animals, the main threats imposed on wetland, the effect of natural reserve in their daily life, and how to establish a harmonious relationship between natural reserve and resident life.

4. Results

4.1. Area change in wetland area

In this study, the land is firstly divided into wetlands and non-wetlands. Wetlands are then further divided into ten types: river, pond, saline, pool, shallow sea, channel, freshwater aquaculture, wetland vegetation, saltwater aquaculture, and mudflat. Non-wetlands are classified into: farmland, build up, and unused land. The results of the above classifications are presented by three remote sensing images in Fig. 2 and Table 1.

Based on the accuracy assessment, the maps of classification with higher accuracy were used to contrast the changes of wetland area (Table 1). The matrix of wetland use change shows an increase of 340 ha in wetland vegetation between 1987 and 1998 (Tables 2

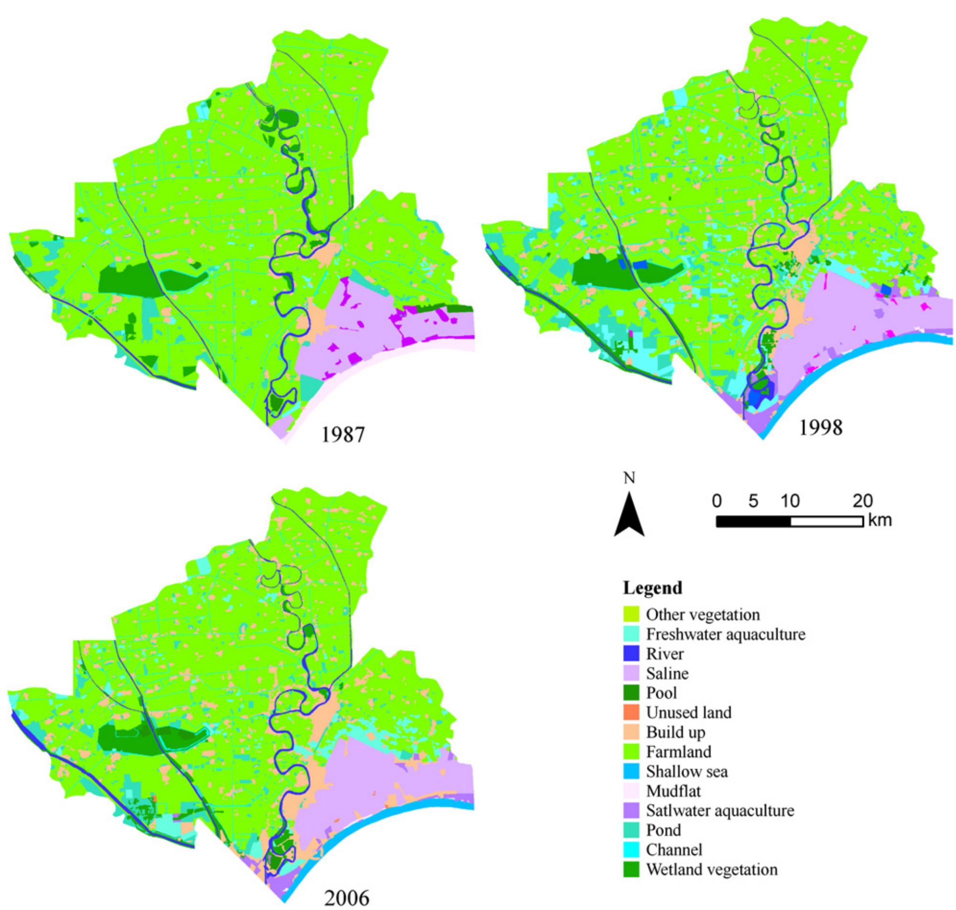

Fig. 2. The classification results of the remote sensing images.

Table 1
Composition of different wetland types in 1987, 1998, and 2006 (km^2).

