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Recent Environmental Changes Influenced by Human Being in Lower Reach of Yellow River

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황하강 하류지역에서의 인간에 의한 최근 환경변화

Abstract : Under background of global change, regional and local environmental changes in short-term are significantly influenced by human activities in recent time. This paper deals with serious environmental problems which has become a barrier of sustainable development in the lower reach of Yellow River due to over use of diverted water from Yellow River and underground water from coastal plain. Some countermeasures for improving local environment and economic development are introduced in the paper.

Key Words : Lower reach of Yellow River, Human impact, Recent environmental change, Environment project

요약 : 중국 동부해안 저지대는 지구적 환경변화에 민감하다. 이 지역의 장기간에 걸친 환경 변화는 주로 지구 기후변화에 따른 해수면의 변동에 의한 것이라는 증거가 나타나고 있다. 예를 들어, 마지막 빙하기(약 18,000년 전)동안의 해수면은 현재보다 130-150m정도 낮았다. 이 때는 해안선이 현재의 해안보다 동쪽으로 수 백 km까지 확장되었었기 때문에, 보하이만과 황해는 존재하지 않았고 동중국해 대륙붕의 절반이상이 평평한 해안 평야였다. 이와는 반대로 Holocene(약 5,000-6,000년 전)의 "최적 기후(Climate Optimum)"환경이 지속될 때의 해수면은 현재보다 높아서, 보하이만, 황해 그리고 동중국해의 해안평야지대에서는 해침 현상이 나타났다. 이에 따라 천진(天津)과 강소성(江蘇省)북부 지방에서는 현 해안선에서 서쪽으로 100km이상 들어간 지역에 조개껍질이 포함되어 있는 높은 모래 마루(sand ridges)가 분포한다. 이러한 사실로부터 우리는 상해(上海)와 천진(天津)과 같은 대도시 지역의 인간 문화의 역사가 채 5,000년이 되지 못한다는 것을 알 수 있다.

중국 동부해안지역에서의 단기적인 환경변화는 전지구적 기후 변화와는 별도로 인간 활동에 의해 많은 영향을 받는다. 1970년대 이후 천진(天津)지역에서 한해 평균 70mm씩 지반이 침하된 것은 해수면 상승에 의한 것이 아니라, 지나친 지하수 개발에 따른 것이다. 이에 따라 1985년 이후 천진(天津)지역에서의 지하수 이용은 엄격하게 제한되고 있으며 800개 이상의 관정이 폐쇄되어, 그후로 연간 지하수 생산이 2천만m^3 이내로 감소하였다. 이와 함께, 겨울동안 지표수를 관정을 통해 지하로 공급한다든지, 이용하는 지하수의 층과 이용 시간 등을 조절하는 것과 같은 기술적 방법들이 활용되어 현재 천진(天津)지역의 지반 침하 현상은 중단되고 있다.

황하 하류지역에서 1980년대 말부터 연중 몇 개월간 유량이 급격히 감소하는 현상은, 현재의 지연 조건하에서 환경이 인간활동에 의해 교란되는 것을 보여주는 또 다른 예이다. 상류와 중류 지역의 강수량이 적은 상황에서 중류지역에서 허천수를 과다하게 사용하는 것이 주된 이유인데, 이러한 환경파괴에 따라 하류지역에서의 지반침하가 가속되고 황하하구 주변의 육지-해안생태계가 심각하게 교란되고 있다. 중국정부와 과학자들은 현재 이 문제에 많은 관심을 기울이고 있으나, 문제를 해결하는 데는 많은 시간이 필요할 것이다.

주요어 : 황하하류지역, 인간의 영향, 최근 환경변화, 환경프로젝트

Introduction

Under background of global change, regional and local environmental changes in short-term are significantly influenced by human activities in recent time, especially in the deltaic low land and coastal plain(Zhang, 1991, 1992). Richness of natural resources and suitable position allow faster

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economic development and growing up high density of population in the areas. On the other hand, however, serious environmental problems caused by human being, like deterioration of eco-system due to flow stop in the lower reach of Yellow River, and land salinization caused by saline water intrusion due to over extracting of underground water etc., are being increased rapidly(Fang and Liu, 1998; Tian, et al., 1997; Jin and Cheng, 1993; Yin, 1992; Zhaou, 1996). Therefore it is most important to understand geologic and geographic features of river mouth delta and coastal plain for the policy maker of designing integrate development of these areas. Also it is important in use of new techniques to recover a better condition for the influenced areas. This paper deals with tremendous changes of the Yellow River delta, integrate development of the Yellow River Delta, flow stop of Yellow River and its impact and saline water intrusion in Laizhou city at the southern coastal plain of Bo Hai Sea. Dynamic of these changes are analyzed and some countermeasures to preventing these disasters are also briefly introduced.

