Impacts of Human Activities on the Hydrological Cycle in the Heihe River Basin, Western China

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1. Introduction

Heihe River is one of the biggest inland rivers in the semi-arid region of northwestern China. The Heihe River basin consists of three parts, namely the upper mountainous area which is the source of the Heihe River by rather big amount of precipitation and glaciers, the middle oasis area like Zhangye and Jiuquan, and the lower terminal arid area like Ejina. Each area has independent hydrological sytem and ecosystem. Surface runoff from the upper mountain area by rain and melt water of snow and glaciers is the only source of water available in the middle oases area and the lower arid area. Figure 1 shows the location and the outline of the study area. During past fifty years, many river courses have dried up, and the terminal lakes have vanished. This paper focuses the human induced impacts on the hydrological cycle of the Heihe river.

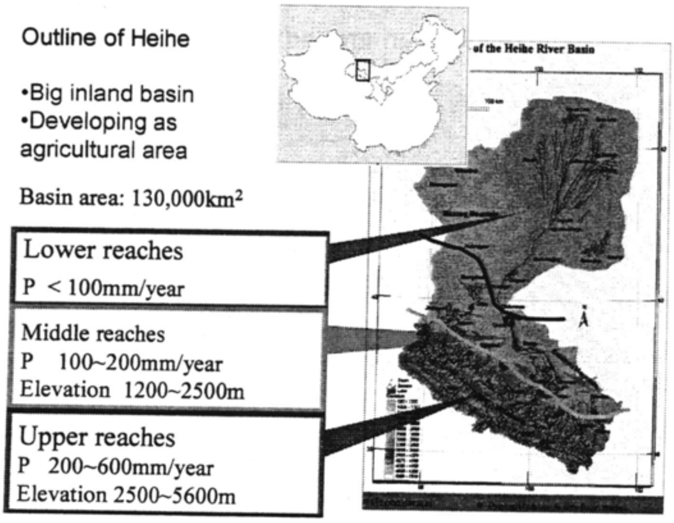

Figure-1 The outline of the Heihe river

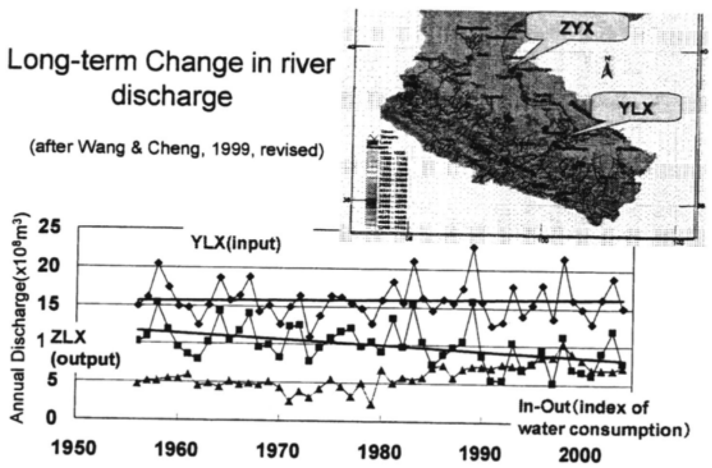

Figure-2 Long-term change in river

2. Water use and its effects on

the hydrological cycle in the middle reaches

Figure 2 shows changes in amounts of incoming water to the middle reaches and outgoing water to the lower reaches during past 50 years. The differences between two is an index of water consumption of the middle reaches. Although the river discharge from the upper mountain area has a slightly increasing trend during past fifty years, the increase of water consumption in the middle oases area mainly by irrigation for agricultural land has caused the serious shortage of water resources and the degradation of vegetations in the lower arid area. Recently, the extracted volume of groundwater significantly has increased due to the high cost of river water irrigation and the intensive water use for newly introduced cash crops (Fig.3). At 2000s, groundwater contributed 25% to the total irrigation water (Fig.4). The intensive extraction of groundwater near the city area for cash crops has caused the rapid decline of ground water table (Fig.5 and 6). Possible damage on groundwater resources should be considered.

