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WETLAND LANDSCAPE CHANGES AND NATURAL ENVIRONMENTAL PROTECTION IN THE YELLOW RIVER ESTUARY REGION

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Abstract: The Yellow River estuary region is a coastal zone with the fastest evolution. There exist typical newly-formed river estuarine wetland and coastal wetland. It is also a fast developing economic region. Land-ocean interaction and human activities have deeply made impacts on the landscapes in this region. This paper studies the characteristics of wetland landscape changes through comparing the shape and area of the coastal zone, the areas of natural and artificial wetlands in different years, and provides some measures to prevent coastal erosion and protect natural wetlands.

Key words: The Yellow River estuary region, Wetland landscape, Environmental change, Natural protection

1. INTRODUCTION

In the Yellow River estuary region, there is the most active land-ocean interaction in the world because of the river flow with the most sediment concentration and the sea with the typical weak-tide character. Large quantities of silts have been deposited to form new land and have extended toward the sea continuously, so as to develop a vast area of river estuarine wetland and coastal wetland. On the other hand, according to the natural rule, the tail course of the Yellow River wanders and changes its channel cyclically, and the old estuary would be eroded when the course changed off because of lacking supply of sediment. Since 1970's, it has made great effects to stabilize the river course artificially. But the land-forming speed has slowed down and the coastal erosion has intensified due to the aggravation of the Yellow River flow disruption in the low flow period. Further more, the Yellow River estuary region plays more and more important role in economic development and natural protection. The region is the important bases of china in both petroleum industry and food production, and there also exists a national nature reserve which aims at protecting newly-formed wetland ecosystem and those rare and endangered birds. This context must be considered when we study on wetland landscape changes in the Yellow River estuary region. Therefore, "Development and Conservation in the Yellow River Delta" has been listed in the priority projects for *China's Agenda 21st Century.*

The status of estuarine wetland and coastal wetland changes can reflect the impacts of land-ocean interaction and human activities. The research region includes the current river course Qingshuigou estuary formed since 1976, the old river course Diaokouhe estuary before changed its channel in 1976 and the coastal wetland located in the Yellow River Delta, which

is from the Taoerhe River estuary northwest to the Zimaigou River estuary southeast. Based on the causes of formation, wetlands in the research region can be divided into the Yellow River bottomland, newly-formed estuarine wetland, coastal wetland, interfluve depression, interface depression wetland, river, reservoir, pond, channel and other manual wetlands. According to landscape types, the area of terrestrial wetlands is 4167 km^2 occupying 9.3% of the total area of the Yellow River Delta, in which the natural wetlands (such as river, estuary, coastal wetland, marsh and reed wetland, meadow wetland, shrub and sparse forest wetland) cover 3131 km^2 occupying 69.3% of the area of terrestrial wetlands, and the human-created wetlands (such as paddy field, reservoir, channel, prawn pool and salt pan) cover 1036 km^2 occupying 24.9%.

The paper pick-ups wetland information from remote sensing images in different periods, and revises the "land-sea interacting line" into the zero meter of the Huanghai Sea (the elevation datum of China), then combines related statistical data with wetland area and landscape changes acquired by investigation. On the basis, we put forward some measures for the development, management and protection in the Yellow River estuary region.

2. EXTENSION AND EROSION OF THE YELLOW RIVER ESRUARY

The driving forces of the estuarine wetland changes mostly come from land-forming due to the Yellow River sediment and land-ocean interaction. During the flowing period of the tail course of the Yellow River, large quantities of silt have been deposited in the estuary zone and made land rapidly extend to the sea. However, when the river changed its course, the land would be eroded by sea due to no sediment accumulation. What is the rate of extension and erosion of the estuarine wetland? Which situation is the whole wetland in the modern Yellow River delta during a rather long period? These questions would be answered by data supporting.

