Water balances in large scale irrigation districts in the Yellow River basin

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1. Introduction

This report will present water balances in large scale irrigation districts in the Yellow River basin briefly based on some existing reports and studies by management organizations, institutes and universities in China. In addition, details of water balance and directions for more adequate water management in Hetao Irrigation District that is the largest irrigation district in the basin will be discussed through analysis of simulation results by IMPAM (Irrigation Management Performance Assessment Model) (Hoshikawa et al., 2007).

2. Water balances in primary large-scale irrigation districts

Outline of water balance structures, monthly water withdrawals and long-term trends of them in Qingtongxia Irrigation District (Qingtongxia ID) (Ningxia Autonomous Region; upper basin), Hetao Irrgation District (Hetao ID) (Inner-Mongolia Autonomous Region; upper basin) and Weishan Irrigation District (Weishang ID) (Shandong Province; lower basin) will be presented in this section. Qingtongxia and Hetao IDs which withdraw $6\times10^9 m^3$ and $5\times10^9 m^3$ annually from the Yellow River respectively strongly affect runoff of the Yellow River especially. Weishan ID is the largest irrigation district in the lower basin. Such information is important to discuss future changes in water resource reallocation in this basin.

Qingtongxia Irrigation District

Annual precipitation around Ningxia ID is about 200mm. Agriculture in this area almost completely depends on irrigation. This autonomous region has four major irrigation districts (Qingtongxia, Weining, Taole Pumping, Guyuang Pumping Irrigation Districts), group of which are called Ningxia Yellow River Irrigation District. Qingtongxia and Weining Irrigation Districts which are gravity irrigation districts return about a half of water withdrawn from the Yellow River as drainage to the Yellow River. Drainage water mostly consists of tail-water. Because of a terrain, this region is ill-drained. North of Yinchuan City is troubled by salt accumulation.

Monthly water withdrawal and drainage is shown in Fig.1. Irrigation is applied also during the late autumn to the early winter after harvest. Drainage quickly follows water withdrawal. This indicates that drainage water mostly consists of tail-water.

No drastic change in amount of annual water withdrawal can be seen in the last 20 years. Institute for Hydraulic Power Survey, Ningxia Autonomous Reion (1999) presented a plan for reducing annual water withdrawal from the Yellow River to $4.0\times10^9 m^3$. According to it, lining and rearrangement (making shortcut routes) of main canals enables to reduce delivery losses 63% to 50%. In addition, exploitation of groundwater will be promoted. However, *net* water requirement of the districts will rather increase slightly. This plan also aims to increase irrigated area by 251,000 ha at the same time. Measures for water saving presented in the plan are not for reducing water consumption in the area but for increasing agricultural production within the area. Amount of water consumption will not be changed substantially. A reason why this district is not required to reduce water use different from Hetao ID is that agriculture in this region is one of the important

components of the Great Development of the Western (*xibu dakaifa*).

Hetao Irrigation District

Hetao ID locates in a dry-area with annual 100–200mm of annual precipitation. Agriculture of this region completely depends on irrigation. At Sanshenggong Headworks, $5.3\times10^9 m^3$ and $0.6x10^9 m^3$ of river water is diverted to Conveyance Canal (*Zongganqu*) and the First Main Canal (*Yiganqu*) of Hetao ID. In addition, Yimeng Irrigation District, which is out of Hetao ID, on the right bank takes about $0.3\times10^9 m^3$ annually. Conveyance Canal releases $0.7–1.0\times10^9 m^3$ annually as tail-water. Difference of total amount of water withdrawal at Sanshenggong and tail-water from Conveyance Canal is reported as amount of water withdrawal of Hetao ID (about $5\times10^9 m^3$/year). About 0.2 – 0.3×10^9 m^3/year of water is drained through drainage canal network. It is much less than that of Qingtongxia ID. Analysis on quality of drainage water indicates that drainage water is mostly from irrigation canals directly (Wang et al., 1993).

