Virtual water measure and analyses of structure change for regional agricultural products in Sanjiang plain

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***Abstract*—Virtual water is the new method of realizing sustainable development of water resources. It plays an important role in changing the uneven distribution of the spatial pattern of water resources in our country. Through confirming the virtual water content in units' crops of Sanjiang Plain, this paper furthermore finds the virtual water content over the years of all types of crop, and undertakes an analysis to structural changes of crop on this foundation; comparing with the average virtual water content of crop, draws the total virtual water content of food crop in Sanjiang Plain displayed increasing tendency since 2003, and the rise range is bigger, indicating that the food crops of this region generally have water-saving planting advantage.**

Keywords- virtual water; agricultural products; Sanjiang plain

I. INTRODUCTION

Virtual water firstly put forward by British scholar Allan is new concept of water resources management, and is the water used to produce goods and service [1]. The research of virtual water trade can promote efficient use water resource. Food as the main water consumption, there are a lot of virtual water implicit within it. At present agricultural products are main water labor-intensive goods in our country [2]. Sanjiang plain as the base of the important commodity grain production in China, take important mission for grain production and output. Although the region are plenty of rainfall, but in recent years the status quo of water resources is not optimistic. A higher percentage of agricultural water accounts for more than 90% of total water consumption. So in this paper total amount and structure change of agricultural products virtual water are analyzed, to systematically understand local water resources utilization, and then help to further develop virtual water related research. To adjust and optimize the planting structure based on virtual water, improving the utilization ratio of water resources provides new train of thought for water resources management.

II. THE DEVELOPMENT SITUATION OF WATER RESOURCES AND AGRICULTURAL PRODUCTS IN SANJIANG PLAIN

Sanjiang plain has total area of 10.8 ten thousand km^2, cultivated land area of nearly 3.51 million hm^2. The soil quality is good, the terrain is flat and concentrated, which is suitable for the agricultural production of mechanization and intensification. It is rich in water resource, and can meet the farming and animal husbandry requirements, produce high quality agricultural and sideline products. So we can reduce water resources pressure in domestic arid areas, through the way of trade to implement virtual water strategy, and meanwhile develop virtual water economy of Sanjiang plain.

The water resources mainly include abundant local precipitation and transit water in Sanjiang plain. Mean annual precipitation is 556 mm, about 60 billion m^3 water resources; Transit water is about 278.5 billion m^3, mainly including Heilongjiang River 147.6 billion m^3, Songhua River 68.7 billion m^3, Wusuli River 62.2 billion m^3. Sanjiang plain is well irrigation area, almost no loss. In this region there is the great advantage and potential to implement virtual water strategy.

III. RELATED MEASURED FOR VIRTUAL WATER OF MAIN AGRICULTURAL PRODUCTS

A. The determination of crop water requirement

Crop water requirement is calculated based on transpiration of water evaporation in the growth period, is evapotranspiration ET_c accumulated in the whole process of crop growth [3]. In this region the reference crop evapotranspiration of main crops is calculated according to the method of reference crop evapotranspiration recommended by FAO. ET_0 can be calculated by Penman formula recommended [4].

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273}(e_a - e_b)}{\Delta + \gamma(1 + 0.34U_2)} \quad (1)$$

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Where, Δ is the curve slope of saturation water vapor pressure related to temperature [kPa/T （℃）]; ET_0 is the reference crops evapotraspiration quantity （mm/d） ; R_n is net radiation of the surface of the crops （MJ/m2· d） ; G is soil heat flux （ MJ/m2· d） ; T is average air temperature [T （℃）]; U_2 is the wind of 2 meters high （m/s） ; e_a is saturation water vapor pressure （KPa） ; e_b is measured water pressure （KPa） ;

e_a - e_b is the gap between saturation water vapor pressure and measured water pressure （KPa） ; γ is dry humidity constants （KPa/T）

The reference crops evapotraspiration quantity means water requirements of Alfalfa under the condition of the soil moisture enough, ground completely covered, growth normal, height on the open short grass [5]. To calculate virtual water, some appropriate adjustments still need be done based on reference crops evapotraspiration quantity, and then ET_c is calculated under the standard conditions.

$$ET_c = K_c \times ET_0 \qquad (2)$$

Where, K_c is crop coefficient, which is the composite index of key elements measured the crop different from other crops because of climate, soil and crop planting mode.

Through the ClimWat2.0 database obtain ET_c, mainly using the CropWat8.0 software to calculate. Data download time for May 2011. Select Sanjiang plain subordinate 15 farms as the study area, according to agricultural products data statistics from 1999 to 2009, the main agricultural products are divided into two types: (1) food crops, including rice, wheat, corn, soybean; (2) economic crops, including sunflower, vegetables, melons, potato. This paper selects water requirements of the main crops in Table Ⅰ.