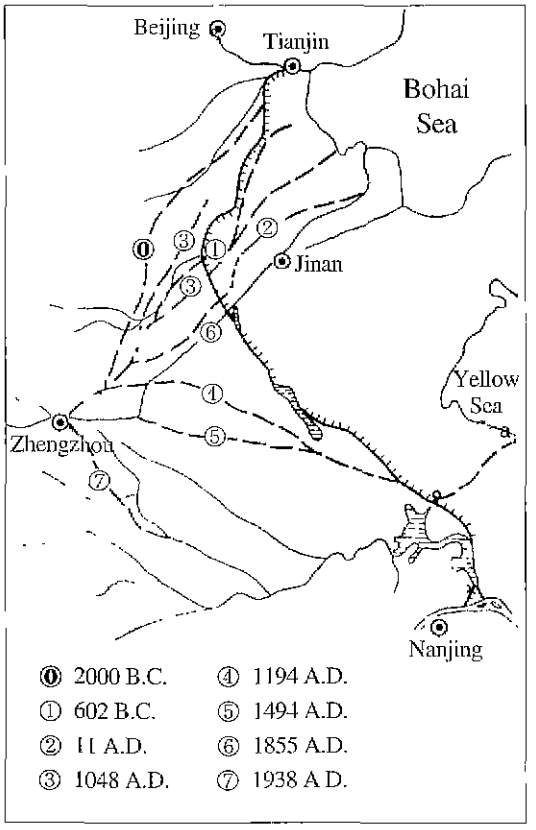


Figure 1. Changes of lower reach of Yellow River since 2000 B.C.(after Jin and Cheng, 1993)

1. Tremendous Changes of Yellow River Delta in Recent Time

The lower reach of Yellow River is a wander river with extremely high content of soil derived from the Loess Plateau. It shifted in a large area(200,000 km^2) in the history, north to the Hai He and south to the Changjiang(Yangtse River), resulted in formation of the great North China Plain(Figure 1). Chinese people started to build embankments along the river to protect flooding since 602 B.C.. However bursts and shifting of courses had emerged for more than 1500 and 5 times respectively in the past 2500 years before 1946 A.D., which resulted in big disasters often occurred in the area. After a burst of 1855, a new Yellow River Delta formed with the apex placed at Ninhai(Figure 2) owning an area of 5,450 km^2. Due to extension of river mouth, the apex shifts down to Yuwa from Ninhai and the area of youngest delta decreased by 3,200 km^2. However ongoing sediment transport brings large number of soil to the Yellow River Delta, resulting in delta expansion rapidly, by an average rate of about 2,000 ha a year. The Yellow River inside the delta had changed its courses for more than ten times in 1855-1976, roughly once each ten years. For the need of environmental protection and development of the Shengli Oil Field, the channel of Yellow River(Diaokou He) was cut off at the Xihekou in May of 1976, forced it flowing linearly eastward along with the Qingshue He. Since than the mouth

