Sustainable agriculture production and agricultural water use
in the Yellow River basin, China
-Evaluation by index of agricultural WUE (Water Use Efficiency) -

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1. Introduction

Food demand in China is increasing due to rapid population growth, changes in society and economic development. Food production has therefore become an important state policy issue. Amid this background, in the Yellow River basin, grain production has expanded dramatically through increases of agricultural yields per hectare. However, as a region suffering from severe water shortages, there were concerns that excessive water use will deplete the water resources in the Yellow River basin. Such shortages were caused by increased agricultural water use (Otsubo *et al.*, 2000) and its inefficient use. Thus, it is essential to consider how to manage agricultural water use while continuing increasing agriculture production.

The area of the Yellow River basin is vast (about twice the area of Japan) (JBIC, 2004), and the conditions of agricultural production vary greatly within it. In the river source region (upper than Lanzou) precipitation supplies about 60% of the water resource to the Yellow River. In the upstream there are extensive irrigated areas, including for example the Qingtongxia irrigation district in the Ningxia, and the Hetao irrigation district in Inner Mongolia (Watanabe and Hoshikawa, 2006). These irrigation districts are mostly located in the arid and semi-arid areas, and the level of precipitation is low. Therefore, the large quantity of water for grain production is drawn from Yellow River. The midstream region is located in the Loess Plateau region which covers the arid and semi-arid areas. Grain production is high here, but in the basins of the Fen River and Wei River (tributaries of the Yellow River), groundwater levels are dropping due to urbanization and industrialization. The downstream region is located in the North China Plain, where modern agricultural technology has been widely introduced —including mechanization and the use of chemical fertilizers — and the region grows wheat and maize with high yields per hectare. Although the characteristics of each area are different, it is clear that advances in modern agricultural technology has raised grain production by producing higher yields per hectare (Onishi *et al.*, 2005), and the increases in grain production have come at the cost of excessive use of agricultural water —a situation that exacerbated the dry up phenomenon. Thus, when considering the effective and proper use of agricultural water, it is important to consider approaches that limit to the lowest possible level the amount of water used while obtaining a certain amount of production.

This study evaluates the agricultural water use efficiency (WUE) of year 2000 by using the statistic data, land use data and hydrological model.

2. Background

Grain production in the Yellow River basin has been increasing steadily (Figure 1).

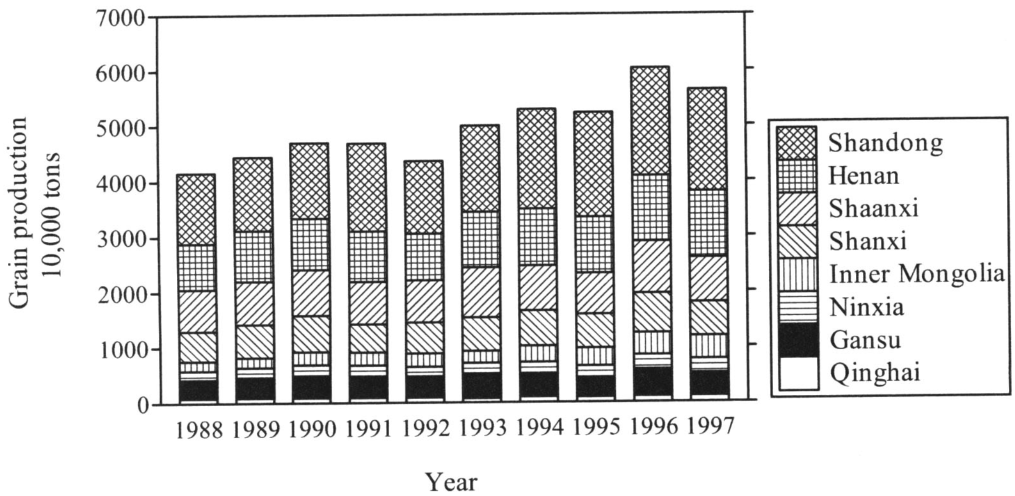

Figure 1. Grain production trends.

Source: Prepared by authors from National Bureau of Statistics of China (1989-1991), National Bureau of Statistics of China, and the Institute of Geographic Sciences and Natural Resources Research (Chinese Academy of Sciences)[1].

Note: Grain Production includes production of rice, wheat, maze, beans and tubers.

