Mechanisms of the water shortage of the Yellow River basin

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1. Introduction

In recent years, the measured annual river flow of the Yellow River has declined significantly. Still now, the basin is confronted with frequent water shortage, and it has been great concern of the Chinese government and attracted international attention. It is well known that the drying-up of the lower reach has occurred since 1972, and the situation has become more and more serious during the 1990s. Therefore, the immediate attention and action are needed to mitigate or solve the water shortage and its related problems. In general, there are two causes for the flow drying-up in the lower Yellow River: climate change and human activity. Basically, water resources in the Yellow River basin are scarce, because the annual precipitation is much lower than the annual evaporative capacity. Furthermore, the decrease of annual precipitation may be one of the most important factors for the decrease in the river runoff. On the other hand, the impact of human activity due to intensive water use is another major reason for the drying-up. Most of the recent investigation concluded that the drying-up is due to extensive water withdrawal for agriculture irrigation. However, the contributions of these factors had not been investigated quantitatively. Thus, in the present study, we attempt to clarify the mechanisms of the drying-up of the Yellow River basin by long-term water balance analysis and several hydrological model simulations.

2. Data and Method

For the long-term analysis, we used 41 years (1960-2000) of daily observation data from 128 meteorological stations. Then, to predict the evapotranspiration loss from various land use types, a high resolution satellite remote sensing data (Matsuoka *et al*., 2005) were used . The remote sensing data includes the elevation, land surface classification map, and normalized difference vegetation index (NDVI) data sets. The hydrological model used in this study is based on the SVAT-HYCY model (Ma and Fukushima, 2002). However, this hydrological model could not predict long-term water balance of the Yellow River basin as it includes a lot of anthropogenic factors such as irrigation water intake, large reservoir operation, and human-induced land-use changes. Thus, in the present study, we considered these artificial factors in our model by applying simple sub-models. The details of model structure and parameters used in this study are summarized in Sato *et al*. (2007a,b,c).

3. Results and discussion

The performances of the hydrological model applied in this study are shown in Figure 1. These figures indicate that the annual discharges from source area to lower reach during the past 40 years (1960 to 2000) estimated by the model (red bars) and observed results (blue bars). The locations of each sub basin are shown in Figure 2a. Although, we did not consider the influence of long-term land-use change in this model simulation, the observed discharges were reasonably captured by the model except for the Middle reach-1. Therefore, the influence of land-use change on long-term water balance of the Yellow River basin will not be so severe. The disagreement in the Middle reach-1 was solved by considering the influence of land-use change (soil and water conservation) conducted in the Loess Plateau (Sato *et al.*, 2007b).

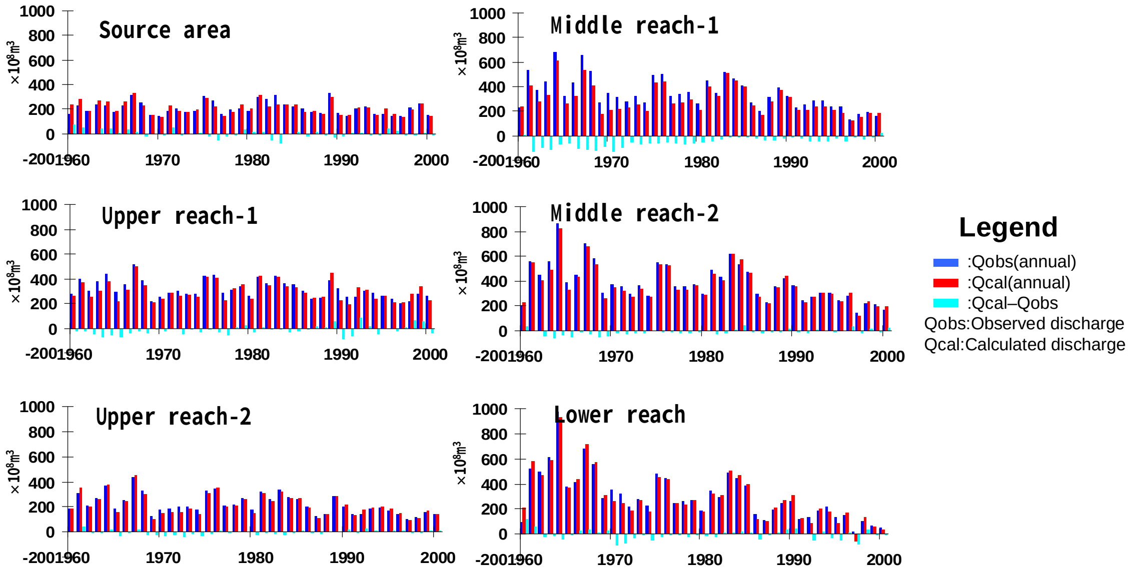

Figure 1 Performance of model simulation

Figure 2b shows that the amount of water decreased in each sub-basin between the periods from the 1960s to the 1990s. From this result, we can see that the water shortage in the lower reach of the Yellow River basin (36 billion m^3) was induced by the following two factors: (1) increase in water consumption within the lower reach (31%) and (2) decrease in water supply from upstream of lower reach (69%).