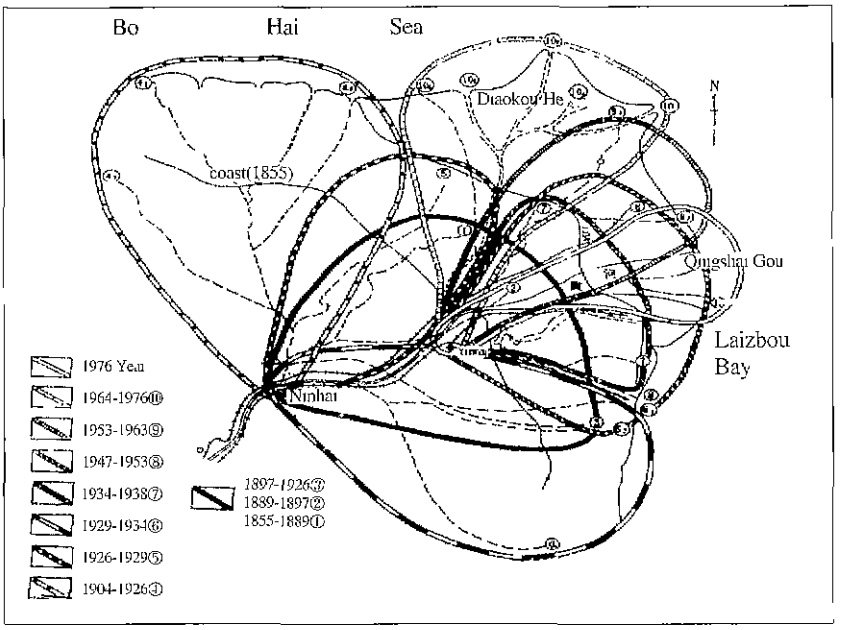


Figure 2. Tremendous Changes of the Yellow River Delta since 1855 A.D.(after Jin and Cheng, 1993)

of Yellow River(Qingshue He) rapidly expensed by average rate of 3-6 km a year with maximum of 10 km a year. The former river mouth(Diaokou He) at the northern side of the delta is being retreated by oceanic erosion. Therefore the shape of Yellow River Delta has varied markedly(Fang and Liu, 1998). Since 1949 burst has not ever emerged and the channel has being controlled within the man made embankments along the Yellow River. Which resulted in great number of soil deposited inside the river bed by an extremely high deposition rate, 14 cm /yr. in 1954-1959 and 5.9 cm/ yr. in 1959-1983(Jin and Cheng, 1993).The lower reach of Yellow River has become a hanging ground river and increased its elevation yearly.

Main Characteristics of Yellow River depend on its extremely high content of soil(36.9 kg/m^3 in average). For aiming to decrease input of soil into the Yellow River, several projects of planting trees and soil reserve on the Loess Plateau and in the river basin have been implemented for decades of years. And a large number of reservoirs in deferent size, Sanmen Gorge Reservoir for instance, were built up since 1960's. All these efforts have made a great benefit to the local people. However the accumulated problems in the history still exist and many new problems are emerged. So, how to reduce the danger of flooding along low reach of the river, how to make sustainable use of natural resources in the lower reach of the river effectively, and also how to protect the environment properly in the area, has been a long term project to the Chinese Government and scientists.

2. Integrated Development of the Yellow River Delta

In fact, the Yellow River Delta has been listed amongst the "China's Priority Projects on the Agenda 21". As a result, the government of Shangdong Province has decided to set up a project for the integrate development of the delta. Development efforts have created the conditions

for a full range of development project in this region to expand. Five immediate objectives were identified:

a. to build an information system for environmentally sound economic development;
b. to set up an experimental area for environmentally sound agriculture;
c. to harness the Yellow River Delta;
d. to establish a wetland conservation area; and
e. to build a petroleum pollution monitoring and fast response net-work.

Problems concerning population, natural resources and environment should be resolved through integrated planning, by coordinating social development and ecological environment in order to improve and maintain regional sustainable development. Based on this rational, the key project, in title of Yellow River Delta GIS(YRDGIS), leaded by the National GIS Laboratory in the Institute of Geography, Chinese Academy of Sciences, is focusing on the main works of integrated planning, management and regional sustainable development in the Yellow River Delta. An integrated plan for the Yellow River Delta, including in land use planning, nature reservation, developing of the oil field, planning for agricultural expansion, effective treatment for air and water pollution etc., now is going to improve by municipal government(Fang and Liu, 1998).

3. Flow stop of the Yellow River and its impact

Yellow River is the second largest river in China, which had nurtured Chinese people and long historical culture. However, annual mean runoff value of the Yellow River is quite small, varied in 280-550 $\times 10^8$ m^3 a year only(near by Zhengzhou). Due to rapid increasing of diverted water for irrigating in the middle and lower reach of Yellow River, under the background of less precipitation in the basin in past 20 years, flow stop of the river emerged, and increased days and distance subsequently since 1972(Table 1, Figure 3).

