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Evaluation on winter wheat water use efficiency in the haiheriver

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ABSTRACT

Based on the definition of WUE and reliable data sources officially published by the government, winter wheat WUE in the Haiheriver is evaluated. The results indicate that the three-year average winter wheat WUE in the Haiheriver is 0.89kg/m^3. Less than 0.89kg/m^3 winter wheat WUE appears in the seven regions accounting for more than 90% area in the Haiheriver. And it is the lowest in Inner Mongolia, winter wheat WUE is 0.35kg/m^3. And 1.77kg/m^3 winter wheat WUE comes out in Beijing. Compared with the present national winter wheat WUE in China, 0.8kg/m^3~1.6kg/m^3, winter wheat WUE in the Haiheriver remains a lower level. And it means winter wheat WUE in the Haiheriver has a great potential to improve in the future. With lower water consuming, higher winter wheat yield and WUE in Beijing, cultivated measures and management way in Beijing should be taken references by the other seven regions in the Haiheriver in order to improve winter wheat yield and WUE with lower water consuming.

KEYWORDS

Winter wheat; Water use efficiency (WUE); The haiheriver; Water consuming; Yield.

INTRODUCTION

Crop water use efficiency can reflect the relationship between crop yield and water amount in its growing in a region. Especially, it has a great significance to center on winter wheat WUE with limited irrigation in semi-arid or arid regions. After all, much more winter wheat yield gets, much more people can be raised. Nowadays, more scholars made the relative research with winter wheat WUE at home and abroad. For instance, MooreA.D., etc.[1] developed evaluation of the water use efficiency of alternative farm practices at a range of spatial and temporal scales. Chen,Suyin[3] studied effects of winter wheat row spacing on evapotranspiration, grain yield and water use efficiency, and draw a conclusion that winter wheat production in the North China Plain, narrow row spacing reduced soil evaporation, but had minor improvements on grain production and WUE under irrigated conditions with adequate nutrient levels. Dong, Qinge etc.[4] centered on effects of chemical fertilizer combined crushed straw application on yield and water use efficiency of winter wheat. Xue, Qinwu etc[5] focused on physiological

Mechanisms contributing to the increased water-use efficiency in winter wheat under deficit irrigation etc. Other scholars like Ali, Hakoomat[2] also contributes to the relative research on wheat WUE.

However, winter wheat water use efficiency (WUE) in the Haiheriver is very limited. Meanwhile, considering intensive population density, lower per capita water resources, water shortage, water pollution, low precipitation, high evaporation and arid climate, it is also necessary to make a research on winter wheat WUE in the Haihe river in order to get much more winter wheat yield in the future with less and better quality water resources.

EXPERIMENTAL SECTION

Experimental region choosing: To focus on winter wheat WUE in the semi-arid region in northern China from macro-perspective, we chose a typical region, the Haiheriver, as experimental site, in which there exists some typical problems such as shortage of water resources, water pollution, intensive population density, concentrating industries foundation, limited cultivated land, low precipitation and high evaporation etc. Its area is 31.82×10^4 km^2, and accounts for 3.3% of the national area. The Haiheriver flows through six provinces like Hebei, Henan, Inner Mongolia, Liaoning, Shandong and Shanxi, and two municipalities directly under the central government such as Beijing and Tianjing, and includes three water systems, seven rivers systems and ten main rivers. Annual mean temperature is 1.5~14°C, annual average relative humidity 50%~70%, annual average non-frost period 150~220 days, annual mean sunshine 2500~3000h, annual mean precipitation 539mm, annual mean continent evaporation 470mm, and it is suitable for varieties of crops like winter wheat to grow. And winter wheat is the main research objective in the paper.

Methods: Winter wheat WUE can effectively evaluatethe relationship between its product and water consuming in a region from macro perspective. It can be defined as the winter wheat yield (Y) getting from unit of its actual water consuming (ET) in its growing. And it can be shown with equation.1.

$$\mathrm{WUE} = \frac{\mathrm{Y}}{\mathrm{ET}} \tag{1}$$

Where WUE is the winter wheat water use efficiency, kg/mm or kg/m^3;. Y is winter wheat yield, kg; ET is actual winter wheat water consuming in its growth, m^3 or mm.

Data sources: Usually, to evaluate a small area like 2m×2m is easy to operate. We can set waterproof board at the bottom and surrounding of the experimental pit, and control precisely its irrigation, evapotransprition, soil water content and underground recharging etc. in its growing, and actual crop ET will be accurately ensured.

However, it is a challenging problem for a large area such as 31.82×10^4 km^2. To assess objectively winter wheat WUE in the Haihe river, reliable data sources are key with less soil water content, groundwater recharging etc, and include daily precipitationofficially published by the national meteorological center,annual irrigation from water resources public report of the Haihe river,annual irrigation area, annual sowing area and winter wheat yield etc. getting from China agricultrual yearbook, and economic yearbook of each province or municipality directly under the central government in each region in the Haihe river. All these data are published officially in China, and are reliable and available.