	1987		1998		2006	
	Area	Percent (%)	Area	Percent (%)	Area	Percent (%)
River	42.25	2.21	39.37	2.06	51.42	2.69
Pond	74.49	3.90	132.05	6.92	90.86	4.76
Saline	145.77	7.64	166.22	8.81	159.53	8.36
Pool	10.55	0.55	7.10	0.37	8.30	0.43
Shallow sea	0	0	32.68	1.71	31.04	1.63
Channel	55.09	2.89	46.21	2.42	34.39	1.80
freshwater aquaculture	17.61	0.92	110.15	5.77	77.73	4.07
wetland vegetation	83.36	4.37	86.76	4.55	74.01	3.88
saltwater aquaculture	0.29	0.02	35.62	1.87	21.40	1.12
Mudflat	37.04	1.94	2.18	0.11	1.86	0.09
Total area of wetland	466.50	24.44	658.38	34.39	550.5	28.83

and 3). On the contrary, it decreased by 1275 ha between 1998 and 2006. The main types of wetland are saline, pond, and wetland vegetation, among which saline accounts for 7% of the total area, pond 4%, mudflat, pool, and saltwater aquaculture in total only about 2%. The wetland undergoes both whole area and in parts. The water body (including river, pond, saline, pool, shallow sea, channel, freshwater aquaculture, and saltwater aquaculture) shows an increasing tendency due to the large amount of precipitation in 1998 to some extent. The unused land continues to decrease during the whole period because of the expansion of farmland and saltwater aquaculture.

4.2. Water quality of groundwater and surface water

Heavy metal concentrations in surface sediments can provide historical information on heavy metals inputs. The samples of surface sediments can be used as environmental indicators of many pollutants in the current marine systems (Ergul et al., 2008). The component of heavy metal is harmful to intertidal crab inhabiting in coastal wetland (Sara et al., 2008). In order to probe into the status of quality of groundwater, we began to monitor the water quality in the core area of national natural research in May 2003. Two wells located in the west and east were selected to be monitored for their water quality in kinds of aspects, such as pH, F^-, Pb, Cd, Hg, Cr^{6+}, As, TN, TP etc. The results show that the contents of F^- exceed the Groundwater Quality Standard GB/T14848-1993, reaching as much as 1.56 mg l^{-1} and 1.21 mg l^{-1}, so it can be classified into Class IV groundwater. Indexes from the other all correspond with the Class I standard. Some other items could not be detected except pH, F^-, which can go up to the standard of Class II. In general, the groundwater is uncontaminated. The absorption of excessive nutrients has emerged as one of the most important direct causes of change in wetland ecosystem.

At the same time, we also monitored the quality of surface water in the national natural reserve with items of pH, DO, COD_{Mn}, BOD_5, Pb, Cd, As, and Cr^{6+}. The results are shown in Figs. 3 and 4.

The monitor results reveal that the DO, COD_{Mn}, BOD_5, Pb, Cd during the period from 2001 to 2005 have exceeded the standard of Class V of Surface Water Environmental Quality Standard (GB3838-2002). The content of DO and As shows the continuous degradation in the period while the content of COD_{Mn}, BOD_5, Pb, Cd displays a general tendency of improvement. The content of Cr^{6+} cannot be found in surface water quality monitor program. This may increase the spread of disease, especially for those vulnerable people in developing countries, where medical technologies and services are not readily available (Zhao and Lai, 2007).

5. The causes of changes in wetland

Natural factors and anthropogenic ones are found to be responsible for the change of ecosystem (Zhao and Lai, 2007). The direct causes affect ecosystem, including climate change, the diversion of freshwater flows, nitrogen loading, over-harvesting, siltation, changes in temperature of water, and specie invasions. The indirect ones affect ecosystem via having influencing over one or several direct factors. The indirect ones include population growth, economic development, social politics, technological advancement, social culture, and life style and religion and so on (Zhao and Lai, 2007).