In order to look for the answers of above questions, we compared three satellite images taken at different time (Jun. 2, 1976; Jun. 5, 1986; Sept. 20, 1996). However, this is a mud coastal zone with a very small slope. Obviously the measured results would have large errors if we simply compared those images of coastal waterlines that were at different tide faces. Therefore, we revised them into the annual "zero meter line of the Huanghai Sea", the elevation datum of China, by using the data of local tide and water-depth, to set a comparable criterion (XU Xuegong, 1986; FAN Zhaomu et al., 1992). Then we overlay the three images' zero meter waterlines. The result (Fig. 1) shows the delta shape has changed in the 20-years period due to land-ocean interaction. With a place named Wuhaozhuang as a division, the south-eastern is the current estuary zone, mainly accumulating and extending; the north-western is the old estuary zone, mainly eroding. Based on this division, we have calculated the area changes (Table 1).

Table 1 The area changes above the zero meter lines in the current estuary and old estuary (1976-1996)

Years	Current estuary (Qingshuogou)		Old estuary (Diaokouhe)		Modern River Delta	
	Area Change (km^2)	Rate (km^2 / a)	Area Change (km^2)	Rate (km^2/ a)	Area Change (km^2)	Rate (km^2 / a)
1976-1986	+ 386	+ 38.6	- 167	- 16.7	+ 219	+ 21.9
1986-1996	+ 117	+ 11.7	- 68	- 6.8	+ 49	+ 4.9
total	+ 503	+ 25.15	- 235	- 11.75	+ 268	+ 13.4

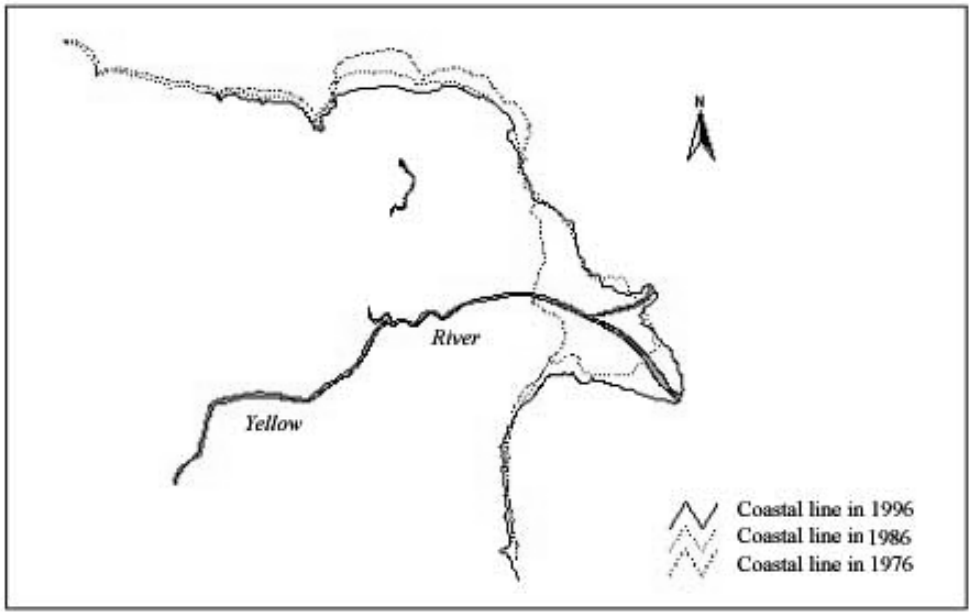

Fig. 1 The changes of coastline of the Yellow River estuary from 1976 to 1996

Fig.1 shows that the current estuary has been extending, where the area above zero meter line has increased 386 km^2 from 1976 to 1986, and 117 km^2 from 1986 to 1996; but the Diaokouhe old estuary has been eroded, where the area has decreased 167 km^2 during the former 10 years and decreased 68km^2 in the latter 10 years. Totally the area of the modern Yellow River delta has increased 219 km^2 during the former 10 years and increased 49 km^2 in the latter 10 years. The rates of evolution reduced gradually, which are related with the changes of silts carried by the Yellow River and the depth changes of the shallow sea.

In 1996 the current tail course of the Yellow River (Qinshuigou) was changed its channel to northeast by manpower below the Qing 8 cross section. The similar status occurs that the new estuary extends and the old estuary erodes gradually. In addition the flow disruption of the Yellow River became much more severe to cause scarce silts supplement. It has been paid more attentions to the issues such as estuary erosion and wetland area decrease.