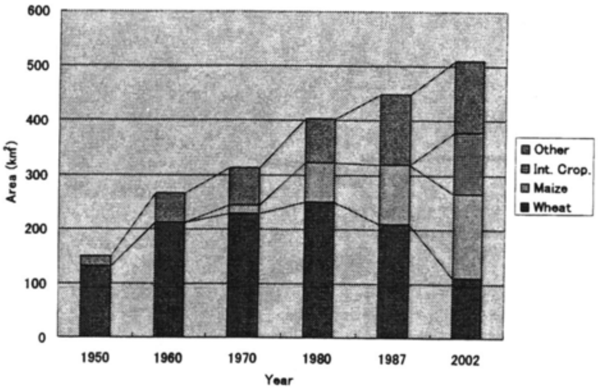

Figure-3 Crops in irrigated fields

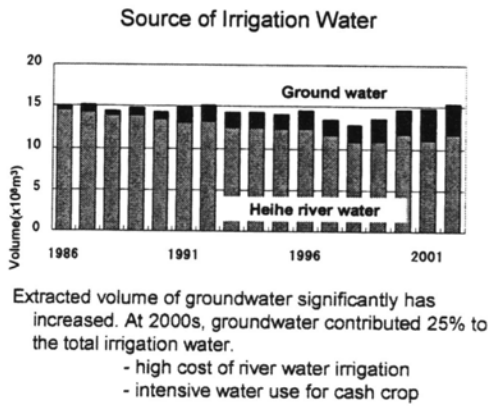

Figure-4 Source of irrigation water

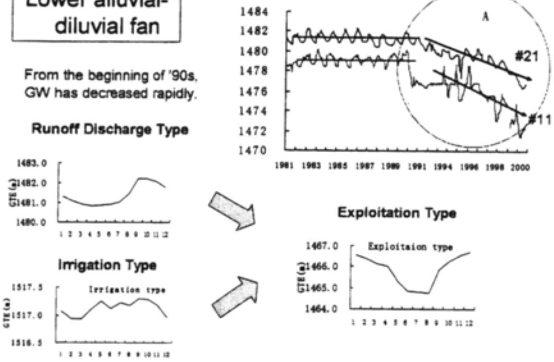

Figure-5 Change in groundwater level

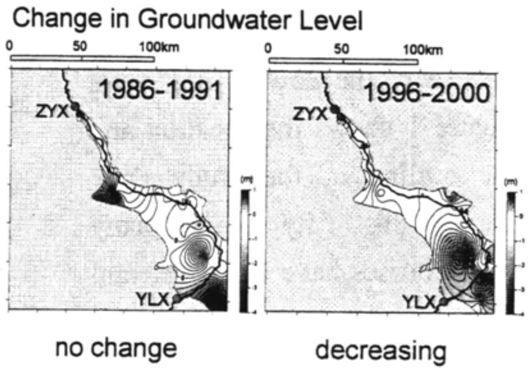

Figure-6 Distribution of Groundwater Change

Fig.7 shows comparison of annual water budget of the middle reach in 1970 and 2004. While, in 1986, over 80% of river water had been irrigated to agriculture fields and 70% of discharge to the lower reaches came from groundwater, both irrigated water and outcome from groundwater have decreased.

