Understanding changes in ecohydrological processes caused by human interventions for integrated basin-scale water management: Heihe River Basin, northwest China

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Abstract Inland river basin takes up 1/3 of the total area in China, with natural scarcity of water resources and unreasonable utilization. For regional development human activities have changed natural waters system into artificial channels and re-allot water resource in space and time with major projects. They are rebuilding a model of hydrological cycle. It is worth mentioning that impacts of many activities in society and economy on hydrological process are often ignored so that hydrological protection is usually inaccurate. This paper, taking the Heihe river as an example, analyzed human being how to affect hydrological process at a basin scale.

Key Words Water Issue, human Impact, Hydrological process, Heihe River Basin, Northwestern China

1. INTRODUCTION

During the World Summit for sustainable development in 2002, water is identified as the first in a list of five topics, in which others are energy, public health, agriculture and bio-diversity. Water issues focus on water and development, water and environment and water resources management. The quantity of water resources per capita in China ranks number 110 in the world and China is one of the 13 water scarce countries in accordance with the United Nation (Feng Q, et al, 2000). Shortage of water is threatening our economic and social development as well as food security, and there are still around 20 million people in the northwest region who could not access safe drinking water. (Xiao Hongliang, 2000; Feng Qi, et al, 1999).

The northwest inland region covers 1/3 of the total area in China but only occupies 5% of the total water resources. Water shortage has restricted economic development and caused ecological deterioration in the northwest. The rate of water exploitation and utilization is 20% in the state, but 53.3% in the northwest. The rate is more than 70% in rivers along the Hexi Corridor and in Xinjiang province. The mainstream of Tarim river, the biggest inland river in China, has been dried up more than 400 km because of the over-exploitation of water and soil; In the Shiyanghe river there is the most serious water crisis and the highest water utilization rate 154% as well as a lot of ecological refugee. Because 98 reservoirs with water storage capacity of 456.7 million m^3 had been constructed in the Heihe river, the dried river course and lake have become significant sources of sandstorm. State government has been carrying out Ecological

Rehabilitation Engineering Projects in recent decade.

In terms of the China conditions, impact of development of water resource on river hydrological process concentrates changing natural water cycle into artificial water system both for higher benefits of water use and for ecological restoration. Reservoirs and canals replaced river courses and lakes. On the other hand, rapid development of local economy makes virtual water process more and more complex. For these, hydrological prediction should focus on integrated water system, a river basin scale, and understand fully the relationship among water, ecology and economy.

2. WATER RESOURCE AND ITS UTILIZATION

The Heihe River is a typical inland river in northwest of China. It covers an area of nearly 130,000 km^2 and passes through Qinghai, Gansu and Inner Mongolia (Figure 1). Accordance to the integrated characters, the land in the Heihe River Basin is classified into three categories ---- mountain areas, gobi desert and oasis. Of which, gobi desert occupies 57.49% of total area, mountain area covers 33.60% and oasis takes up the remained 8.90% (Table 1). In terms of landscape, the basin is divided into the Qilianshan Mountain, the Hexi Corridor and the Alashan Highland (Figure 2) (Xiao Honglang, et al, 1999; Chen Longheng, et al, 2003).