Grain production is accomplished through the use of irrigation, which accounts for about 84% (calculated by authors from data on the amount of water use for 1988 through 2002) [2] of all usable water (Sun *et al.*, 2001; Yellow River Conservancy Committee, 1997-2002). In particular, Shandong Province and Inner Mongolia have some of the largest irrigation districts in the river basin and use enormous amounts of water for

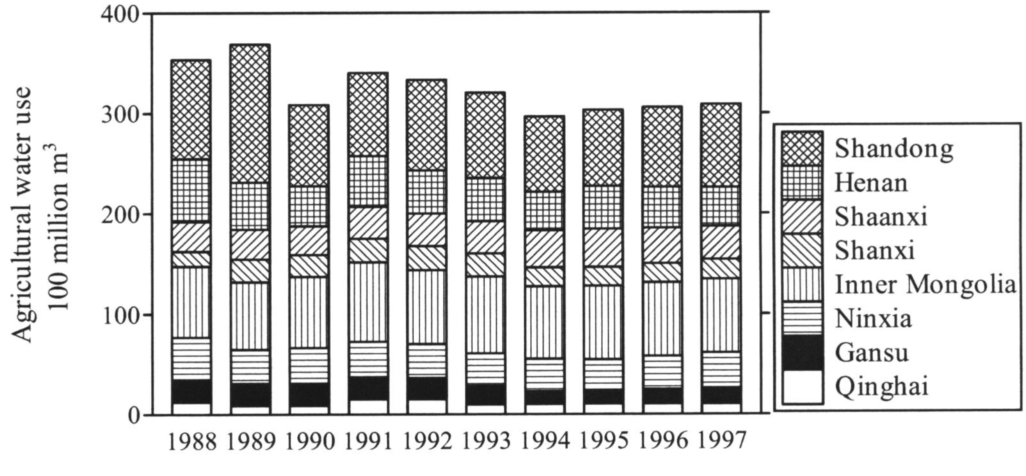

Figure 2. Agricultural water use trends.

Source: Prepared by authors from Sun *et al.* 2001.

Note: Figures for 1996 and 1997 are estimates.

agriculture, accounting for about 50% of use in the entire river basin (Figure 2).

Meanwhile, food production per cubic meter of agricultural water used has been increasing in recent years. And its average amount of the river basin rose from about 15 to 20 tons/ten thousand cubic meter during 1990's (Figure 3).

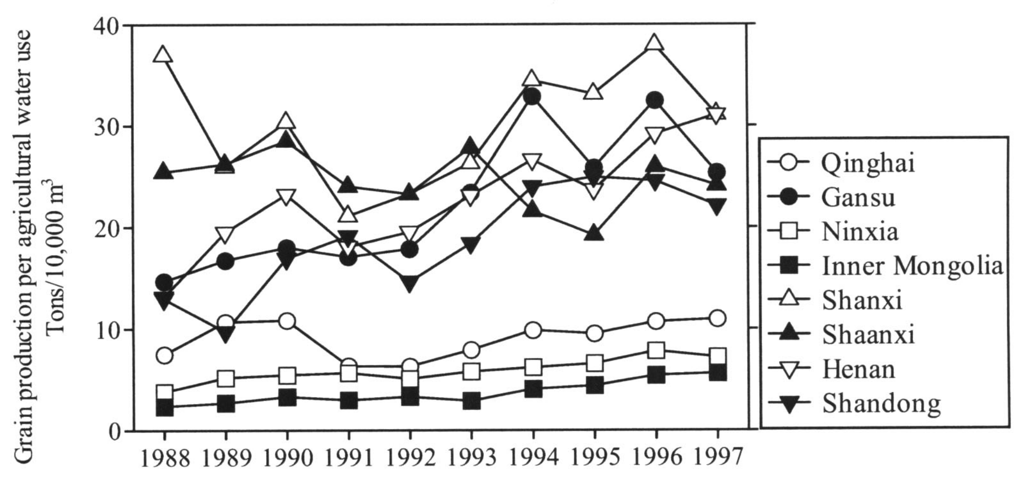

Figure 3. Grain production per agricultural water use.

Source: Prepared by authors by using Figure 1. and 2.

The dry up phenomenon were first happened in 1972, but worsened dramatically in the 1990s, with the most extreme event occurring in 1997 (Figure 4). During this period, the amount of water used for agriculture has been on a declining trend, but in the Yellow River basin which has unstable water resource amounts, so excessive water use leads easily to depletion of water resources. For this reason, it is important that water be used efficiently and rationally. Furthermore, the amount of water for industrial and urban household has been increasing in recent years, along with industrialization and urbanization. Thus, it is likely that the agricultural use of water will be increasingly constrained (Chinese Academy of Engineering, 2001).

In order to achieve sustainable development in the Yellow River basin under water resource constraints, it is essential to have information about how water can be allocated in the most physically and economically efficient ways, and about the extent to which water use can be reduced in what regions. Thus, it is important to estimate the efficiency of agricultural water use.