We can see on Table 1 and in Figure 3 that the flow stop of Yellow River had not ever emerged before 1950's. Because water was not diverted in the lower reach of Yellow River and the diverted water from middle reach of the river was relative small, ranging in 40-50 $\times 10^8$ m^3 only. Since 1970's, total value of diverted water in both middle and lower reaches rapidly increased from about 200 $\times$ 10^8 m^3 to 280 $\times$ 10^8 m^3, and it reached the maximum of 334 $\times 10^8$ m^3 in 1989 which is almost the same to the total usable runoff value of the river. The flow water of Yellow River is mainly nourished by monsoon rainfall, and more than 60% of annual precipitation, varying in 400-700

Table 1. Relationship between flow stop and diverted water and runoff in the lower reach of Yellow River*

Year	Mean annual runoff at Huayuankou (10^8 m^3)	Diverted water in mid-reach(10^8 m^3)	Diverted water in lower reach(10^8 m^3)	Total days of flow stop
1920's	398	40.4		0
1930's	497	48.8		0
1940's	543	53.4		0
1950's	482	113	11.3	0
1960's	503	151	24.3	0
1970's	379	165	81	86
1980's	411	180	106.6	105
1990-96	288	182.7	97.2	491

* data from You Lianyuan, 1998, in press.

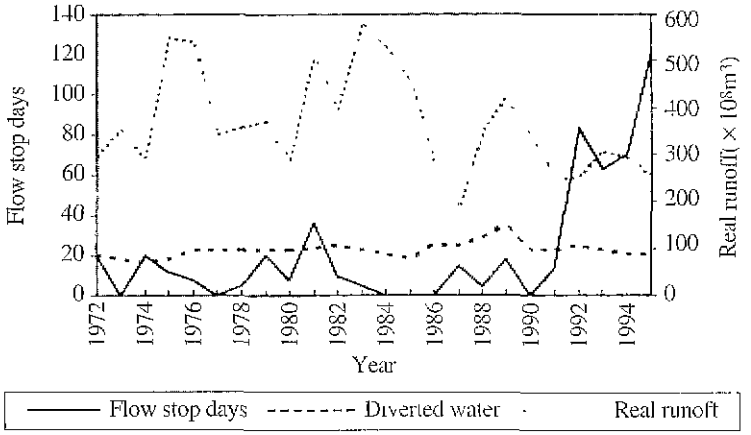


Figure 3. Comparison amongst changing course of flow stop days(solid line), diverted water volume(dash line) and real runoff(fine dash line) (after Tang Qicheng, 1998)

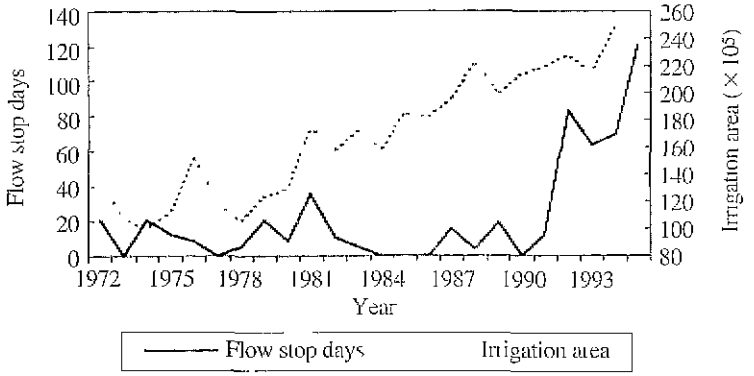


Figure 4. Changing course of flow stop days(solid line) and irrigation area(dash line) in 1972-1995(after Tang Qicheng,1998)

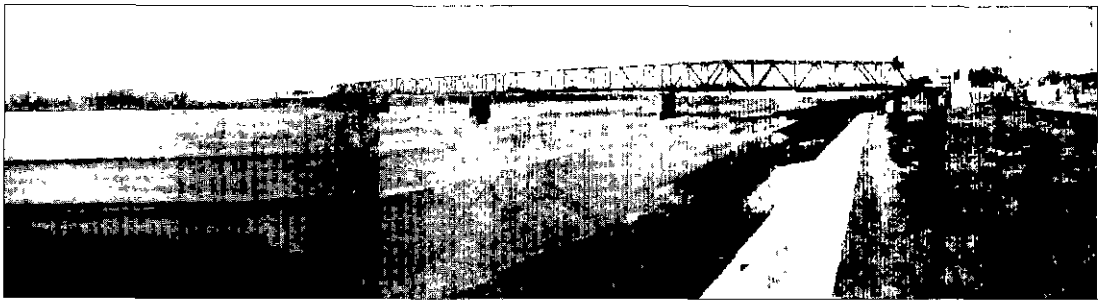


Figure 5. Total 122 days of flow stop emerged in the lower reach of Yellow River between March and October in 1995. This photo taken by Prof. Dai Qing on May 14,1995 at Lijin of Shandong province, showing the sandy river bed completely dried up.

mm/a, concentrated in July and August. While water diverting from the river for irrigating is concentrated in the Spring and late Autumn seasons, when runoff in the Yellow River is relatively small, flow stop thereafter emerge frequently in Spring and late Autumn times. So the flow stop of Yellow River is closely related with water diverting(Figure 4, Figure 5) (You, 1998; Tang, 1998).