RESULTS

Based on the above data and the theory connected with WUE, it is necessary to analyze each element of water balance, such as precipitation, irrigation, soil water content and groundwater recharging etc, and corresponding winter wheat yield in the Haihe river.

Water balance analysis

Precipitation:In fact, precipitation (P) contributing to winter wheat growth is effective precipitation (P_0) instead of the total. Part of them will produce slope flow, the rest is key to promote its growth. Generally, P_0 is zero if P is less than 5mm each time. While P_0 can be calculated with the following equation if P is more than 5mm.

$$\mathbf{P_0 = \alpha P} \quad (2)$$

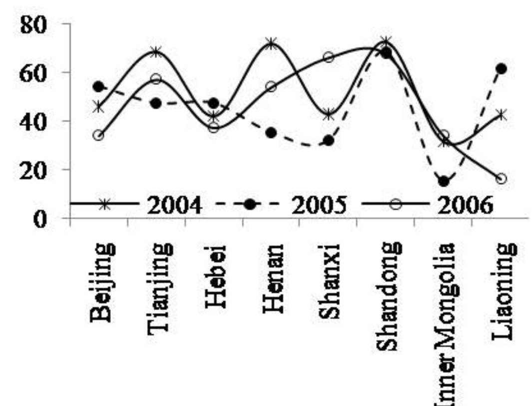

Figure 1 : Effective precipitation in each region in the Haihe river from 2004 to 2006 (m^3/mu)

Where α is rainfall infiltration coefficient. And it can be finally valued 0.8 based on the soil types in the Haiheriver.

The results show that the three-year average P_0 is changed from $27m^3$/mu to70 m^3/mu in the Haiheriver. And P_0 are much higher in Shandong and Tianjing, and the three-year mean are 69.77 m^3/mu and 57.84 m^3/mu, respectively. While P_0 is the lowest in Inner Mongolia, 27.27 m^3/mu. P_0 is from 40 m^3/mu to55 m^3/muin the rest regions. Generally,winter wheat can develop its growth with at least $300m^3$/mu, and it means that autumn irrigation or spring irrigation is must carried in its growing.

Irrigation (I): Being lack of surface water, groundwater irrigation must be done in the Haiheriver. Statistically, groundwater irrigation accounts for more than 70% of the total irrigation. And the percentage of each region is shown below (Figure 2). Generally, the total irrigation in the Haiheriver takes an increasing trend from 2004 to 2006, and has 3% increment each year. Finally, the average irrigation pu mu in each region is shown Figure 3. The results indicate that the three-year average irrigation in the Haiheriver is $292.82m^3$/mu. While the three-year mean in each region is from $147m^3$/mu to $424m^3$/mu. It means that there exists unbalanced water distribution for each region in the Haiheriver.

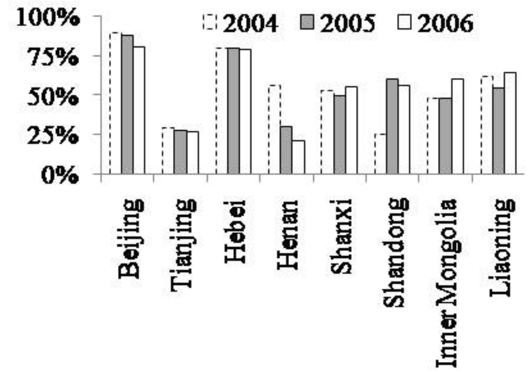

Figure 2 : Percentage of groundwater irrigation accounting for the total irrigation in each region from 2004 to 2006

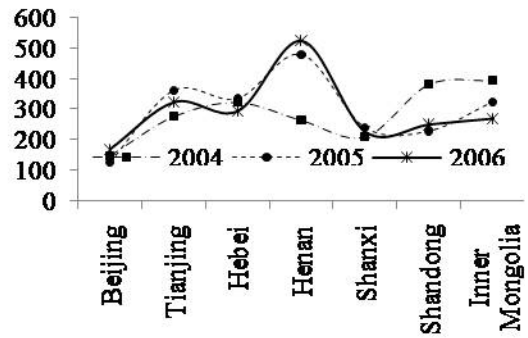

Figure 3 : Irrigation in each region in the Haihe river from 2004 to 2006 (m^3/mu)

Soil water and underground water recharging: Compared with P_0 and I in winter wheat growing, soil water content and groundwater recharge can be regarded as zero from macro perspective. The reason is that soil water content before sowing and after harvest has a tiny change, less than 5%, and the shallowest and the deepest average groundwater table is 4.57m in Shandong and 28.75 in Hebei, respectively. While the longest winter wheat root is usually 2m. So, groundwater recharging to winter wheat nearly clings to zero. Consequently, winter wheat water balance in its growth mainly includes P_0 and I. And it can be taken with the following equation.

$$P_0 + I = ET \quad \textbf{(3)}$$

Where ET is the actual consuming water in the winter wheat growth.

