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Analysis on reasons for the Yellow River's dry-up and its eco-environmental impacts *

Gao Yan-chun

Institute of Geography, Chinese Academy of Sciences, Beijing 100101, China

Abstract—The Yellow River, or Huanghe, is one of the most important river in China. It is the major water resources for north and northwest China. Since 1972, the Yellow River's dry-up has occurred frequently and become even more year by year. Except the huge loss to social life and economic development, the Yellow River's dry-up brings about great impacts to eco-environment. This paper analyzed the reasons and impacts from multi-aspect: effects of climate change, influence of human activities and impacts to delta's eco-environment, aquatic life resources, agricultural eco-environment, water pollution and flood prevention as well.

Keywords: Yellow River; runoff change; human activities; dry-up; eco-environmental impacts.

1 Introduction

The Yellow River is regarded as the cradle of Chinese civilization. Due to its long history and splendid civilization, the river basin had been the center for politics, economy and culture of China for quite a long time in history. It is the second largest river in China, with a vast drainage area of 752443 km^2 and main course length of 5464 km(Fig.1). There are about 20 million hectares of arable land(Liu, 1989) and more than 100 million people inhabited in the basin. The Yellow River is the most important water resources for north and northwest China and plays an irreplaceable role for economic development and social life in these regions(Chen, 1996).

However, since 1972, the first occurrence of the Yellow River's dry-up in its lower reaches, the situation become worse year by year. In the past 25 years(1972-1996), frequency and duration of dry-up, and the length of dry river channel in low reaches increased rapidly (Table 1). In 1995, the length of dry-up channel reached 662 km, accounting for 86% of the whole length of the lower reaches. Dry-up channel traced back to Jiahetan cross section, near Kaifeng City, Henan Province, and dry-up duration exceeded 152 days(Cui, 1996) at the river's estuary. The Yellow River's dry-up has caused huge loss to economic development directly, and produced great potential impacts to the eco-environmental system.

Table 1 Dry-up statistics of Lijin site

Year	Frequency	Annual average days of dry-up	Average length of dry channel	Month of first occurrence
1970—1979	0.6	8	130	May
1980—1989	0.7	9	180	Apr.
1990—1996	0.8	69	300	Feb.

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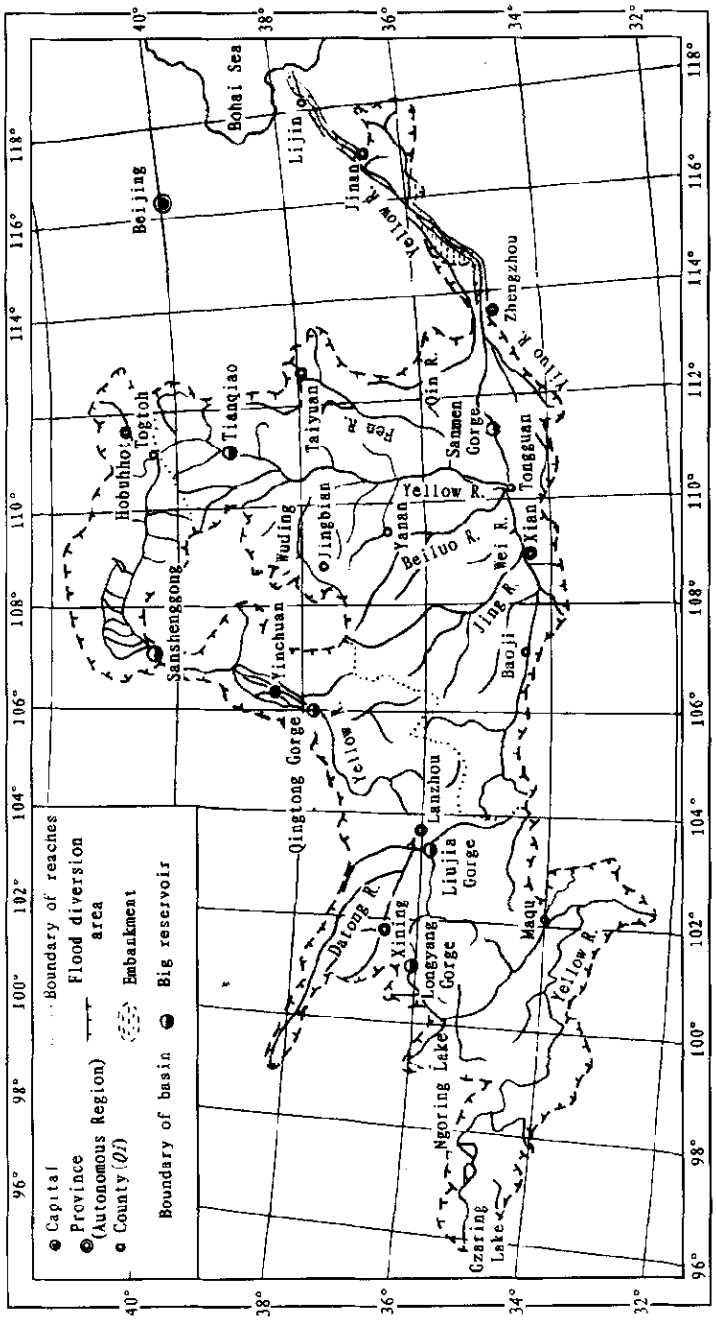