With the land forward and sea backward in the Yellow River delta, other natural features are also in succession. From shore to inland, soil desalting process intensifies, and vegetation changes gradually from barren land to halophytic vegetation and to general grass. At the same time, overall natural landscapes have corresponding changes, especially coastal wetland and estuarine wetland.

3. THE CHANGES OF TYPICAL WETLAND LANDSCAPES

We chose several typical wetland landscapes to investigate their changes. There are two data sources: the data in 1988 come from the land resources survey including the following four related administrative units as Dongying District, Hekou district, Kenli county and Lijin county; the data in 1996 are according to the remote sensing images interpreting result and relative statistical yearbooks.

3.1 EXPLOITING HUMAN-CREATED WETLAND

Fig.2 illustrates the area changes of paddy field, salt pan and prawn pool from 1988 to 1996.

In the eight years from 1988 to 1996, the area of paddy field has decreased 1193 hm^2, but that of salt pan increased 3179 hm^2, and that of prawn pools has increased 16617 hm^2. Yellow River flow disrupted seriously in the low flow period, while rice planting was so lack of water that it would cause yield reduction or rather no harvest from paddy field. As a result, local people have reduced the area of paddy field. On the other hand, the area of salt pan and prawn

pool has increased, which shows that the exploitation was strengthened in the foreshore and the place above tide zone.

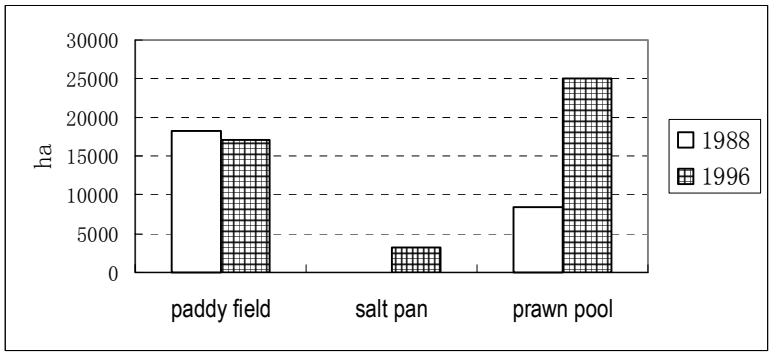

Fig. 2 The area changes of paddy field, salt pan and prawn pool from 1988 to 1996

3.2 FRESHWATER WETLANDS

Freshwater wetlands involve the wetlands for water storage such as reservoir and pond, and the wetlands for transporting water such as river and channel. From another aspect, reservoir and channel belong to manual wetlands, and river and pond belong to semi-natural wetland (The Yellow River has been controlled by manpower in the region).

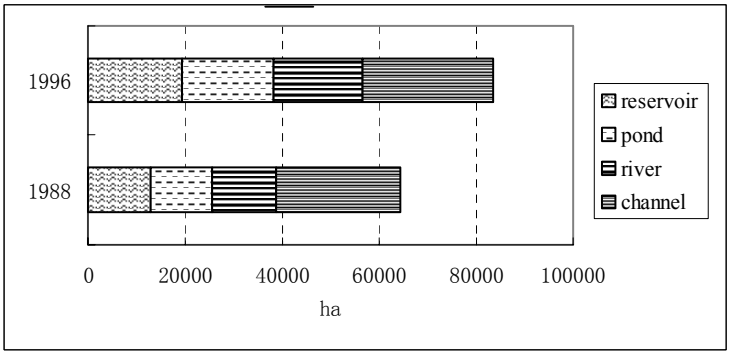

Fig. 3 The area comparison of reservoir, pond, river and channel between 1988 and 1996

In the Yellow River delta, because of the groundwater with high salinity cannot be used for industry, agriculture and living, the Yellow River is almost the only one freshwater source for existence and development in the region. Along with severe flow disruption, water supplement and utilization appears to be more and more conflicting, and local people have built many plain reservoirs and ponds. Furthermore, with the Yellow River extending to the sea, the river length and area are increasing. From 1988 to 1996, freshwater area increased: reservoirs +6377 hm^2, river +5111 hm^2, pond +6310 hm^2, channel +1407 hm^2. Totally water transportation and storage has been strengthened, but the quantity of coming water in the region does not make us optimistic.