5.1. The effect of natural factors on changes in wetland

Many natural factors can influence the formation and distribution of wetland, such as geologic structure, landform, climate, hydrology, vegetation, and soil. Geologic structure and landform are two basic ones in natural ecological composition, which are formed in geologic epoch and unlikely to change too much in several decades. Therefore, they will not be discussed in the research. All the factors have to be considered in different time and space while the time scale of human activities is relatively short,

Table 2
The transition matrix of wetland types (units: km^2): 1987–1998 in the study area. Value in bold: wetland types without change from 1987 to 1998.

	Wetland type	1998													
		River	Pond	Saline	Pool	Shallow sea	Channel	FA	WV	Farmland	SA	Mudflat	Build up	Unused land	Total 1987
1987	River	**19.64**	1.71	0.00	0.00	0.00	0.95	0.50	4.96	10.7	0.13	0.00	3.53	0.08	42.20
	Pond	0.26	**20.57**	9.18	0.67	0.00	0.48	12.25	1.56	24.02	0.89	0.00	4.41	0.10	74.39
	Saline	0.00	0.01	**135.11**	0.00	0.12	0.00	0.14	0.02	0.05	7.95	0.62	0.75	0.98	145.75
	Pool	0.09	0.00	6.45	**2.51**	0.00	0.21	0.01	0.02	0.77	0.47	0.00	0.01	0.01	10.55
	Shallow sea	0.00	0.00	0.01	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	Channel	0.59	4.07	0.00	0.48	0.00	**6.67**	3.6	1.07	34.12	0.38	0.00	4.08	0.02	55.08
	FA	0.04	2.39	0.03	0.00	0.00	0.36	**8.50**	0.43	5.00	0.07	0.00	0.76	0.01	17.59
	WV	2.63	7.18	0.00	2.20	0.00	1.39	3.86	**43.01**	20.26	0.01	0.00	2.80	0.02	83.36
	Farmland	14.60	92.66	1.77	1.25	0.14	34.66	79.45	34.90	**985.90**	16.99	0.00	73.82	1.29	1337.46
	SA	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.26**	0.04	0.00	0.00	0.31
	Mudflat	0.08	0.01	0.71	0.00	32.11	0.02	0.02	0.05	0.06	2.35	**1.22**	0.09	0.31	37.03
	Build up	1.44	3.43	0.63	0.00	0.02	1.77	1.77	0.74	21.80	0.45	0.00	**50.42**	0.06	82.53
	Unused land	0.00	0.00	12.33	0.00	0.29	0.04	0.04	0.00	0.40	5.69	0.30	0.02	**2.63**	21.74
	Total 1998	39.37	132	166.23	7.11	32.68	46.55	110.14	86.76	1103.11	35.64	2.18	140.69	5.51	

Abbreviation: SA: saltwater aquaculture; FA: freshwater aquaculture; WV: wetland vegetation.

Table 3
The conversion matrix of wetland types (units: km^2): 1998–2006 in the study area. Value in bold: wetland types without change from 1998 to 2006.

