ADJUSTMENT PROPOSAL OF CROP PRODUCTION PATTERN AND WATER ALLOCATION IN QIRA, XINJIANG, CHINA

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ABSTRACT

In this paper, the current situation of water usage by irrigated agriculture in Qira County of Xinjiang Uyghur Autonomous Region, China was discussed and the adjustment proposal of crop production pattern in the area was examined. In Qira County, the river flow amount in spring and summer is 9% and 77% of the annual total amount, respectively and the water supply including spring water and groundwater in spring and summer is 15% and 57% of the annual water supply, respectively. However, the water requirement of the area is concentrated in spring (34%) and summer (43%). It causes a water insufficiency for spring irrigation. The excessive wheat cultivation needs high water demand in spring and it's considered to be a main cause of water shortage in the area. Therefore, the wheat acreage replacements of 2,000 ha and 4,000 ha with cotton were examined to improve the current situation of water resources usage and economy in the county. In both plans, the water shortage in spring was not resolved, however the water shortage in autumn was resolved completely in 4,000 ha replacement. The increase of the value of production by expansion of cotton area was also shown in both cases and the net increase portion of income in 2,000 ha replacement was at the same level as 4,000 ha case.

Keywords: Irrigation, Crop production pattern, Water allocation, Qira County

1. INTRODUCTION

Qira County of Xinjiang Uyghur Autonomous Region, China is still an agricultural based area despite its industrialization and urbanization progress. Therefore, it is important for the area to make full use of its arable land and water resources by establishing a reasonable crop production pattern.

The river flow amount is concentrated in summer in this area and a great water shortage problem occurs in spring season because of seasonal imbalance of river flow and high water demand for spring agricultural use. According to the area's water demand, water supply and value of production for each crop, wheat cultivation seems to be one of the causes of water shortage because of its high water demand during the spring season. In addition, the increase of wheat cultivation area is accelerating the high water demand. However, the value of wheat production is relatively low with regard to its large water consumption.

In the comparison of wheat and cotton, the water demand of cotton is low in spring and high in summer and the value of cotton production is much higher than wheat. Therefore, considering the current situation of water resource and food problem, the production pattern of wheat and cotton in the area should be adjusted.

In this paper, based on the current situation of water usage in Qira County, the amount of water usage of each crop was analyzed and the adjustment of crop production pattern in Qira County was examined. The adjustment proposals in the paper will support the sustainable water resource usage and will contribute to the economical development of the area.

2. OVERVIEW OF XINJIANG UYGHUR AUTONOMOUS REGION AND QIRA COUNTY

2.1 Xinjiang Uyghur Autonomous Region

Xinjiang Uyghur Autonomous Region (hereinafter called “the region”) is located in the northwestern part of China, the region area of 1.66 million km^2 is about one sixth of the country's territory. In the region, three major mountain ranges stand in a row, which are the Altay mountain range in the north, the Tian Shan mountain range in the middle, and the Kuenlun mountain range in the south. The region is split by the Tian Shan mountain range into two parts of north Xinjiang and south Xinjiang. There are two large basins in the region; the Dzungarian Basin in the north Xinjiang and the Tarim Basin in the south Xinjiang. Much of the Tarim basin is dominated by the Taklamakan Desert which is the second largest desert in the world just after the Sahara desert (**Fig.1**).

The annual precipitation of the plain area of the region is about 150-250mm in north Xinjiang, 40-60mm in south Xinjiang and the annual evaporation rate (small pan evaporation) is 1,600-2,300mm in north Xinjiang and 2,200-2,700mm in south Xinjiang; it means that the region is an extremely dry climate all year around. For this reason, the autonomous region’s agriculture is not suitable for rain-fed agriculture and it is mainly based on oasis irrigated agriculture (wheat, cotton, etc.) and stock farming (sheep wool) in the pastures which are formed in the plain area.

In the region, there are about 570 large and small rivers which are formed by water flow originated from precipitation and glacial melt water in mountain ranges. They are able to flow until the plain areas, but almost all rivers disappear in the desert and the river bottom cannot be found. The annual flow amount of all rivers is about 81 billion m^3 and the amount of flow changes greatly by season. Almost all water is concentrated in the summer season and water shortages occur in other seasons.