3.3 NATURAL WETLANDS

In this part we compare the reed area and foreshore area. Fig.4 shows the result.

With land extending and new-forming in the Yellow River estuary, large area reeds have grown up in the depressions of both sides of the Yellow River, as well as in the coastal depressions. In the research region the Yellow River Delta National Nature Reserve was established in 1992. So natural reed wetland has been protected well, and its area increased (+599 hm^2) in 1996 compared with that in 1988, although there is the impact of the Yellow

River flow disruption. The area of foreshore decreased 16336 hm^2, which mainly results from oil extraction and salt pans and prawn pools development in the coastal zone. In addition, the area of the wetland above tide zone and meadow decreased as a result of being cultivated and often interrupting water resource supplement. In the interleaving zone between coastal wetland ecosystems and terrestrial wetland ecosystems, the landscape patch density index is rather high (BU Rencang et al., 1999), and the landscape diversity index is also high (CHEN Liding et al., 1996).

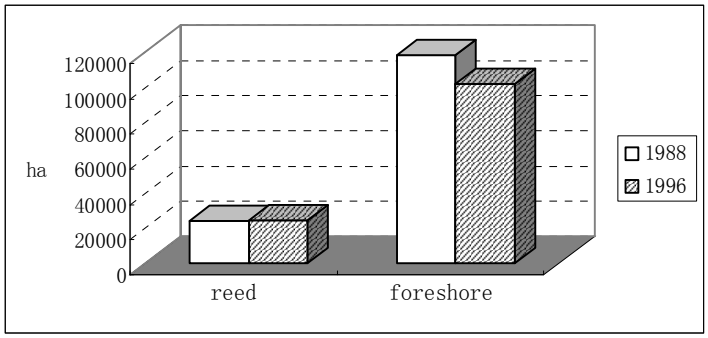

Fig. 4 The area comparison of reed and foreshore between 1988 and 1996

4. THE PROTECTION MEASURES OF THE WETLAND

The wetland protection in the Yellow River estuary region must involve controlling coast erosion, ensuring ecological water demand and making natural conservation. These different measures should be adopted aiming at the issues in different parts of the region.

4.1 CONTROL COAST EROSION BY MEANS OF ENGINEERING AND BIOLOGICAL MEASURES

The Diaokouhe old estuary is an eroded segment. Here the coast nearby Feiyantan oil field has backed off 11 km, consequently the Chengdao oilfield once established in the foreshore have become a shallow sea oilfield now. Coastal erosion has great impacts on production of oil fields. At the same time, partial sections of Qingshuigou flow course have been eroded too, for instance, seawall in the Gudong oilfield are eroded seriously. So in the import segments which are much relevant to oilfield production and city defense, engineering measures must be adopted to control coastal erosion and prevent from storm tides. In this aspect Shengli Oilfield and Dongying City have made great efforts. For example, Gudong seawall was designed to stand with the one-time-within-50-years storm tide. The protective revetment of seawall in water-side was constructed by using platform and duplicate section structure, and adjuvant groynes were built to abate wind wave and reduce erosion strength. Dongying urban district seawall to be finished is also designed as the criterion of one-time-within-50-years. In addition, there is an anti-storm-tide command system and other supporting facilities. Certainly these engineering structures are able to efficiently defend against storm tide disaster and coastal erosion. Besides coastal engineering, subsidiary biological measures must be adopted such as cultivating coastal Chinese Tamarisk (*Tamarix chinensis Lour.*) forest, building coastal shelterbelt, resuming and reconstructing coastal wetland vegetation and constructing hazard prevention buffer zone and so on.