	Wetland type	2006													
		River	Pond	Saline	Pool	Shallow sea	Channel	FA	WV	Farmland	SA	Mudflat	Build up	Unused land	Total 1987
1998	River	**32.53**	0.05	0.00	0.01	0.00	0.03	0.07	2.10	2.37	0.00	0.00	2.26	0.00	39.42
	Pond	1.73	**46.24**	0.00	0.00	0.00	1.62	8.97	2.34	59.89	0.06	0.00	11.28	0.00	132.14
	Saline	0.01	0.19	**152.00**	0.00	0.35	0.00	0.08	0.00	0.21	0.78	0.29	12.43	0.00	166.33
	Pool	0.00	1.48	0.00	**5.17**	0.00	0.00	0.04	0.14	0.02	0.04	0.00	0.21	0.00	7.10
	Shallow sea	0.00	0.00	0.03	0.00	**30.45**	0.00	0.00	0.00	0.00	0.48	0.27	1.46	0.00	32.69
	Channel	1.10	1.06	0.00	0.41	0.00	**16.68**	0.52	1.49	23.04	0.00	0.00	1.91	0.00	46.21
	FA	0.56	19.03	1.21	0.00	0.00	0.59	**0.08**	3.56	24.48	0.68	0.01	9.95	0.00	110.35
	WV	9.56	3.75	0.30	2.46	0.00	1.08	0.97	**48.81**	12.74	0.00	0.00	7.06	0.00	86.73
	Farmland	4.86	17.10	0.28	0.23	0.00	13.32	3.37	12.84	**1010.70**	0.31	0.01	30.00	0.00	1103.07
	SA	0.33	0.24	5.01	0.00	0.08	0.00	2.70	1.41	0.21	**18.00**	0.74	6.89	0.00	35.61
	Mudflat	0.00	0.00	0.04	0.00	0.11	0.00	0.00	0.00	0.00	0.68	**0.51**	0.85	0.00	2.19
	Build up	0.67	1.72	0.26	0.00	0.04	1.05	0.78	1.12	18.49	0.19	0.01	**116.33**	0.00	140.66
	Unused land	0.11	0.05	0.5	0.00	0.00	0.03	0.09	0.02	0.17	0.16	0.00	3.43	**0.94**	5.50
	Total 1998	51.46	90.91	159.60	8.28	31.03	34.40	77.87	73.93	1152.3	21.38	1.84	204.06		

often like only hundreds of years. Factors of meteorology and climatology are basis of ecology and environment, which have fundamental effects on wetland landscape change.

Climate is the basis of the formation and development of wetland and the most essential factors in wetland formation. The influence of climate change on wetland is embodied in temperature and precipitation. Climate change can greatly influence the circulation of elements of wetland ecosystem, energy flow, productivity, distribution and function of wetland. At the same time, the pendulum of wetland can change wetland ecosystem and accelerate the velocity of climate change. Moreover, the impact of human activities upon wetland is accomplished through changing the hydrothermal condition (Zhao and Lai, 2007). The amount of precipitation has direct influence on the change of wetland area and continuous lessening of rainfall can lead to the weakening and degradation of wetland (Liu et al., 2004a, 2004b). Changes of temperature can influence evaporation process, wetland vegetation, and soil while the decrease of precipitation reduces the supply of demanding water for wetland. Climate change affects human activities. In turn, human beings increase the utility of freshwater to satisfy the demand of urban and agricultural development for water, which in turn will lead to the reduction of runoff, water level fluctuations and the decline and degradation of wetland function. Fig. 5 shows the changing tendency of climate factors.

Fig. 5 indicates that the temperature continued to increase during the period from 1954 to 2005 while the precipitation and evaporation showed a tendency of decrease in the same period. The remote sensing data taken in 1987, 1998, and 2005 demonstrated that the amount of precipitation in 1998 was relatively higher than any other year and the evaporation in 1998 was smaller than adjacent years. That is why the wetland area in 1998 was relatively larger than 1987. The decreasing tendency of precipitation will inevitably reduce wetland water demand while the great capacity of evaporation will also have negative effect on wetland water environment. The impacts of global climate change will often exacerbate the degradation of wetlands. Decreased precipitation as a result of climate change will aggravate the situation of growing demand for water (Zhao and Lai, 2007). Climate change may increase precipitation, providing more available water to human activities and ecosystems. However, increases in precipitation will not be universal, and climate changes will also cause substantial decrease in precipitation in other areas.

5.2. The effects of anthropogenic factors on changes in wetland

Human activities are becoming the main factors of wetland change at present. However, human activities can accelerate or avoid wetland degradation, depending on how they change the relationship between humankind and nature. The research on how the anthropogenic factors influence wetland utilization structure can be greatly helpful for optimizing the structure of land use and raising the utilization rate of wetland. Also the degradation and loss of wetland have been caused by infrastructural construction, land use conversion, water withdrawals, pollution, over-exploitation of