The results show that the three-year average ET of winter wheat is from 192m^3/mu to 476m^3/mu (Figure 4). There is much yearly higher change on winter wheat ET in some regions among them. For example, ET in Henan in 2004 is 35% and 43% lower than in 2005 and 2006. Meanwhile, ET is more than the yearly mean in 60% area in the Haihe river, while is less than the yearly mean in 20% area. All these indicate there exists uneven irrigation distribution in these regions, and has a yearly big change on irrigation, and it will have directly affected on ET and yield each year.

Winter wheat yield: The results showwinter wheat yield per mu varies from 95kg to 411kg. And the yield in Henan province is the highest, and the three-year mean is 410kg/mu, and it is about 30% more than the mean in the Haiheriver (Figure 5). While the yield in Inner Mongolia is the lowest, and the three-year mean is 110kg/mu. Generally, there is big change each year in each region.

Winter wheat WUE: On the basis of winter wheat yield, its actual water consuming ET and the theory of WUE, we finally evaluate winter wheat WUE in the Haiheriver. And the results show that the three-year average WUE in the Haiheriver is 0.89kg/m^3. And the highest and lowest WUE are in Beijing and Inner Mongolia, respectively, and their corresponding values are 1.77kg/m^3 and 0.27kg/m^3. While winter wheat WUE in other regions varies from 0.82kg/m^3 to 1.05kg/m^3 from 2004 to 2006. Generally, compared with the current WUE mean in China, 0.8~1.6kg/m^3, WUE in some regions in the Haiheriver is much lower than the mean. Considering lower water consuming and higher winter wheat yield and WUE in Beijing, cultivated measures and management experiences in Beijing should be referenced by other regions in the Haihe river so as to the winter wheat WUE in the Haihe river.

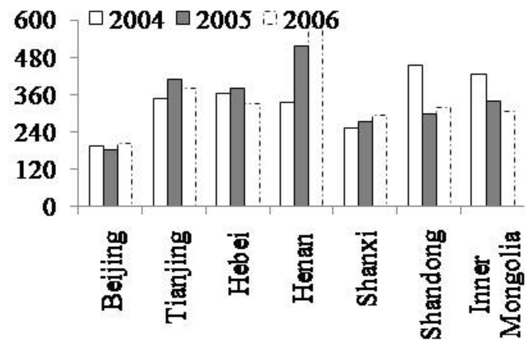

Figure 4 : Winter wheat ET in each region in the Haihe river from 2004 to 2006 (m^3/mu)

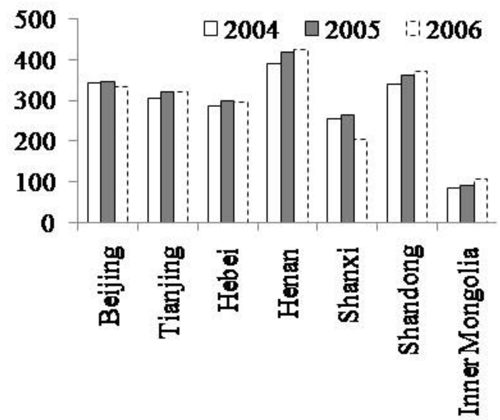

Figure 5 : Winter wheat yield in each region in the Haihe river from 2004 to 2006 (kg/mu)

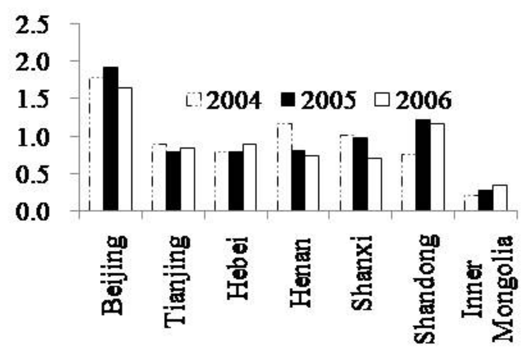

Figure 6 : Winter wheat WUE in each region in the Haihe river from 2004 to 2006 (kg/m^3)

CONCLUSIONS

Combined with the definition of WUE and officially reliable data sources published by the government, we assess winter wheat WUE in the Haiheriver. The results show that the average WUE in the Haiheriver is 0.89kg/m^3. There are seven regions having lower than 0.89kg/m^3 winter wheat WUE. Especially, winter wheat WUE in Inner Mongolia is 0.35kg/m^3. And it is only in Beijing having 1.77kg/m^3 winter wheat WUE. It means that winter wheat WUE in most regions in the Haiheriver is much lower than the present national mean in China, 0.8kg/m^3~1.6kg/m^3. And it also indicates that winter wheat WUE in the Haiheriver must be improved further. Finally, it is suggested for the seven regions in theHaiheriver to make a reference on the cultivated measures and management experiences in Beijing so as to winter wheat WUE in these regions, because of lower water consuming and higher winter wheat yield and WUE in Beijing.

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