Fig.2 shows monthly pattern of water withdrawal by Hetao Irrigation District. It is almost stable every year. Irrigation after harvest for cultivation in next spring is also applied in autumn. Much more water is allocated for autumn irrigation than in Qingtongxia ID. It accounts 30% of annual total water withdrawal.

Water withdrawal by Hetao ID was increasing year to year by 1980s because of enlargement of irrigated area, and it leveled out in 1990s. Hetao ID is now requested to decrease water annual water withdrawal to $4.0\times10^9 m^3$. Lining of main canals has been conducted to decrease seepage loss that accounts for 60% of total withdrawn water. In addition, irrigation after harvest was decreased from $2.0\times10^9 m^3$ to $1.6\times10^9 m^3$.

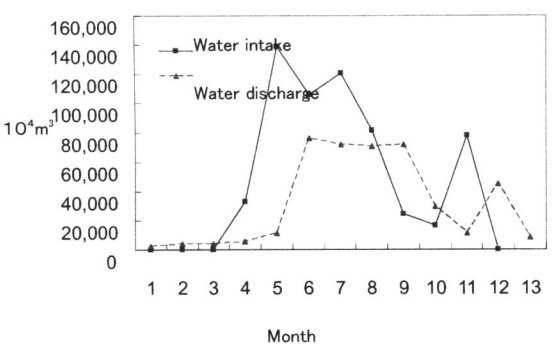

Fig.1 Monthly water withdrawal and drainage from/to the Yellow River (2000)
X-axis: Julian month; Y-axis: 10,000 m^3

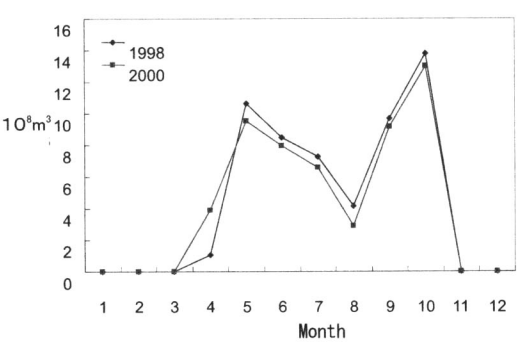

Fig.2 Monthly water withdrawal from the Yellow River (1998 and 2000)
X-axis: Julian month; Y-axis: 0.1 billion m^3

Weishan Irrigation District

Area around Weishan ID has precipitation mostly in summer. Irrigation is applied for winter wheat in spring and autumn. Crops other than wheat are maize as second crop of winter wheat, vegetables, cotton, and beans etc. All of them are cultivated in summer. Annual precipitation is around 600mm. It is barely enough to cultivate crops without irrigation. Irrigation is irregularly applied to supply deficit when droughts. Although area of irrigated wheat is almost stable, water withdrawal for

irrigation varies much year to year because of annual variation of amount of precipitation.

There is no drainage system. In the lower part of the irrigation district where elevation is relatively low, depth to groundwater becomes shallow (less than 1m) in summer. Significant part of the irrigation district was salt affected in 1960s to 70s. It is said that salt affection was reduced by digging riverbed of two natural streams for drainage.

Weishan ID is located in the lower part of Yellow River basin where water shortage is severe. Secure of water for irrigation is important subject for the ID. In addition to various measures of water saving, exploitation of groundwater is being tried. Significant part of irrigation canal system is lined to prevent soil contained in irrigation water from depositing in canals. This lining helps water saving. Reduce of water withdrawal may not be important subject for Weishan ID.