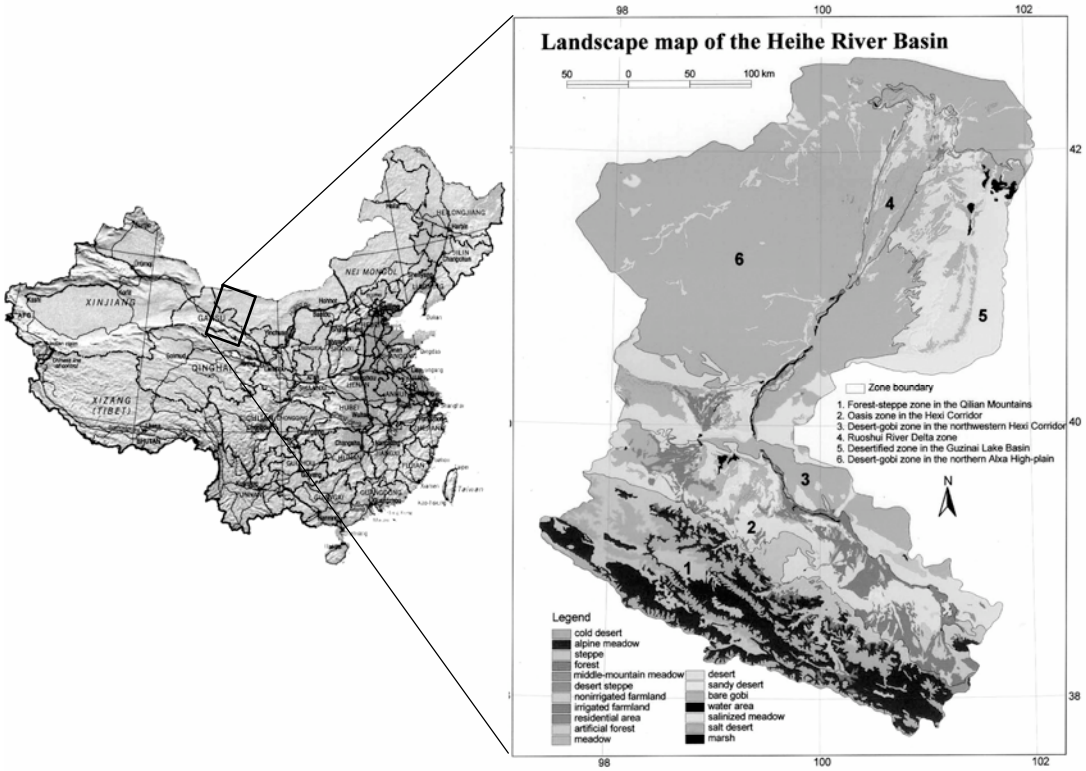
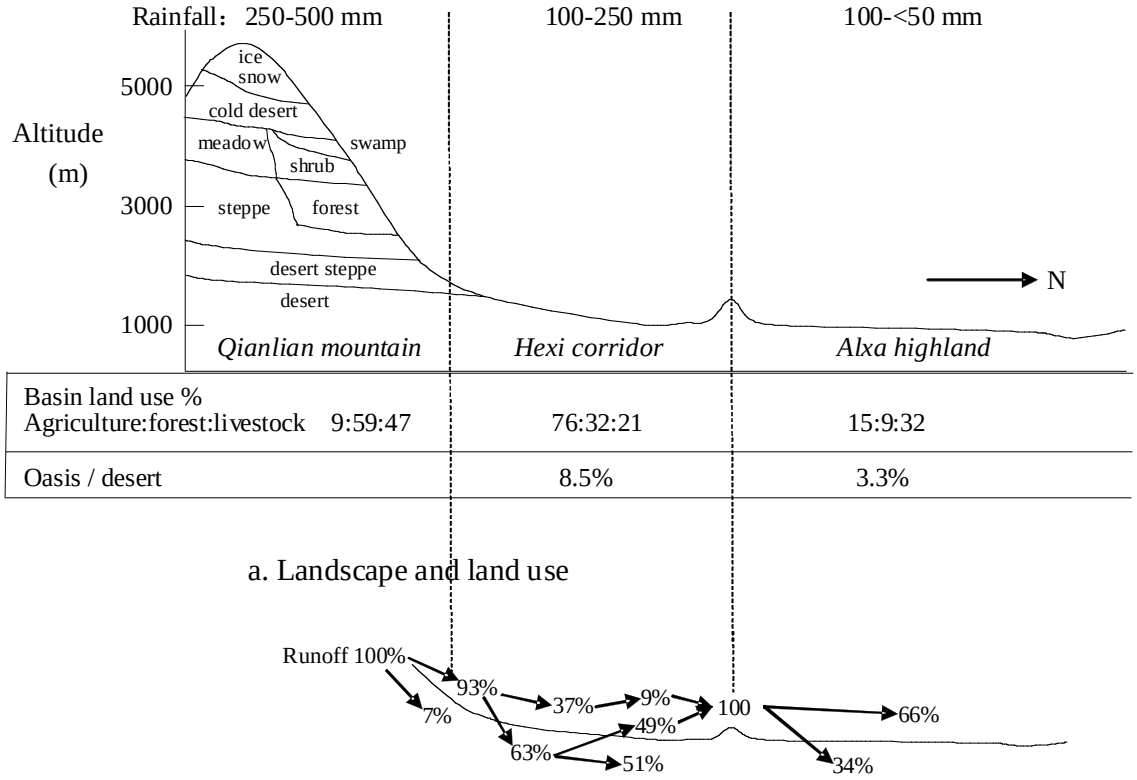


Fig. 1 Landscape and Location of the Heihe River Basin

Table 1 Land Distribution in Provinces/Regions

Land	Qinghai		Gansu		Inner Mongolia		Basin
	Area	% of total	Area	% of total	Area	% of total	