Fig. 1 Sketch map of the Yellow River basin

2 Reasons for the Yellow River's dry-up

There are two possible reasons for the Yellow River's dry-up : natural runoff change and human activities.

2.1 Variation in natural runoff of the Yellow River

Based on statistics data, the annual natural runoff is shown in Table 2. Designating r as the relative change rate of the natural runoff, then

$$r = \frac{R}{\bar{R}},$$

where R is the average in different decades, $\bar{R}$ is the average in whole time(1920—1989). Then, we get the relative change in natural runoff of the Yellow River (Fig.2).

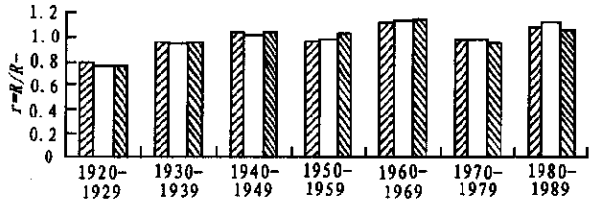

Fig.2 Relative change in runoff of the Yellow River
Lanzhou Hekouzhen Huayuankou

Table 2 Annual natural runoff of the Yellow River basin($10^8 m^3$)

	1920—1929	1930—1939	1940—1949	1950—1959	1960—1969	1970—1979	1980—1989	1920—1989
Lanzhou	267	318	349	325	372	329	366	332
Hekouzhen	253	305	331	321	369	325	368	324
Longmen	318	386	409	399	440	382	410	391
Sanmenxia	389	487	534	528	583	499	540	507
Huanyuankou	438	546	596	595	662	542	609	570

Clearly, the occurrence of the Yellow River's dry-up is not corresponding to low-runoff periods(e. g. 1920's). Contrarily, it occurred frequently in relatively high-runoff periods(e. g. 1980's). Therefore, the variation in natural runoff is not the reason for the Yellow River's dry-up.

2.2 Human activities — source for the yellow River's dry-up

2.2.1 Rapid increase of water demand

Along with rapid economic growth, water demand in the river basin has increased at an unprecedented speed. Based on statistics, annual water demand was 121.7×10^8 m^3 in 1950's, it has increased to 307.2×10^8 m^3 in 1990's, 2.52 times of that in 50's. Under the condition of little change in natural water supply, rapid increase of water demand is the direct reason for the Yellow River's dry-up. The data of water demand growth in different periods and water consumption in different sectors are shown in Fig.3 and Table 3, respectively.