4.2 GUARANTEE THE TRANSPORT-SILTS WATER AND THE ECOLOGICAL WATER

The delta region is the tip end of water utilization of the Yellow River. Because of the water shortage, a saving water supply system for production and lives must be established. In the meanwhile, the watercourse transport-silts water and the ecological water must be

guaranteed. Since the water sediment concentration has been on the decline in the lower Yellow River after Xiaolangdi Reservoir was built，only sufficient transport-silts water can ensure the Yellow River course a straightway, and improve the river status to control flood efficiently. Except for the functions mentioned above, the water can maintain current estuary with certain sediment, and also keep balance of nutrient salt in the sea nearby the estuary, and it also water can be supplied for wetland by the leakage from both sides of the river. The transport-silts water plays an important role on protection of river wetland, estuarine newly-formed wetland and shallow sea wetland.

Ecological water utilization mainly consists of such water for wetland natural vegetation and for manual protective forest. The ecological water can be divided into ecological water demand and environmental water demand. The former includes wetland vegetation demand water, soil demand water and wildlife demand water, and the latter refers to the water supplement for environmental consumption every year, and includes water demand to dilute and clean pollutants. Considering above aspects, the total ecological demand water can be calculated in order to afford foundation for decision of water distribution.

4.3 PROTECT WETLAND ECOSYSTEM IN NATURAL STATE

The National Nature Reserve of the Yellow River Estuary is a resources conservation area mainly for protecting the wetland ecosystem newly-formed and rare-endangered birds. There are the youngest estuary wetland and large area of original coastal wetland. And this reserve provides the birds with exceptional habitat for breeding, migrating and wintering, and becomes an important international “transfer station” for bird migration. Since the ecosystem is very vulnerable, except for some necessary patrol roads and management facilities it must make the most of maintaining in original state to process natural succession. Therefore a unified tidal barrage system must be planned and designed in the whole delta, but different measures should be adopted according to different functional zones. For instance, in the current estuary zone, the tidal barrage should not be constructed because this place requires natural exchange between tide and freshwater, thus coastal wetland ecosystem and its biodiversity can be maintained. Newly-formed wetland ecosystem in the estuary zone has some unique characteristics in the world. If human intervention decreases its value, the loss is incalculable.

5. CONCLUSIONS

As above, by studying on wetland landscape changes of the Yellow River estuary zone, we have following conclusions:

1. From the area and shape changes of the estuary and coastal zone during 20 years, the current river course (Qingshuigou) estuary zone had made 503 km^2 newly-formed wetlands which extending continuously, but the older river course (Diaokouhe) estuary zone had been eroded and decreased 235 km^2. The coastal wetland has changed fast. Although the total land area has been increasing, the changing speed tends towards lower.

2. We compare with the wetlands area changes in different years including manual exploiting wetland, freshwater wetland and coastal natural wetland separately. In general, manual wetlands expand continuously, in which the salt pans, prawn pools, reservoirs and channels increase but paddy fields decrease because of the Yellow River flow disruption. On the other hand, natural wetland has decreased in area, only reed marsh increased a little because of the management of the national Nature Reserve. The changes of wetland landscape well reflect that land-ocean interaction and human activities have made ecological and environmental impacts deeply on the landscapes.

3. The protection of the coastal wetlands and relevant landscapes in the Yellow River estuary region need a unified planning and an integration of engineering and ecological

measures. But special measures should be adopted in different functional zone. In the sections related to oilfield and city, engineering measures must be adopted to control coastal erosion and prevent from storm tides. At the same time, combining with biological measures to resume and reconstruct coastal wetland vegetation, a hazard prevention buffer zone will be set up. In the current estuary zone, the tidal barrage is not suitable to construct where exchange between tidal water and freshwater is required frequently so as to keep the succession of coastal wetland ecosystem under natural state. In the mean while, the watercourse transport-silts water and the ecological water must be guaranteed. The research result would provide scientific basis for decision-making of water distribution.

In a word, only by harnessing, developing and protecting in the Yellow River estuary region in accordance with natural rule, and by improving the occasion to land-human harmony, can the Yellow River estuary region tend towards great environmental stabilization, resources sustainable utilization and regional sustainable development.

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