TABLE I. WATER DEMAND OF CROPS IN SANJIANG PLAIN

Crop name	rice	Whe-at	corn	Soy-bean	Sun flower	Veget-able	Melon	Pot-ato
CWR	5829	3462	3688	2930	3695	3292	3590	4147

B. The calculation of virtual water of main crops

Accurately measured agricultural products virtual water content in Sanjiang plain, water resources elements can be brought into the regional planting planning and food trade strategy choice.

The computation formula of agricultural products virtual water content is as follows:

$$SWD[e,c] = \frac{CWR[e,c]}{CY[e,c]} \qquad (3)$$

Where, *SWD [e, c]* is virtual water of the crop c in the country or region of the e (m^3/t), *CY [e, c]* is every hectare production of the crop c (m^3/ha).

According to Table Ⅰ and statistical data of 1999-2009 main agricultural product per unit yield, using formula (3) to calculate the per-unit virtual water content of main crops, then obtain total virtual water for various crops. Results see Table Ⅱ .

TABLE II. TOTAL VIRTUAL WATER FOR VARIOUS CROPS × 10^8/M^3

	rice	wheat	corn	Soy-bean	Sun-flower	Vegetal-able	melon	potato
1999	11.940	2.373	0.404	2.078	0.000	0.020	0.005	0.007
2000	11.868	1.316	0.246	2.930	0.000	0.005	0.002	0.002
2001	11.613	1.187	0.199	3.546	0.000	0.006	0.001	0.002
2002	11.789	0.959	0.439	2.917	0.005	0.019	0.002	0.002
2003	8.752	0.955	0.504	3.934	0.007	0.035	0.000	0.008
2004	12.722	0.539	0.682	3.255	0.022	0.004	0.004	0.003
2005	14.344	0.391	0.683	2.701	0.012	0.010	0.000	0.000
2006	19.569	0.677	0.813	2.671	0.032	0.000	0.000	0.000
2007	25.249	0.018	0.961	1.518	0.030	0.002	0.002	0.000
2008	26.186	0.161	1.334	2.486	0.007	0.002	0.001	0.007
2009	28.649	0.663	2.861	3.298	0.000	0.000	0.000	0.006

IV. RESULTS AND ANALYSIS

From Table Ⅱ can see, the great decrease in virtual water volume of agricultural products of Sanjiang Plain is wheat, melons; the rice and corn are slightly decreased to some extent, for the economic crops, the change range is bigger.

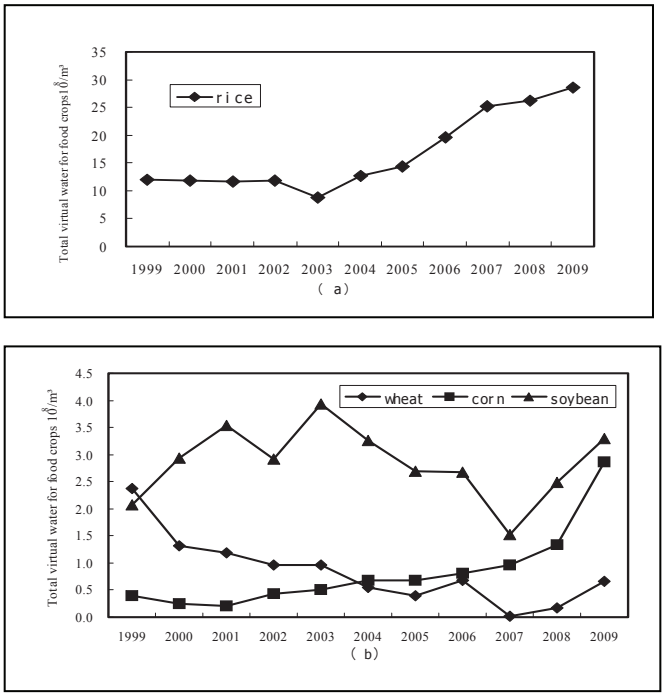

Figure 1. Virtual water for food crops in Sanjiang plain from 1999 to 2009

During the change of total virtual water volume of food crops, Figure1 (a) shows that the total virtual water volume of rice was maintained basically decreasing gently level in the period 1999-2003, the change rate was not very big, and it

soared after 2003, the change rate was bigger. The total virtual water volume increased from $8.752\times10^8m^3$ of 2003 to $28.649\times10^8m^3$ of 2009, rose 69.45%. The virtual water content of unit mass rice decreased somewhat in the period 2003-2009, obviously, they enlarged the planted area of rice in these years. Figure1 (b) shows that the virtual water content of wheat decreased in fluctuation, the change rate was little. The virtual water content of corn increased in fluctuation, the change rate was smaller before 2008, and reached the maximum in 2009. The virtual water content of soybean increased in fluctuation, the change range was bigger in individual years, and reached the minimum in 2007.