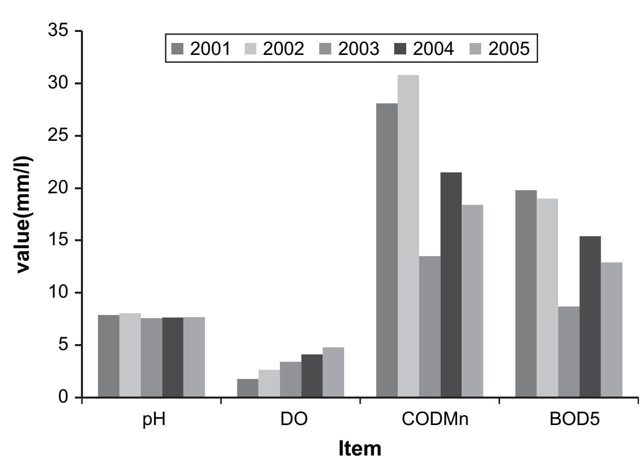

Fig. 3. Change tendency of pH, DO, COD_{Mn}, and BOD_5 of surface water from 2001 to 2005.

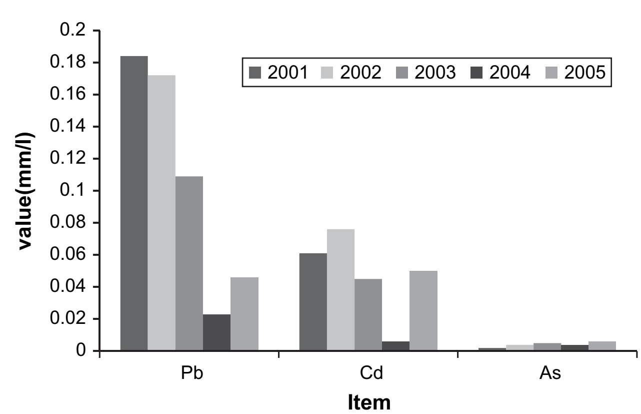

Fig. 4. Change tendency of Pb, Cd, and As of surface water from 2001 to 2005. Data from: Environmental Protection Agency of Ninghe County.

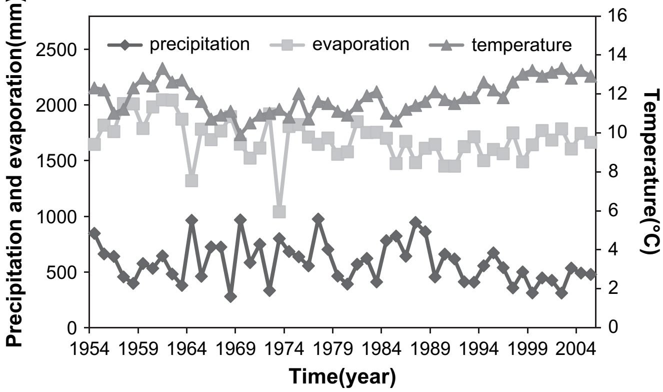

Fig. 5. Change tendency of precipitation, evaporation, and annual temperature from 1954 to 2005. Data from: China National Meteorological Information Centre.

wood, and the introduction of invasive alien species (Zhao and Lai, 2007; Katsuki et al., 2009).

Population growth and economic development are the two main forces causing wetland degradation. They can also lead to shrinking of coastal wetlands as a result of urban and suburban expansion. Human pressures on rapidly diminishing areas of coastal wetland are increasingly destroying many of the ecosystem services that are crucial to the well-being of coastal economy and people's life. More importantly, most people living nearby are the poor in China and have no other livelihoods. Original wetland landscape has now been replaced by agricultural landscape and other anthropogenic ones. The population in the research area increased from 485 200 in 1994 to 539 822 in 2005, and in turn the continuously increasing growth of population needed more crop product from land and entailed the expansion of agriculture.

Many researches have demonstrated that gross population has influence on wetland change (Wang et al., 2008). In July 2007, we conducted a questionnaire survey for local residents about wetland protection. A total of 90 people whose education were relatively low were interviewed, among whom 29 only got primary school degree, 43 junior school, 17 high school, and 1 college degree. The low education is correlated with negative attitude against protection. We also compare the annual incomes of people in natural reserve, Ninghe County, Hangu District, Tanggu District, Tianjin City that are, respectively, RMB 6035, 6911, 7535, 7932, and 7202. We found that the income of people in the natural reserve is lower than other regions, which may also affect their opinion.