One of the important topics about water management in Weishan ID is the "From the Yellow River to Wei River (*Yinhuangruwei*)" Project. This project aims to send water of the Yellow River to Tianjin City using the irrigation canal system of Weishan ID and Wei River. Although Weishan ID withdraws water from the Yellow River for this project, Tianjin City is responsible for the water withdrawal. Water for this project is not included in amount of water withdrawal by Weishan ID and Shandong Province. Water withdrawal for Tianjin City is conducted in winter not to disturb irrigation. Fig.3 shows amount of water withdrawal from November to February. This strongly indicates that withdrawal for Tianjin is rapidly increasing,

3. Water balance and possibility for water saving in Hetao ID

Of the above mentioned three irrigation districts, only Hetao ID is required to reduce water consumption. Water saving in Hetao ID will substantially affect runoff of the Yellow River. It is not easy for Hetao ID where agriculture completely depends on irrigation to reduce water consumption without reducing agricultural production. This section will provide results of assessment of impact of water saving measures progressing in Hetao ID on its water balance and agricultural production with the simulation model IMPAM.

Materials and method

In addition to ten-year simulation period, five-year spinning up was done for establishing initial conditions of soil moisture and groundwater level. Parameters for soil physics, groundwater flow, and irrigation management were adjusted through calibrations for groundwater level, water delivery patterns of irrigation canal network, and amount of drainage. Simulation period was from 1988 to 1997 for which calibration data was available.

Simulations were done under four cases: management before modifications after 2000s (base case), and three modified cases. Main canals were lined and seepage was reduced (case1), irrigation after harvest was reduced (case2), both seepage and irrigation after harvest were reduced (case 3) were assumed as the modified cases.

Model was applied to command areas of Yongji and Beibian Main Canals (83,562 ha and 4,156 ha respectively).

Results

Fig.4 shows details of annual water outflow from the simulation area. Soil evaporation accounted for about 60% of total outflow of the HID in the base case. Nearly 80% of the inflow to the HID is

water from the Yellow River. These facts mean that at least about 50% of water diverted for irrigation was wasted due to soil evaporation from the area. Such predominance of soil evaporation in the outflow was attributed to the dry climate, vast seepage rate, bare areas scattered among irrigated farm plots and a rather large groundwater transmissivity that enabled quick water transfer from irrigated farm plots to bare areas. Under such a climate condition with a large saturation deficit, soil moisture was much more quickly evaporated than discharged to drainage channels.

Soil evaporation was decreased in every modified case. It is notable that transpiration that is deeply concerned with crop production merely decreased. Although irrigation after harvest is applied for crop growth in the next spring, it can be decreased without significant effect on agricultural production.

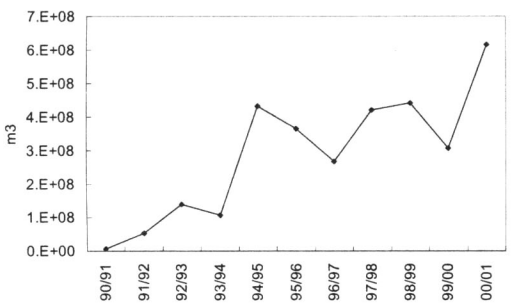

Fig.3 Water withdrawal during November to February (1999–2001)

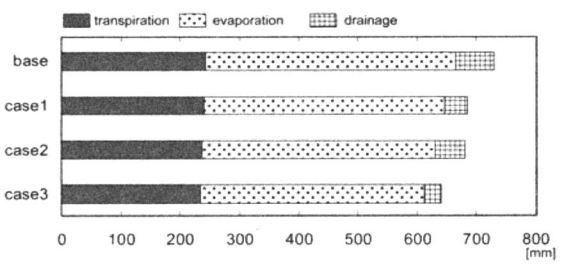

Fig.4 Details of annual water outflow from the simulation area for the four cases (10-year mean).
Base: management before modifications; Case 1: seepage was reduced; Case2: irrigation after harvest was reduced; Case3: both seepage and irrigation after harvest were reduced

4. Conclusions

Water saving in Hetao ID strongly affects reallocation of water resource in the Yellow River basin. It is technically possible for Hetao ID to reduce water consumption and water withdrawal without significant decrease of agricultural production. Possibility of water saving strongly depends on how investment will be done for Hetao ID. In other words it depends on economy and food demand and supply in China.

References

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