	(km^2)		(km^2)		(km^2)		
Mountain	9483.48	21.86	25222.36	58.15	8671.14	19.99	43376.99
Desert	0.00	0.00	24704.90	33.29	49510.15	66.71	74215.05
Oasis	0.00	0.00	8059.33	70.13	3433.45	29.87	11492.77
Total	9483.45	7.35	57986.59	44.92	61614.74	47.73	129084.81



a. Landscape and land use

b. Cycle between surface water and groundwater

Fig. 2 Soil and Water Resources and Their Utilization in the Heihe River Basin

It is generally recognized that the annual average water resources in Heihe River Basin is 4.173 billion m^3, of which the river discharge flowed out of the Qilianshan Mountain is 3.683 billion m^3. The mainstream of the Heihe River flows out of the Mountain with annual average discharge of 1.598 billion m^3. Water utilization rate in the Heihe River Basin has exceeded 112% (Feng Qi, et al, 2002). The total water consumption in the Heihe River Basin in 1998 is 3.433 billion m^3, of which agricultural water consumption is 2.986 billion m^3; forest, animal husbandry and fishery water consumption is 0.227 billion m^3; urban industrial water consumption is 0.1564 billion m^3. The activities in the middle reaches consume 68.1% of the total water resources in the basin (Xiao Hongliang, 2000).

3. HYDROLOGICAL PROCESS CHANGE DRIVEN BY RE-ALLOCATION OF WATER RESOURCES IN A BASIN-SCALE

Many human activities always reallocate insensibly water resource both on space and on time, thereby change water cycle and hydrological process and ecological process at basin scale. In general there are following ways.

3.1 Long-term domino effect

In fact, we have been remodeling hydrological process since human being began to use natural resource. Growing population recorded pressure change on water resource. In Heihe river basin population had been fluctuated between 10000 and 100000 since Han Dynasty, and increased to tow million in 21st century. At same time, economic development has been accelerated dramatically (Table 2, Figure 3). In 2000, GDP in the Heihe River Basin is 11.027 billion RMB *yuan* in which 3904.94 million RMB yuan comes from the first industry, 4137.90 million RMB yuan comes from the second industry and 3215.11 million RMB yuan comes from the third industry, with the proportion of 35.41%, 37.53% and 29.16% respectively. Hydrological process was changed greatly with population increase and irrigation area extension as well as industry modulation.

Table 2 Population Change in Different Stages in Heihe River Basin (unit: 10000)

Year	Zhangye County	Jiuquan County	Year	Zhangye County/City	Jiuquan County/City
2nd year of Han Taichu (BC103)	8.8731	7.6726	Qing Jiaqing (1796-1820)	53.1119	13.2295
2nd year of Han Yongshou (156)	4.8085	1.2760	Qing Guangxu (1875-1908)	26.0685	10.7233
Jin Dynasty (265-420)	0.3700	0.4400	Qing Xuantong (1909-1911)	25.9789	16.1703
Sui Dynasty (605-618)	6.1216		1922	30.8972	20.5424
5th year of Tang Wude (622)	2.2092	0.8476	1944	31.2576	21.3458
1st year of Tang Tianbao (742)	2.2092	0.8476	1978	98.32	
1st year of Tang Qianyuan (758)	1.1680	0.7118	1995	117.9	45.81
Yuan Dynasty (1271-1288)	2.3987	8.679	2000	125.1	49.17
Ming Jiajin (1544)	4.4293	2.2373			

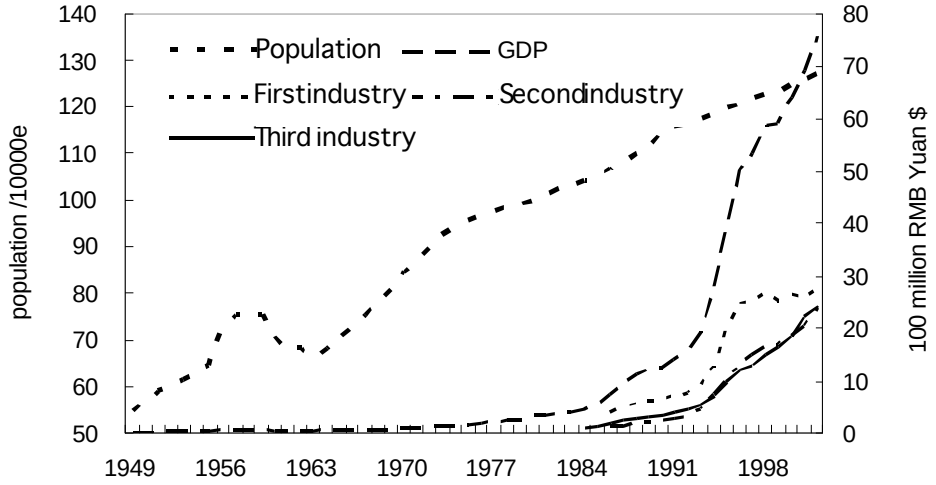


Fig. 3 Population Increase and Industry Development in Last 50 Years in Zhangye County/City

3.2 Major projects

Some key engineering and economic activity, which we do not judge right or wrong at first, often affect hydrological process to make hydrological prediction more difficult. Tow typical examples as following. It is worth to mention that the state council approved a "Water Allocation Plan in Mainstream of the Heihe River" in 1997 in order to mitigate ecological deterioration in the lower reaches. This plan will discharge 0.95 billion m^3 of ecological water to the lower reaches each year. However, less than 0.5 billion m^3 runoff can enter the lower reaches in the past decades. The state engineering is producing a new water environment and hydrological cycle in Heihe River Basin.