The results of the questionnaire survey show that residents in the natural reserve care little about the wetland protection. Owing to the construction of natural reserve, some of their livelihood has been deprived since crop farming activities is forbidden in the natural reserve. Moreover, their education degree is relatively low so that it is hard for them to find other livelihood. There are many farmers in the natural reserve and some of them have no capital goods and jobs. On the contrary, if the resident has substitution livelihood instead of living on wetland production, they are inclined to wetland protection and it will beneficial to wetland protection. Moreover, the land became property of the people who have the usufruct right rather than the natural reserve. The conflict between absolutely unilateral protection and traditional laissez-faire management of wetland often occurs because of the land tenure administration. Therefore, social environment is basically harmful to the protection of natural reserve.

Wetland degradation has damaged the function of coastal ecosystem in daily life, harmed local communities as well as national economies. Coastal social developments have been trapped in a vicious cycle of poverty, resource depletion, and further impoverishment. Even when people become aware of the importance of wetland ecosystems, they still may not be able to change the developing pattern that destroys or degrades these areas unless alternative resources or livelihoods are made available to them.

Wetland significantly influences the hydrological cycle, and hence, the supply of water for people, such as irrigation, water energy, and transportation (Zhao and Lai, 2007; Yanagi, 2008). Scarcity and limitation of water in life or economic use, and reduction of the source water are major challenges that threaten human society and are key factors impeding economic development. The stability of wetland ecosystem is guaranteed by the stability of the water source, such as periodicity of river flood, groundwater. Hydrologic condition can directly change physicochemical property of wetland, and then influence the component and abundance, primary productivity, accumulation of organic and nutrition circle.

Positive effects of dams and other planned facilities on human well-beings may include stabilization of irrigating water for food production, domestic water supply, and flood control. Negative effects may include loss of economic livelihoods, fragmentation and destruction of habitats, disappearance of some species, health issues associated with stagnant water, and loss of sediments and nutrients supplied to the coastal cites. Large dam construction may cause the outbreak of certain diseases, and small dams are likely to have an equal or greater impact on human health because water is essential to human beings and animals (Zhao and Lai, 2007).

Lizigu Dam was built in 1978. We can see in the past 30 years, Lizigu Dam decreased the discharge of the river obviously and reduced the quantity of water entering the Qilihai, the core area of nature reserve of Tianjin. Fig. 6 is the average water discharge of Chaobai River, which was continuing to decrease since the construction dam in general.

The estuaries in the study area are characterized by many muddy river mouths entering into the sea, low levels of flux, and a number of man-made rivers. Since 1970s, water runoff in the downstream of the rivers has decreased rapidly, and most of the muddy estuaries have stagnated due to human activities. Therefore, the dam at the estuary has changed the balance of seawater and sand. The rapid decrease of water runoff in the estuaries and the river, changes of the sea level, and land subsidence have all caused a series of marine problems. In general, water scarcity and

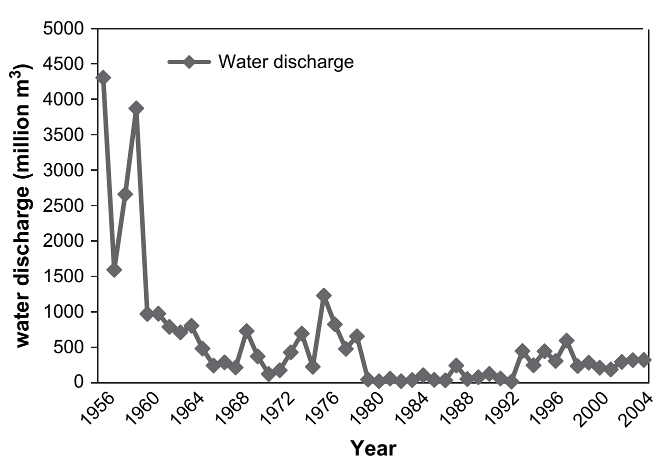

Fig. 6. The changing tendency of water discharge of Chaobai River. Data from: Centre of hydrology and water resources in Tianjin.

reduction of the source of freshwater become a globally significant and serious problem, which may have negative effects on food production, human health, and economic development.