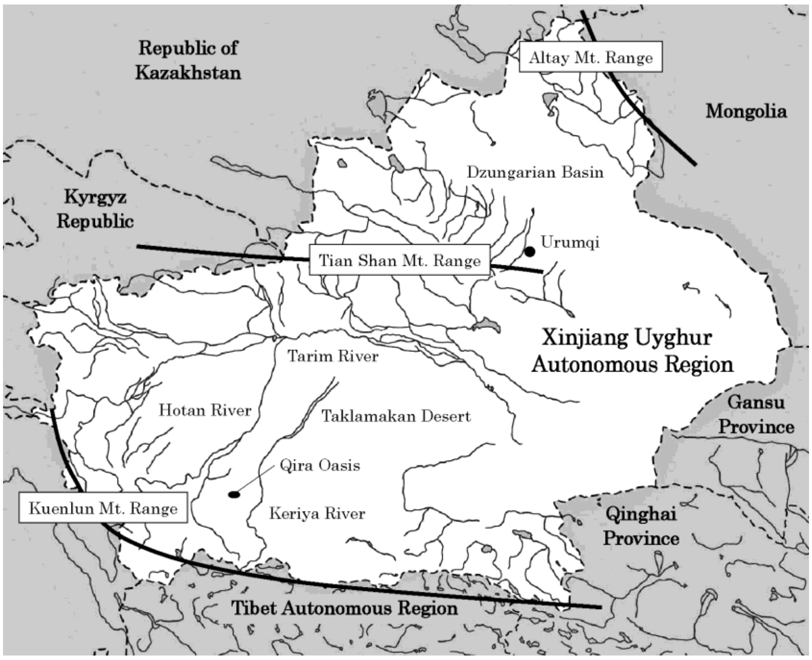

Fig.1 Xinjiang Uyghur Autonomous Region and Qira Oasis

2.2 Water Resources of Qira County

Qira County is one of the counties of Hotan Prefecture, which is located in the southern part of the Taklamakan Desert. Although Qira County contains an area of 31,591 km^2, use of residential land and production activities in oasis is only 1.6% of the total area. The unused portion of Gobi or desert is 64%; the arable land is only 0.7% [1].

The annual precipitation of Qira County is 36 mm and the annual evaporation is 2,752 mm; this means the area is extremely dry. Although there are 9 rivers which gather precipitation and glacier melt of the Kuenlun mountain range at the southern part of the county and flow to the north direction, they carry out 584 million m^3/year of average flow; among them there are only two perennial rivers. The flow amount of spring, summer, autumn and winter is 9.3%, 76.9%, 10.9%, and 2.9% of annual amount, respectively. The summer flow takes up more than half of the total flow amount [1].

The total amount of the water used in 2009 in Qira County was 2.55×10^8m^3, only 0.04×10^8m^3 water was used by residents living in the county, and the rest of the water was used by irrigation for agriculture, forestry, stock farming (water for grass) [2]. In this paper, the domestic and industrial water use is ignored and the all water (2.55×10^8m^3 in 2009) is assumed to be used for irrigation.

2.3 Agriculture of Qira County

Qira County is an agricultural zone where the agriculture and stock farming are firmly connected. The oasis agriculture based on irrigation is very important to the economic development of the area. The oasis of Qira County (Qira Oasis, see **Fig.1**) consists of the eastern oasis and western oasis which are located in the plains, and four river basin oases which are located in each valley of the mountain region. The eastern and western oases are the main agricultural areas which occupy 78% of the total oases area in the county. The main irrigated agriculture crops are wheat, corn, alfalfa and cotton. It is also necessary to irrigate the forest to prevent desertification. The mountain oasis is considered mainly as a stock farming area.

The water used in the eastern oasis is supplied from the spring water, which is accumulated by reservoirs constructed in the plain area, and river water which is conducted by headrace. In the western oasis, the water is supplied from rivers, groundwater and reservoirs.

Since the food problem of farmers has not yet been solved completely, the agricultural production is mainly grains, and most forests are the windbreak forests which were made in order to prevent desertification. Therefore, the economic value of agricultural production is low. In addition, the county has large pasture area, however most pasture belongs to summer pasture and there are few grassy places in winter. Therefore the economic return of grass production is also not so high.

3. CURRENT SITUATION OF WATER USAGE AND CROP PRODUCTION PATTERN IN QIRA COUNTY

According to analysis of the water supply situation from 2004 to 2010 of the Qira County, except 2006, all the years had a similar condition where water demand is higher than supply. Based on the data, the case of 2009 shows the same situation mentioned above, so it was chosen and analyzed as a representative year.