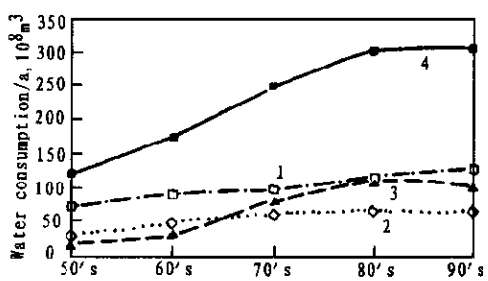

Fig.3 Growth of annual water consumption of the Yellow River basin
1. Upper reaches; 2. middle reaches; 3. lower reaches; 4. whole river

Table 3 Water consumption of different sectors in 1990 ($10^8 m^3$)

	Agriculture	Industry	Domestic use		Total
			City	Country	
Upper reaches	181.38	7.08	1.44	1.40	191.30
Middle reaches	53.53	7.33	1.34	0.73	62.93
Lower reaches	105.21	3.31	1.15	0.00	109.67
Whole rivers	340.12	17.73	3.94	2.13	363.92

2.2.2 Low regulated capacity of water conservancy projects

The Yellow River's runoff is characterized by large variation from year to year and extreme unevenness of distribution in seasons. The peak of water demand greatly asynchronous with flood season(Fig.4). Water resources in low water season accounts for less than 40% of the annual total water resources, while the water demand, at the same time, accounts for 60%—80%. Regulated capacity of dams is very low, about $300 \times 10^8 m^3$, no more than 50% of the average annual natural runoff. And the dams mainly located at the upper reaches. Sanmenxia nearly out of water regulated function due to severe sand silt, is the only dam in the middle and lower reaches. Thus, river's dry-up occurs in the peak time of water demand, while large amount of water flows into the sea in flood season.

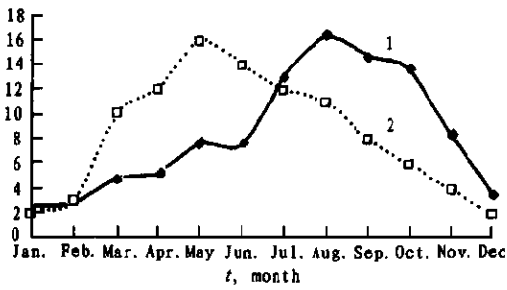

Fig.4 Average distribution in time of water demand and natural runoff
1. Natural runoff; 2. water demand

2.2.3 Poor management of water resources

Poor management is another reason for the Yellow River's dry-up. It is mainly demonstrated in two aspects: water abuse and irrational sharing among the upper, middle and lower reaches.

Water waste is very serious in the river basin. At present, flood irrigation is still prevailing in the rural area. For example, in the irrigation areas of Ningxia and Inner Mongolia in the upper reaches of the Yellow River, irrigation requirement reaches 12300—17100 m^3/hm^2 for its advantageous condition for diversion. Even in the lower reaches, average irrigation requirement exceeds 8000 m^3/hm^2. In addition, industrial water reuses rate is very low, e.g. only 0.5—0.6 in big and middle cities, and merely 0.2—0.3 in small towns, much lower than that of developed countries. Water waste and water shortage have been co-existing for quite a long time in the Yellow River basin.

Strong conflict of water diversion among the upper, middle and lower reaches greatly intensified the crisis of water shortage. Although the State Council of China promulgated the allocation program for the Yellow River's water resources in 1987(Natural Protection Department, 1997), conflicts is far from elimination because the program is only general allocation indexes based on average value of long-term runoff data, without the allocation principle under different natural water supply conditions. Even under the average condition, the program has not stipulated time and amount of diversion for different reaches. In addition, no organization is empowered to direct and supervise the diversion in different reaches and provinces. Thus, it is unavoidable, in a dry year or season, upper, middle and lower reaches are in struggle for diversion. In upper reaches,

advantageous diversion condition and low water price permit flood irrigation. In middle reaches, water is diverted and stored in advance. In lower reaches, there is no water in river channel and dry-up occurs.

3 Eco-environmental impacts

Except the huge loss to social life and economic development, the Yellow River's dry-up brings about great potential impacts to eco-environmental system.