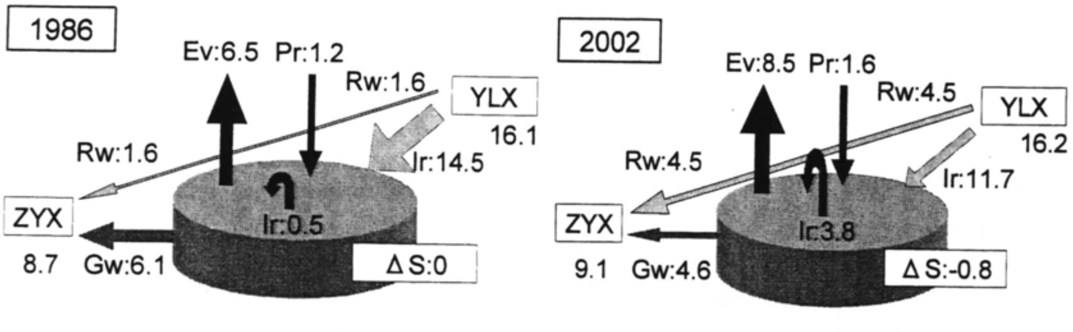

Figure-7 Annual water budget in 1986 and 2002

3. The hydrological cycle in the lower reaches

The lower reaches have been suffered from serious water shortage because of heavy and increasing water consumption in the middle reaches. River water sometimes has dried up. Especially, there has been almost no river water in summer except flooding. It is hard to use river water constantly and people heavily depend on groundwater resources. But the shortage of river water also has resulted in the decline of groundwater level, especially in the terminal area. So, it is important to clarify the recharging processes of groundwater, such as source and recharging amount (Fig-8-Fig-11).

(1) Source of groundwater at the desert area

Figure 12 shows the isotopic diagram of various kind of water in the lower reaches. The isotope analysis indicated that groundwater in the desert area have been recharged by rain water. In other areas, the source of groundwater is river water.

(2) Source of groundwater around the river courses

Figure 13 shows the mixing ratios of groundwater in the lower reaches. In the south area in the lower reaches, the mixing rations were around 0.5, indicating both the summer flood water and the winter water contributed groundwater recharge. The number of days on which river water exists shows better correlation with groundwater increase rather than that of river discharge. On the contrary, the mixing ratios in the north area became higher along the river. This suggests winter recharge is more important in the north area because river water rarely reached the north and terminal area in the lower reaches.