6. Discussion

6.1. Main findings in this research

The wetland change and its causes are become hotspot in global environmental change research (Liu et al., 2004a, 2004b). Understanding the dynamic change is significant for the conservation of wetland biodiversity and its sustainable management (Carreño et al., 2008).

The studied area is located in coastal area of northern China, which faces many environmental problems, such as decrease of water discharge, land subsidence and sea-level rising. Moreover, the area has been undergoing a rapid industrial development and excessive extraction of groundwater which will inevitably affect the ecosystem and marine environment estuarine region. Especially, the sea level here has been rising by approximately 2.2 mm each year. If these issues will not been solved effectively, many negative consequences are likely to emerge. In order to face the challenges of global environmental change and its impacts on coastal zones, we will further study the issues involved to find out effective measures to deal with them. Meanwhile the local government also has taken strong measures to improve the ecological environment since the 1980s.

In the research, the changes of wetland area are studied by remote sensing data in order to analyze implications of temporal and spatial conditions. We find that the area of wetland shows a general tendency of decrease except the year of 1987 due to the special season acquired from remote sensing image. Occupying much wetland for rapid urbanization and economic development in the study area poses negative effect on the wetland protection. Since once the wetland has been converted into farmland or other land use, it would be very hard to be restored and we will suffer great potential damages.

6.2. Limitation of this research

We should also notice the limitations of this research. This paper adopts Landsat TM and ETM+ remote sensing data to monitor the wetland change in Tianjin, northern China and analyzes its causes. Therefore, the quality of Landsat TM and ETM are the most important factors affecting the remote sensing classification results in general. As a matter of fact, there exist two confinements using Landsat TM data. One is that the spatial resolution of Landsat images is 30 m, resulting in a 900 m^2 (0.09 ha) minimum mapping unit (Carreño et al., 2008). The minimum plot size for a correct discrimination of land cover is 0.3 ha, a threshold substantially higher than the coastal wetland in Tianjin City (Nayak et al., 1989). Some small wetland types cannot be detected by Landsat image classification as they may be mistaken as non-wetland types. Moreover, the phases of these remote sensing data may also be unable to reflect the actual wetland area in different seasons. On the other hand, though the Landsat data have been properly processed, but some minor errors caused by the sensor system and atmosphere factor could not be neglected in the research. Otherwise, this will lead to differences in the end. Moreover, there exist many factors causing wetland change, such sea-level rising, climate change, human activities, and hydrologic factor etc. But more importantly, the couple relations between them are very complicated involving many other aspects. This research only investigated the natural factors and human activities leading to wetland changes; their intrinsic mechanism needs intensive studies in future.

7. Conclusion

The causes of wetland pattern changes are important not only for the management and planning of these coastal areas, but also for a better understanding of the role that human activities play in environmental change in a regional or global way. The change of wetland area and its causing factors are heatedly discussed in wetland science. One of the fastest developing regions was selected for the research on the wetland change and its causing factors. This study has demonstrated the usefulness of the technologies of satellite remote sensing, digital image processing of changing statistics for the past 20 years. Furthermore, this research also analyzed the influence of natural and anthropogenic factors upon wetland changes. The precipitation and evaporation show decreasing tendency from 1954 to 2005. Decreasing precipitation as a result of climate change will aggregate the problems of wetland ecosystem. Climate change will exacerbate impacts of other factors in wetland degradation. In the end, measures are appealed to be taken to respond to the environmental change, and for maintaining the balance of wetland ecosystem are proposed to keep the wetland from degrading and decreasing.

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