A series impacts have emerged followed by flow stop of the Yellow River. Difficulties of water use seriously existed in many cities along the lower reach of the river. Which forced industrial production to be decreased. Direct economic lose by the flow stop in 1995 was more than 500 million US dollars, and the Shengli Oil Field lost 50 million US dollars due to interrupting of production. Impact of flow stop in agriculture in the lower reach of the river, especially in the delta area is most significant. Lack of irrigating water resulted in unable to planting and production decreased seriously and or without any harvest in these areas. Some 1,500,000 t of wheat product, which coasts about 250 million US dollars, decreased in the delta area in 1995. Land degradation developed rapidly. Accumulated water and soil pollution and decreased nourishment due to flow stop greatly influenced upon eco-system and or partially damaged bio-diversity in the lower reach and delta. There are more than 800 species of aquatic biota, about 100 species of wild plants, 187 species of birds existed in the wetlands and beaches in and surrounding the delta. These biologic resources are very important for the scientific research and regional sustainable development(Yang, 1997; Cheng et al., 1997).

For aiming to lysis and avoid flow stop of the Yellow River, Some basic countermeasures are suggested and may be implemented effectively. These countermeasures include unifying management in water resources of whole basin of the Yellow River, spreading the advanced irrigating techniques, heightening the price of valuable water and raising the understanding of saving water to the public, and implementing the corresponded scientific dispatch amongst the major reservoirs. The long-term countermeasures consist of implementing of "Water Diverting Project from South to North" and strengthening to resolve the problems on soil erosion in the middle reach of the river(Wang,1997).

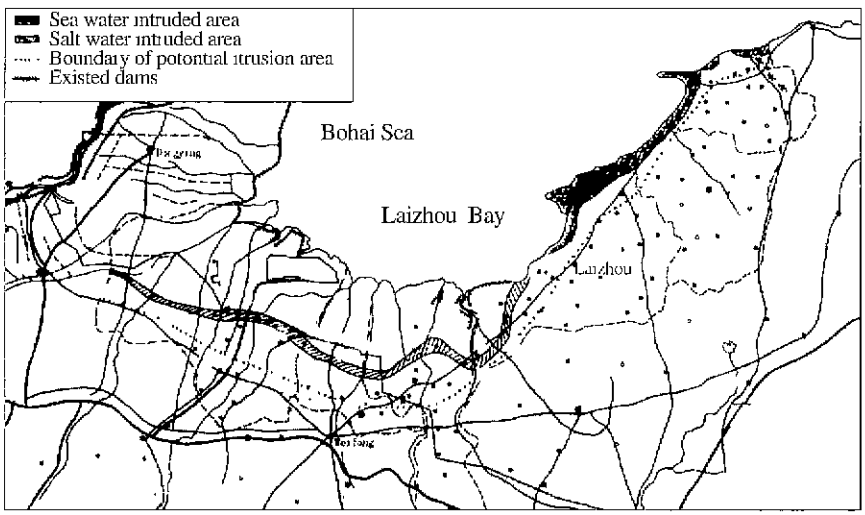


Figure 6. Sketch map of saline water intrusion in the coastal plain of Laizhou Bay(after Zhao, 1996)