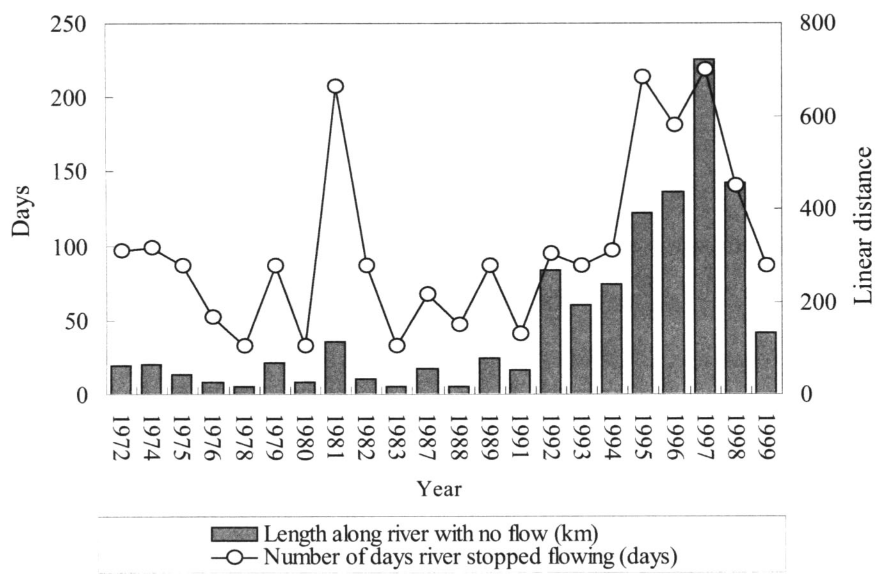

Figure 4. Dry up phenomenon: duration and linear distance.
Source: Prepared by authors from Sun *et al.* 2001.

3. Methods

In this study, we estimated agricultural Water Use Efficiency (WUE = grain yield/ actual evapotranspiration) of year 2000 by the SVAT-HYCY model (Sato *et al.*, 2007) combining with the agricultural filed data and grain yield statistic data. The actual evapotranspiration and grain yield were calculated by the 0.1°×0.1°grid. To estimate the actual evapotranspiration by the grid, the following procedures were applied. Firstly, we estimated the potential evaporation by the heat balance equation by following Kondo and Xu (1997) method. Secondly, the evapotanspiration from the agricultural filed without soil water deficit was estimated by using a function of LAI (Leaf Area Index) (Kondo, 1998). Finally, the actual evapotranspiration was estimated by the soil water content. To estimate the grain yields, grain production statistic data in each county and city was interpolated into the grid scale, based on the agricultural filed distribution data acquired by the remote sensing (Matsuoka *et al.*, 2007). Also, in order to evaluate the agricultural WUE in different irrigation districts, irrigation maps (Yellow River Conservancy Committee, 1989) were used.

4. Results

The results are shown in Figure 5. Here, we show the result of each mesh WUE from upper reach to middle reach. From this result, the WUE in upper reach is lower than middle reach; especially worsen in the large irrigation districts of upper reach. This result shows the same spatial trend of Figure 3. In order to summarize the above obtained result more precisely, we calculated agricultural WUE in different regions and irrigation districts (Figure 6). Here, the result of agricultural WUE in irrigation district of lower reach is included. From this result, the irrigation districts in Ningxia and Inner Mongolia recorded much lower scores compare with other regions and irrigation districts. Especially, the irrigation district in upper reach is approximately 3 times lower than irrigation districts in lower reach. However, we have not acquired some references to check accuracy of our results in detail. So, we have to carefully evaluate our obtained results in future.

This study suggests that further improvement in agricultural WUE in the arid and semiarid areas, especially upstream, is necessary toward sustainable agricultural production and toward prevention from water shortages.