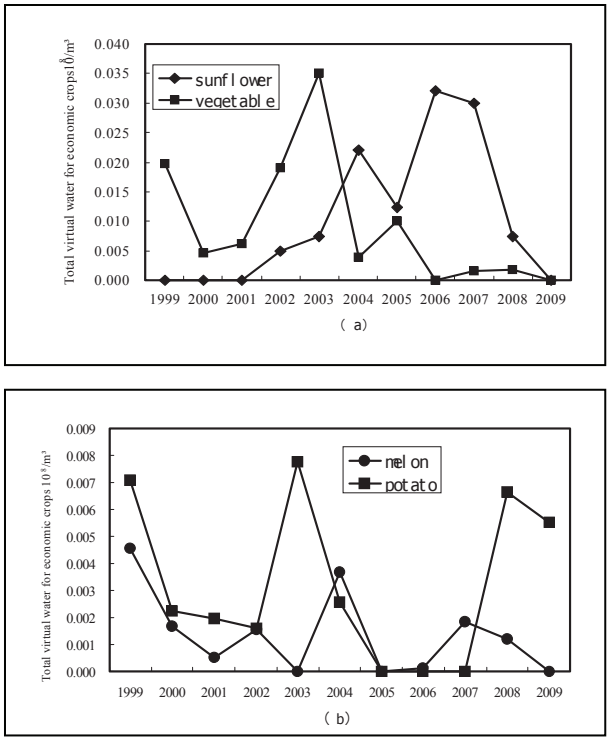

Figure 2. Virtual water for economic crops in Sanjiang plain 1999 to 2009

Figure 2 shows a process for the change of virtual water volume of economic crops, the fluctuation of four kinds of economic crops is great. Figure 2a reveals that the virtual water volume of sunflower increased in fluctuation before 2004, and the change range was bigger, and then it decreased somewhat over the next year. It had a substantial rise in the period 2005-2007, and reached the maximum in 2006. The change rate was bigger for the decrease trend after 2007. The change range of the virtual water volume of vegetable was similar to sunflower, the change rate of increase and decrease was bigger between years. The virtual water volume of vegetable was higher than that of sunflower from 1999 to 2003, and the virtual water volume of sunflower was higher than that of vegetable after 2004. The virtual water content of unit mass sunflower is $3175.763m^3/t$; it is bigger than that of vegetable $153.5413\ m^3/t$, according to above analysis results, Sanjiang Plain does a certain adjustment for the planted area of sunflower and vegetable in recent years. The change of virtual water volume of melons and potato has always remained very fluctuant, and the volume is relatively low.

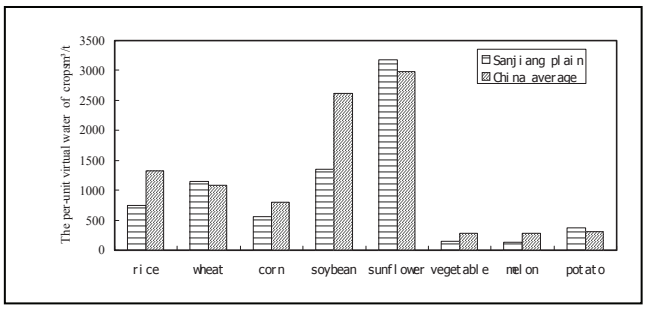

Figure 3. Virtual water content comparation of Sanjiang plain and the Chinese average

From Figure 3 can see, the virtual water content of rice, corn, soybeans, vegetables, melons, etc are lower than the average level in China, so it will save an enormous amount of water resources to plant these crops in Sanjiang Plain than the arid region, and the water-saving result of rice, corn, and soybean is more obvious. From the virtual water volume and change of different kinds of agricultural products look, the virtual water volume of food crops is still the largest. It began to present increment trend since 2003, and increased significantly. Therefore, increasing the plant area of maize basing on original plant is useful to improve the water-saving efficiency of food crops planting.

V. CONCLUSION AND DISCUSSION

- According to the change trends of virtual water of different agricultural products, certain crop product is selected to plant on certain region mainly on the basis of benefits. From the angle of virtual water, it's appropriate to consider reducing the production of water-intensive crop products, to ease the local water resources pressure. For the area have abundant water resources, the water-intensive crop products can be planted, making full use of local water resources, then through the virtual water trade to ease the water resources pressure of water shortage area.
- Comparing with the average level of virtual water of the whole nation crop products, Sanjiang Plain has natural advantage to plant food crops. Virtual water, as a kind of factors to assess food crops layout, it could help to the rational utilization of water resources. Increasing the planting area of food crops in Sanjiang Plain, not only can take full use of the water saving effects of this area, but also can improve the economic actual strength of virtual water of food crops in Sanjiang Plain. From a nationwide perspective, increasing the planting area of food crops in this area means the increase of planted area and the proportion of production of water-saving crops. It is significant to the effective use of agricultural water resources in China.

- Under the primary consideration of both ecological environment and the sustainable development goal, making use of natural precipitation at maximum, and exploiting the groundwater rationally to prevent and reduce water loss and soil erosion. Ensure the highest total output value of each crop in irrigation area, to realize sustainable use of regional water resources.

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