3.1 Impacts to delta's natural eco-environment

3.1.1 Coastal erosion and retreat

The delta is formed by deposition of soil and sand sediment. In average, each year 10.5×10^8 tons sediment is transported to the estuary, and about 73% of the sediment deposits at the delta, only 27% is transferred to deep sea by sea flow. Therefore, the coast expands at an average rate of a 20 km^2 each year, becomes the place with highest growth rate of land resources in the world. However, it is well-known that delta is such a place where cost expansion or retreat depends on the interaction between coastal erosion and sediment deposition. It expands when the deposition speed exceeds erosion speed. Conversely, it retreats. Based on calculation by experts, coast would be in balance when the sediment reduces to 3.7×10^8 tons each year, it would retreat when sediment is less than 3.7×10^8 tons. In the light of statistical analysis, the soil and sand sediment reduced at a rapid speed since 70's. In average, the annual sediment was 13.2×10^8 and 10.9×10^8 tons in 50's and 60's respectively, and reduced to 9.0×10^8 and 6.4×10^8 in 70's and 80's respectively. In the first four years of 90's, it reduced to 4.0×10^8 in average. According to the data on sediment deposition and coast erosion in the time from 1968 to 1980, the erosion speed was only 1/4 of the deposition speed. In the meantime, the occurrence rate of dry-up was 54%, and the average annual dry-up time was 6.9 days. But in the time from 1991 to 1995, the occurrence rate reached 100, and the average dry-up time came to 68 days each year, and the erosion speed had increased by 10 times. At this speed of deposition reduction and erosion increases, the delta coast will be changed from expansion now to retreat by the year of 2000, and unavoidably, a series serious environmental issues will be brought about.

3.1.2 Impacts to groundwater

Almost all ground water of the Yellow River's delta is pore water in loose rock. It consists of three types: fresh, salt and halogen ground water. Fresh water occupies 4% of the total area of ground water, while salts and halogen ground water account for 70% and 20% or so respectively. Variation of ground water depth is controlled by the changes of hydrological, meteorological conditions and the alternation of seasons. The Yellow River's dry -up, on the one hand, directly reduces the ground water supply from river seepage. On the other hands, the consumption of fresh ground water is raised because there is no water from the Yellow River for irrigation. Therefore, it is inevitable that the Yellow River's dry-up brings about the descent of ground water depth in the delta, and the depth descent of ground water certainly causes sea water invasion, and sea water invasion necessarily worsens the quality of ground water, intensifies the crisis of fresh water shortage.

3.1.3 Vegetation degeneration

The delta's vegetation is mainly grassland. It consists of four types of vegetation: common meadow, saline-hygric meadow, and saline vegetation. It is an eco-system which is very fragile, unstable and easy to degrade. Water and sand resources are two basic conditions for beneficial

evolution of the grassland system, while natural tidal invasion and human over-cultivation and grazing are the important reasons for retrogressive evolution of the eco-system. There are 2.18×10^5 hm^2 grassland in the delta, among which natural grassland is more than 1.85×10^5 hm^2. In recent years, the Yellow River has been diverted for grassland irrigation and the area of artificial grassland is more than 2×10^4 hm^2. The river's dry-up directly brings about serious impact on the growth of artificial and natural grassland. By 1994, irrigation area of fodder grassland reduced to less than 200 hm^2. Without water and sand resources, eco system of grassland is easy to retrogressively evolve, that forage grasses will be substituted by saline-hygric meadow or by common meadow even saline meadow. Obviously, the Yellow River's dry-up is great unfavorable to beneficial evolution of the eco-system of grassland in the delta.

3.1.4 Impacts to offshore aquatic life

There are rich aquatic resources in the estuary of the Yellow River due to the large quantity of land nutrient material. So, the river's dry-up will cause unfavorable influence in multi-aspects on aquatic life of Bohai Sea(Cui, 1996):

Reproduction and growth of aquatic life in Bohai Sea will be greatly impacted for loss of their most important food source;

Many migration fishes will migrate to other place. So, the biological chain of Bohai Sea will break. It will cause great and irremediable loss to Bohai Sea eco-system;

Chlorine density around estuary will rise, which is greatly unfavorable for fish and shrimp's reproduction and growth;

Waste water release will not stop after the Yellow River's dry-up. Thus, water pollution of Bohai Sea will be aggravated. It produces great harm to the reproduction and growth of aquatic life resources.