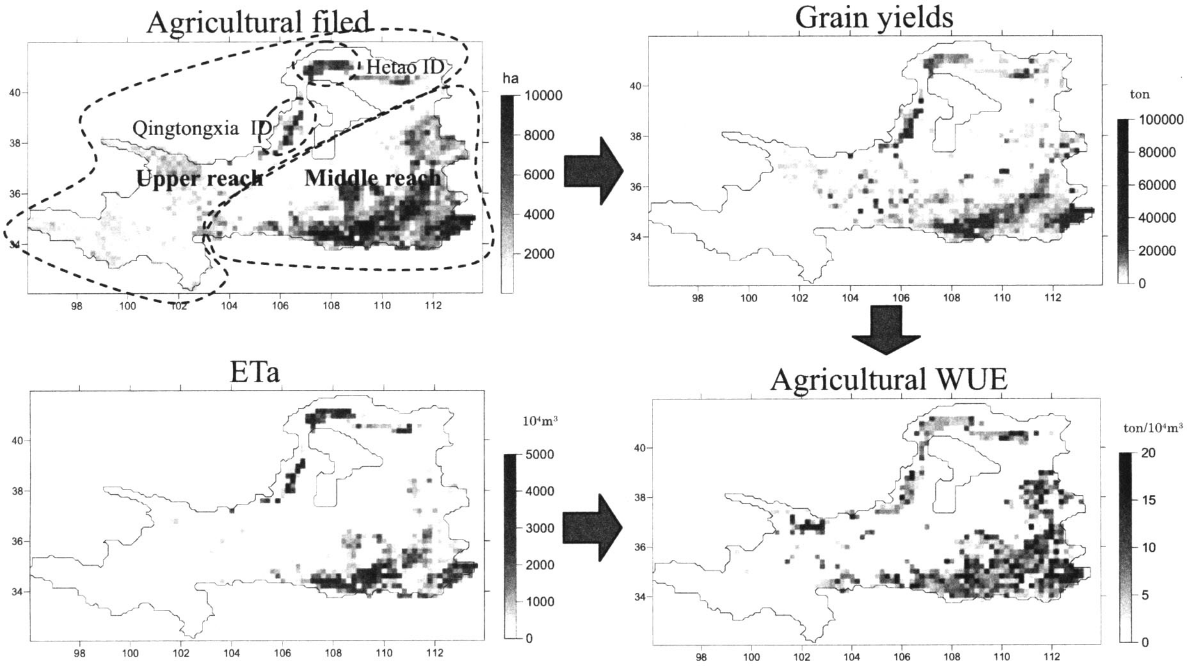

Figure 5. Results for agricultural WUE of year 2000

ID: Irrigation District, Eta: actual evapotranspiration

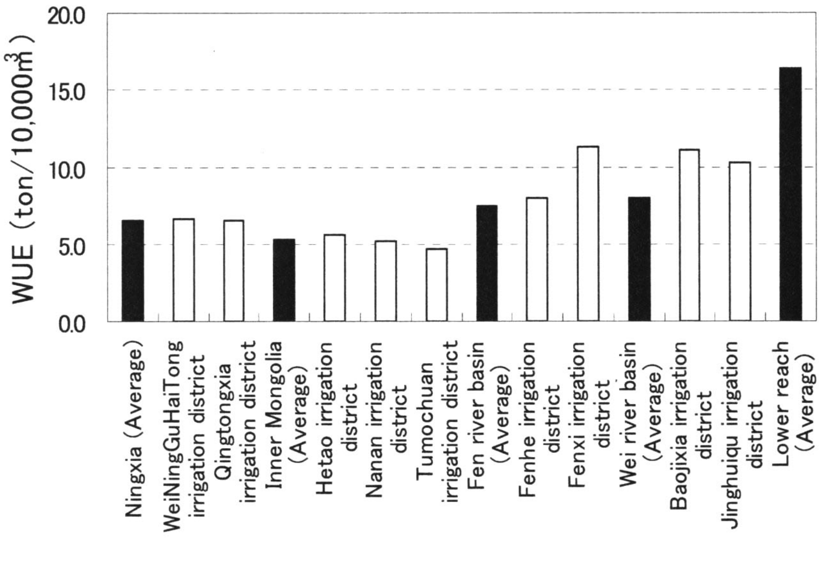

Figure 6. Results for agricultural WUE of year 2000 in different

5. Conclusions

This study evaluated the agricultural WUE of year 2000 by using the statistic data, land use data and hydrological model. As a whole result, the agricultural WUE is lower in upper reach. However, we have not analyzed what influences cause the differences of WUE. By showing this concrete improvement plan, we can suggest more about what sorts of preventions and policies are necessary.

Notes

1) China Natural Resources Database is from the Institute of Geographic Sciences and Natural Resources Research (Chinese Academy of Sciences), accessed 1 Oct. 2006: http://www.naturalresources.csdb.cn/index.asp

2) In this study, we use the data of agriculture water use as water loss. The amount of water loss is the portion of water that evaporates or is absorbed by soil during transport and use, the portion contained in products, and the portion ingested by the human population and livestock—portions that are not restored to surface water bodies or groundwater layers (Xi, 1996; Ministry of Water Resources, 2000).In other words, this is the amount of water lost in the course of being used and not returned to the river or groundwater. Agriculture water loss is calculated from the difference between the amount of water used (including losses) and the amount of water recovered in surface water and groundwater (Ministry of Water Resources, 2000).This study defines agriculture water use to be the amount of water loss, calculated as the amount of water drawn for irrigation purposes and consumed completely within the region.

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