In order to seek higher water benefit, agriculture and animal husbandry in the upper reaches, middle reaches and lower reaches were coupled into integrated system with forage and livestock in the Heihe basin. This model is extended in the whole basin. However movement of forage and livestock is diversion of virtual water really (Figure 4).

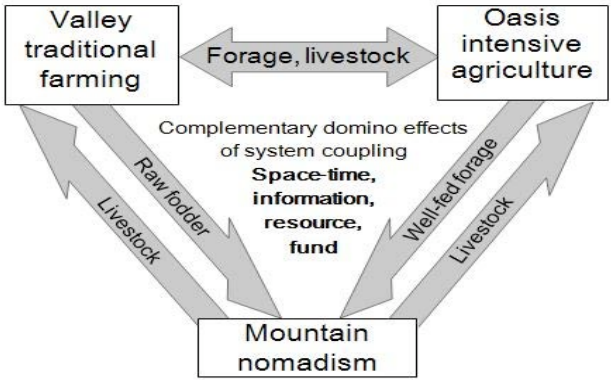


Fig 4 Mountain –Valley –Oasis Integrated System

3.3 Challenge of social management of water resources

High efficient utilization of water resources in the inland river basin of northwestern China must consider water issues broadly in social and economic domain, thoroughly recognize social and economic characteristics of water resources (Chen Guodong, 2002a) in order to meet the objective of water resources management,or to maximize economic and social benefit (Xu Zhongming, et al, 2003). Of cause they are objectives of hydrology and hydrological prediction too. For this hydrology not only researches natural process but also the process of society and economy. A new knowledge, namely hydrology of virtual water, will come into being. It should focus on the hydrological process driving by the benefits of society and economy. Virtual water strategy is a typical example of social management of water resources based on the studies of water-process in the system of society and economy (Chen Guodong, 2003; Hoekstra A Y and Hung P Q, 2003). When emphasis transfers from water resources scarcity itself to state and regional social adaptability, water resources scarcity is no longer a definitive constraint but a driving force of social and economic development due to the interaction of water process and social process.

In view of above, hydrological process is changing in a different way from the past because of extending social management of water resources in Heihe river basin. For example, improve user's water use behavior through economic incentives and technical method, namely water market and water right; keep enough environment flow under the balance between economic productivity and ecological environment value; actualize virtual water strategy at the basin scale.

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REFERENCES

Feng Q, Cheng G D, Masao M K. Trends of water resource development and utilization in arid north-west China. Environment Geology, 2000, 39(8): 831-838.

Xiao Honglang. 2000. Water issue in China: water resource, flood and water conservancy. Beijing, Kaiming publishing company.

Feng Qi. Sustainable Utilization of Water Researches in Gansu Province. Chinese Journal of Arid Land Research, 1999, 11(4): 293-299.

Xiao Honglang, Fan Hengwen, He Baoshan. 1999. Study of basin land classification in arid zone, A case study in Heihe river. Gasu science and technology of agriculture, special, 21-25.

Chen Longheng and Xiao Honglang.2003. Soils and their use in the Hexi mountains. Beijing, Ocean press, pp.132.

Feng Qi, Cheng Guodong, Endo Kunihiko. Towards sustainable development of the environmentally degraded river Heihe basin, China. Hydrological Science Journal-Journal Des Sciences Hydrologiques, 2002, 46 (5): 647-658.

Cheng Guodong, 2002a, Study on the sustainable development in Hei river watershed from the view of ecological

economics. Journal of glaciology and geocryology, 24(4): 335-343.

Xu Zhongmin.,Zhang Zhiqiang,Cheng,Guodong. Theory, Method and Application of Ecological Economics. ZhenZhou: Water Resources Conservancy of Yellow river press. 2003.

Cheng Guodong, Virtual water——A strategic instrument to achieve water security. Bulletin of the Chinese Academy of Sciences, 2003, 17(4): 260-265.

Hoekstra A Y and Hung P Q. Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade. In: Hoekstra A Y edited. Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade. Value of Water Research Report Series No12. IHE DELFT. February 2003. 25-47