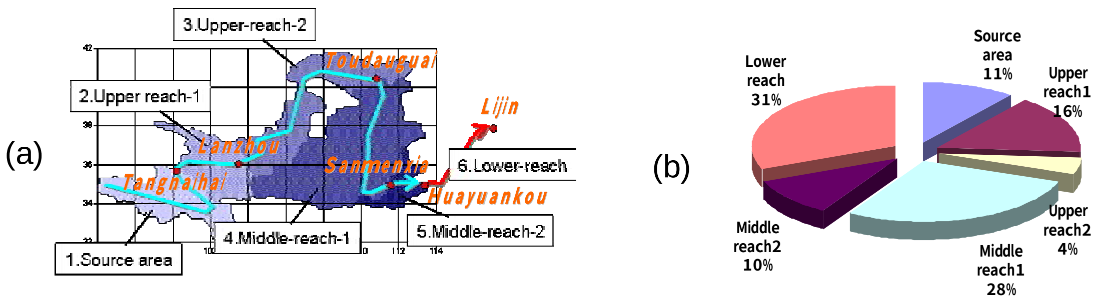

Figure 2 Analysis of long-term water balance of the Yellow River basin.
(a)Distributions of each sub-basin; (b) Amount of water decreased in each sub-basin

According to the decadal analysis of the water use within the lower reach and the water supply to the lower reach, we can find that the water use within lower reach increased between the 1960s to the 1980s and water supply to the lower reach decreased in the 1970s and the 1990s (Figure 3a). The major reason of the increase in water use within the lower reach can be due to the increase in irrigation water use with the increase of irrigation areas from the 1960s to the 1980s (Figure 3b). The decrease in water supply to the lower reach must be induced by the decrease in precipitation in the middle reach-2 in the 1970s and 1980s (Figure 3c). The influence of the increase in evapotranspiration with the increase of air temperature will not be so significant on long-term water balance of the Yellow River basin compared with the influence of the precipitation change (Figure 3d).

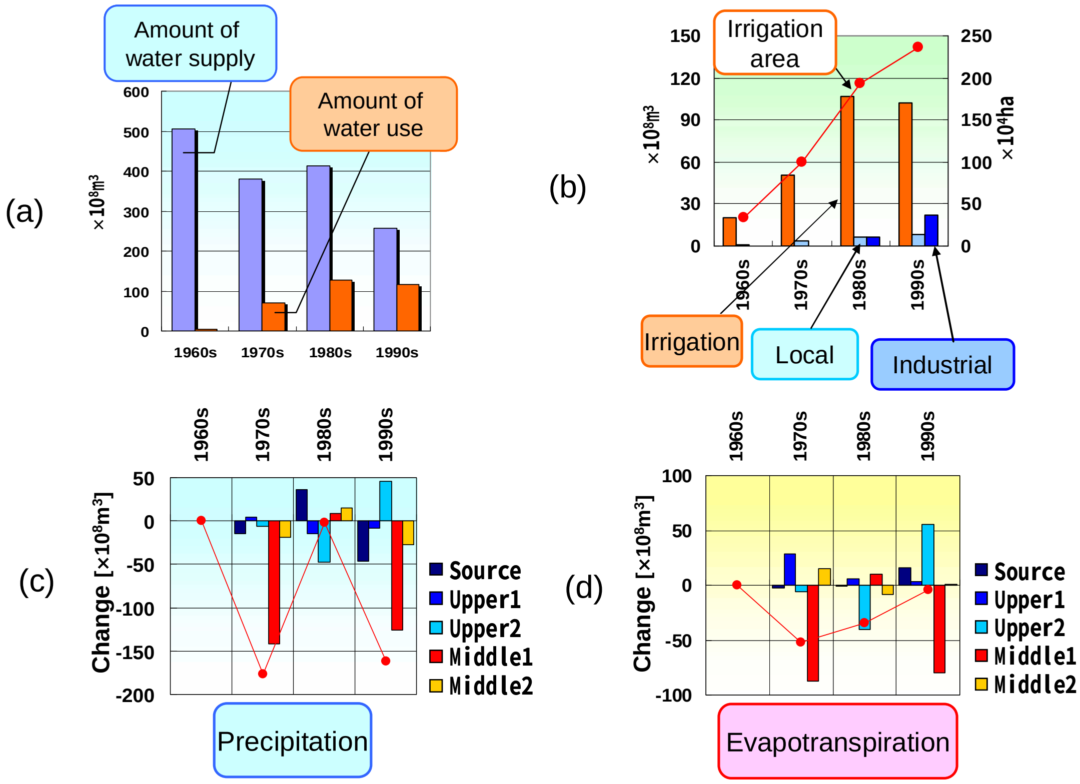

Figure 3 Mechanisms of the drying-up of the Yellow River basin.
(a) Decadal change of water supply for the lower reach and water use within the lower reach; (b) Decadal change of irrigation area, irrigation water use, local water use and industrial water use within the lower reach; (c) Decadal change of precipitation from source area to middle reach-2; (d) Decadal change of evapotranspiration from source area to middle reach-2

4. Conclusion

In the present study, we attempted to clarify the mechanisms of the drying-up of the Yellow River basin by long-term water balance analysis and hydrological model simulation. The results obtained in this study will contribute to the ongoing integrated water resources management in the Yellow River basin, such as the more adequate water allocation or soil and water conservation.

References

Ma and Fukushima (2002): Numerical model of river flow formation from small to large scale river basins. In *Mathematical Models of Large Watershed Hydrology*, Sigh VP, Frevert DK (eds). Water Resources Publications: Highlands Ranch, CO; 433–470.

Matsuoka *et al.* (2005): Land cover classification over the Yellow River domesin using satellite data. *YRiS News Letter* **4**:15-26.

Sato *et al.* (2007a): Application of a reservoir operation model to the upper reaches of the Yellow River basin. *YRiS News Letter* **7**:9-12.

Sato *et al.* (2007b): Impacts of human activity on long-term water balance in the middle-reaches of the Yellow River basin. *IAHS Publication* **315**: 85-88.

Sato *et al.* (2007c): Analysis of long-term water balance in the source area of the Yellow River basin. *Hydrological Processes*, DOI: 10.1002/hyp.6730