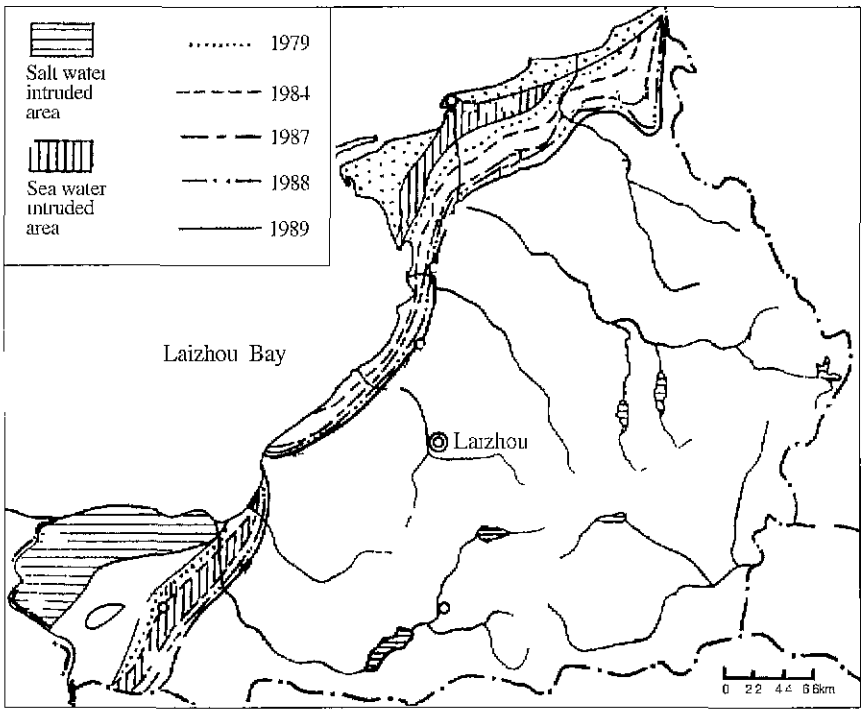


Figure 7. Extension of sea water intrusion at Laizhou county in 1979-1989(after Yin, 1992)

4. Saline Water Intrusion and its Impact to the Coastal Plain of Bo Hai Sea

Disaster caused by saline water intrusion has widely occurred in different level at coastal plain of the world. Since 1970's, saline water intrusion has rapidly developed in the coastal plain surround the Laizhou Bay in south of Bo Hai Sea. The intrusive area expended up to 970 km^2 in 1996 and the potential impacted area may reach to 2,400 km^2 in the Laizhou city. As a result, more than 8,000 of irrigating wells unable use, about 200,000 ha of farm land without irrigating, 300,000 t of wheat and corn decreased, and more than 50 million US dollars lost directly in industrial production in the city in 1996. Therefore the saline water intrusion, has become a serious environmental problem in the area(Zhao,1996) (Figure 6, Figure 7).

The main cause of saline water intrusion is over extracting the underground fresh water, which resulted in the underground water level dropping down below the nearby sea level, and then sea water intrudes toward inland along the buried channel and penetrates in underground gravel layers(Figure 8). The another way is that due to pressure decreasing by extracting of underground water, the saline water, which was trapped in deeper marine deposit layer, expenses upward and mixed into the underground fresh water. Both of them result in the salinization of underground water which is in use of irrigating(Liu Caitang, personal communication).

Countermeasures of decreasing disaster and preventing saline water intrusion, are taking place in Laizhou city area of Shandong Province as follows:

a. to irrigate surface current back to underground during rain season through wells, and to build underground reservoir for increasing of usable