3.2 Impacts to agricultural eco-environment

There is flood land about 3155 km^2 between dykes in the lower reaches of the Yellow River, among which farmland is more than 2×10^5 hm^2 and about 2×10^6 people inhabits there. Most of the sediment which deposits in river channel or on flood land is coarse sand and soil with feature of low water retaining capacity. Vegetation cover rate of the flood land is extremely low because of obstacle remove in flood season each year for flood release. Because of the river's dry-up, ground water level descends. Under the situation of poor protection of vegetation cover, the flood land is very likely to change into a huge sand band. If so, series unfavorable influences will brought about on local climate and biocommunity, such as local climate drying and biotic population decrease and so on.

The channel of the Yellow River is higher than the farmland along both banks in the lower reaches. It is well-known that sand content is very high in the Yellow River. Thus, there are many sand "dragons" and hills in the past flood inundation area and current irrigation regions. In dry season, sand flies up with wind, and the phenomenon of soil desertization is severe. Additionally, the river's dry-up directly reduces water quantity for farmland irrigation, and supply of ground water is decreased while exploitation quantity of ground water is raised. Therefore, series eco-environmental issues are produced, such as depth descent of ground water, decrease of land evapotranspiration, local climate drying, soil desertization, reduction of biotic population and simplification of biocommunity structure and so on.

3.3 Impacts to aquatic environment pollution

The Yellow River is the most important water resources for northwest China and north China. It is the river in China which is under the strongest influence of human activities. Along with rapid

economic growth and population expansion in the river basin, waste water release increases at an unprecendent speed. In early 80's, annual waste water release was $2.18 \times 10^9 m^3$. It increases to $3.26 \times 10^9 m^3$ in 1990's (Nature Protection Dept., 1995). Contrastingly, runoff in the lower reaches of the Yellow River is reduced at a rapid rate, and dry-up occurs frequently. As runoff is reduced, the ratio of waste water to runoff increases. So, river's purification capacity decreases, and so is the aquatic environmental capacity. Water pollution in the Yellow River's basin, especially in its lower reaches, is aggravated rapidly (Chen, 1997).

For many tributaries of the Yellow River, their pollutant concentrations exceed water quality standard for fishery purpose. Especially, in the middle and lower reaches of some major tributaries, such as Fenhe, Weihe, Huangshui, Yiluohe, Dawenhe, and Sushui rivers and so on, their pollutant concentration has already reached or surpassed the lethal concentration for fishes. Almost all fish has been extinct in those rivers except in some dams or river sources.

3.4 Impacts to flood prevention

Flood has been the most important issue in the Yellow River's control ever since ancient history of China. Frequent flood brought about tremendous loss to Chinese people and repeatedly destroyed eco-system balance in the lower reaches.

Occurrence of the Yellow River's dry-up has produced new difficulties to its flood prevention. Firstly, discharge decrease and seasonal dry-up have changed the scouring model of river channel. Due to small discharge and low velocity of water flow, sediment of soil and sand becomes more likely to deposit in river channel, and the capacity of channel's flood release decreases. Secondly, the Yellow River's dry-up has aggravated soil desertization and produced more sand dunes in the channel's flood land. It most likely produces cross-flow when flood occurs (Li, 1997). Once dyke be breached, the loss of economy and eco-system will be larger than ever before.

4 Conclusion

The Yellow River's control has ever been the most important thing for Chinese people. The Yellow River's dry-up has fully exposed the problems in river administration in China. The same as other rivers in the world (Zhou, 1995), basin overall management is the only feasible way for the Yellow River's control (Cai, 1996), which requests unified planning and overall consideration, requests concert relationship between upper and lower reaches, industry and agriculture, city and country, economic growth and eco-system balance, water exploitation and saving, short-term benefit and long-term objective, law constraint and common education and so on.

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