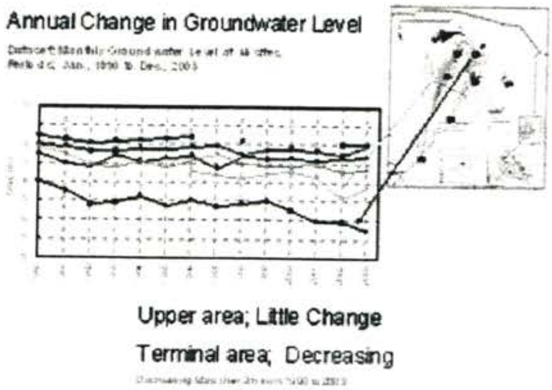

Figure-8 Annual change in Groundwater level

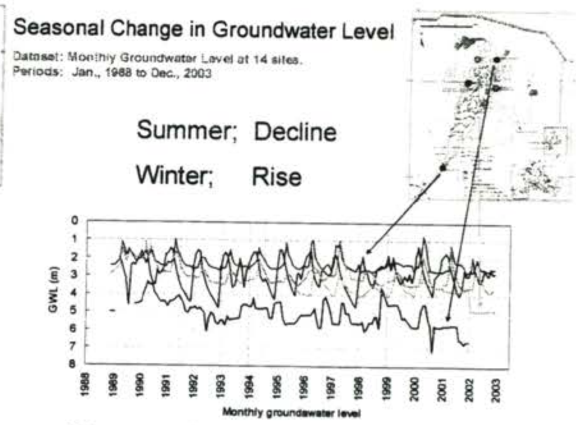

Figure-9 Seasonal change in Groundwater level

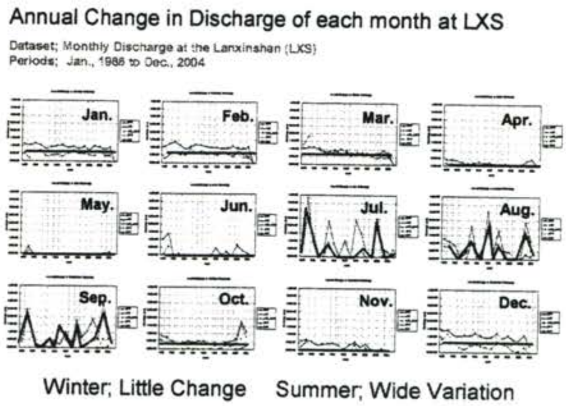

Figure-10 Monthly incoming discharge to the lower reaches

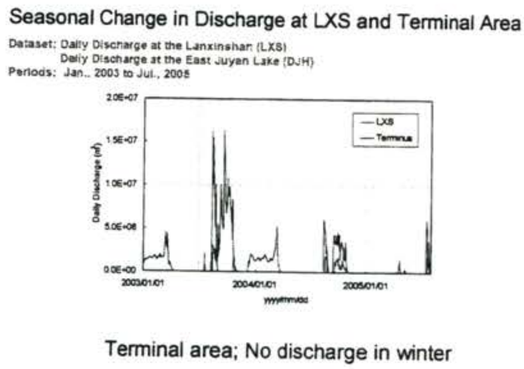

Figure-11 Seasonal change in river discharge at the terminal area

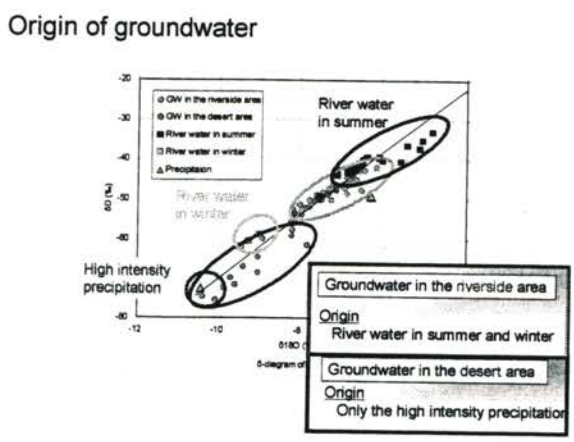

Figure-12 Origin of groundwater

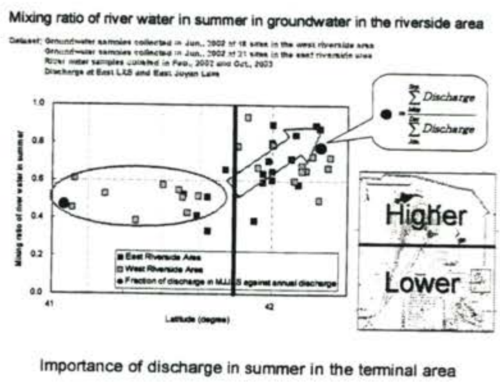

Figure-13 Mixing ratio of groundwater

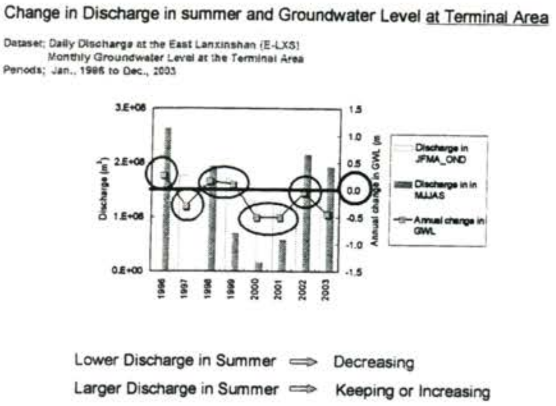

Figure-14 Relationship between summer river discharge and groundwater level in the terminal area

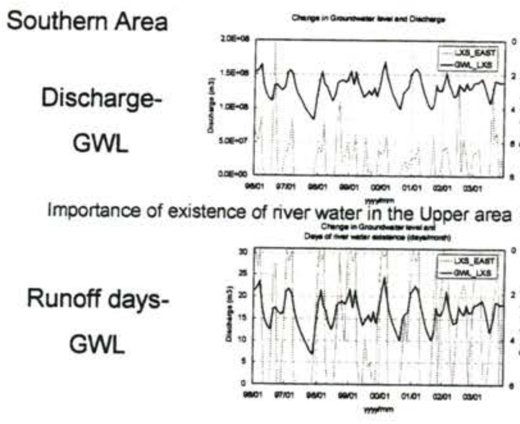

Figure-15 Relationship between river discharge and groundwater level in the upper area of the lower reaches