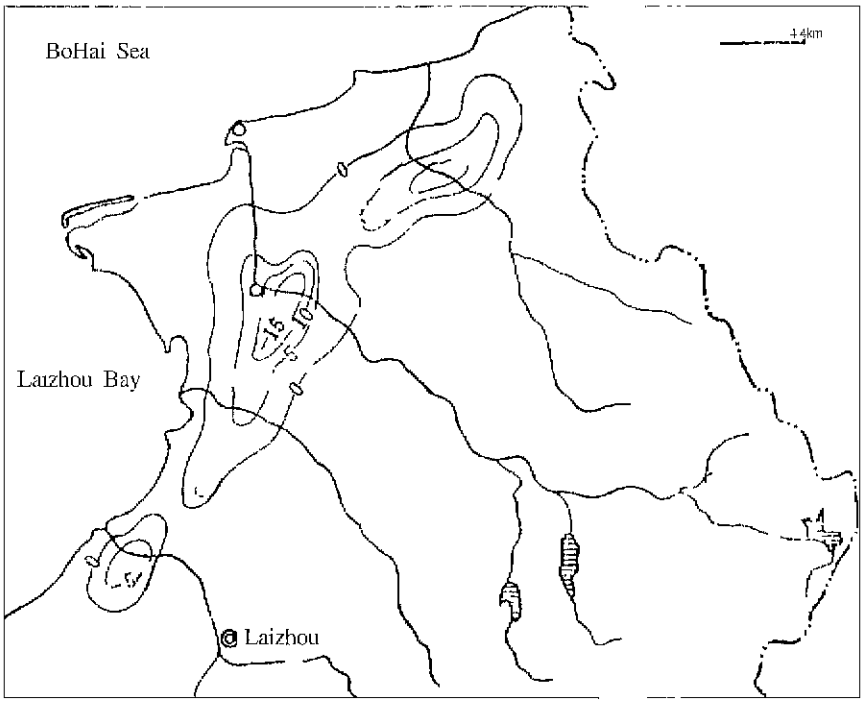
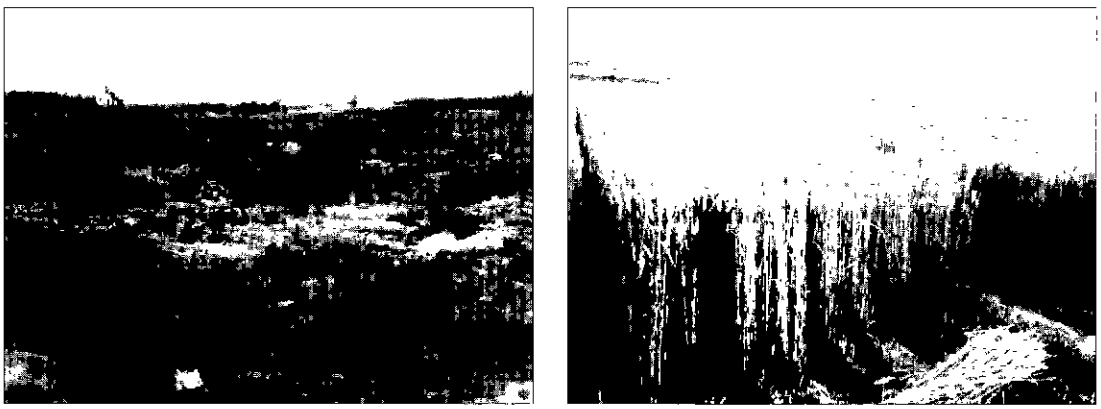


Figure 8. Distribution of underground water level in 1990 at Laizhou county(after Yin, 1992)



(a) (b)

Figure 9. a) Salified land caused by saline water intrusion on the coastal plain of Laizhou Bay(photo by Prof. Zhang Peiyuan on May,1993); b) Salt resisting strains of wheat to be introduced and well growing on the salified land in Laizhou County, which yields 6-7t/ha of wheat(photo by Prof. Liu Caitang, on June, 1995).

fresh water;

b. to build and extent dams and gates at stream mouth for decreasing sea water invasion;
c. to adjust planting structure and spread the advanced irrigating techniques for saving valuable fresh water(Figure 9);
d. to establish a saline water intrusion monitoring system and data bank in Shangdong Province;

e. to carry on integrated experimental research at Laizhou city.

5. Conclusion

Facing challenge of economic and social development under the condition of limited water resources, like northern and central China, it is most important to understand that regional and local impact by human being has seriously increased and which has become a barrier for regional sustainable development Deepening study of science and technology for countermeasure and policy making in improving environment are necessary. Some conclusions may be made as follow:

1. The lower reach of Yellow River, as a hanging ground river by increasing elevation yearly, is a wander river with extremely high content of soil derived from the Loess Plateau. How to reduce the danger of flooding and how to protect the environment along low reach of the river has been a long term project of the Chinese Government and scientists.
2. Yellow River Delta has been listed amongst the "China's Priority Projects on the Agenda 21". An integrated plan for the Yellow River Delta now is going to improve by municipal government. It is an important scientific experiment in China cooperated with government.
3. Due to less monsoon precipitation and rapid increasing of diverted water for irrigating in Spring and late Autumn since 1972, flow stop of the low reach of Yellow River emerged frequently, and many serious problems followed by. For aiming to lysis and avoid flow stop of the Yellow River, Some basic countermeasures, both in short and long-terms, are suggested and may be implemented effectively.
4. Disaster caused by saline water intrusion due to over extracting underground water has rapidly developed in the coastal plain surround the Laizhou Bay in south of Bo Hai Sea since 1970's. Countermeasures of preventing such disaster have been taken place.

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