3.1 Water Supply

In this study, only the data of total amount of water usage in 2009 of Qira County was obtained. Within the total water usage, the water supply from river water, reservoir water and groundwater are $15{,}453\times10^4 m^3$, $7{,}095\times10^4 m^3$ and $2{,}908\times10^4 m^3$, respectively [2]. In order to analyze the seasonal water supply of the area, it is necessary to determine the amount of seasonal water allocation. Here, based on the seasonal distribution of the river flow rate of the area that is described in Chapter 2, the seasonal distribution of river water was determined. The source of reservoir water consists of spring water and flood water. The water supply by spring water in each season is almost the same amount in this area. The situation of groundwater seems to be similar to spring water. Moreover, the seasonal change of flood water is partially averaged by reservoir storage. From these reasons, the seasonal water supply by water storage and groundwater was assumed to be the same, and was distributed by average rate during the year. Based on this method, the estimated seasonal distribution of the water supply is shown in **Table 1**. The table shows that 57% of annual water supply concentrates in summer.

Table 1 Seasonal distribution of water supply

Source of water supply	Total amount	Spring	Summer	Autumn	Winter
River water (10^4 m^3)	15453	1437	11884	1684	448
Water storage and groundwater (10^4 m^3)	10003	2501	2500	2501	2501
Total (10^4 m^3)	25456	3938	14384	4185	2949

3.2 Water Requirement of Irrigation

Table 2 shows the water requirement for seasonal irrigation of each crop in Qira County. Although wheat is a main crop for food in the area, it needs much water rather than any other crop. Moreover, its notable characteristics are that the amount of water requirement is high in spring and autumn, low in summer.

Table 2 Seasonal water requirement for each crop

Crop	Water requirement (m^3/ha)	Seasonal water requirement (m^3/ha)			
		Spring	Summer	Autumn	Winter
Wheat (fall)	12450	5250	1500	5700	-
Wheat (spring)	9600	6450	3150	-	-
Corn (spring)	12150	3000	7350	1800	-
Corn (summer)	10350	-	8550	1800	-
Cotton	11550	3000	8550	-	-
Oil bearing	7950	5025	2925	-	-
Vegetables	10950	5025	4350	1575	-
Melon	13200	3000	7050	3150	-
Other crops	9600	6450	3150	-	-
Alfalfa	12150	2400	6450	3300	-
Other grass	11850	7800	2400	1650	-
Forestry	13350	4500	5550	-	3300

Source: Water Bureau of Qira County [3]

Table 3 shows the cultivation acreage and the seasonal water requirement of each crop in 2009. The total amount of water demand in the area was calculated by using the data on cultivation acreage of each crop and their seasonal water requirement shown in **Table 2**. Looking at the water demand in each season, the water requirement for most crop cultivation concentrates in spring (33.8%) and summer (43.1%). This causes a disagreement with the seasonal distribution of the surface water and especially water insufficiency during spring irrigation.

According to **Table 3**, the cultivation acreage of wheat and corn is 6,890 ha and 6,622 ha, respectively, however, the percentage of total spring water is 35.0% and 8.3%, respectively, and percentage of total summer water is 8.5% and 39.3%, respectively. Although relatively large cultivation acreage is used for both crops, the water requirement characteristics of corn fits the seasonal distribution of water resources in the area, however the characteristic of wheat does not fit. Therefore the high water demand of wheat in spring is considered to be a main cause of the water shortage problem in the area. The same characteristics are found in the autumn season.

Table 3 Cultivation acreage and seasonal water requirement of each crop in 2009

Crop	Cultivation acreage (ha)	Seasonal water requirement (10^4 m^3)				Annual water requirement (10^4 m^3)
		Spring	Summer	Autumn	Winter	
Wheat (fall)	6190	3250	929	3528	-	7707
Wheat (spring)	700	452	221	-	-	673
Corn (spring)	2916	875	2143	525	-	3543
Corn (summer)	3706	-	3169	667	-	3836
Cotton	1738	521	1486	-	-	2007
Oil bearing	1379	693	403	-	-	1096
Vegetables	1045	525	455	165	-	1145
Melon	344	103	243	108	-	454
Other crop	1616	1042	509	-	-	1551
Alfalfa	2512	603	1620	829	-	3052
Other grass	1050	819	252	173	-	1244
Forestry	3788	1705	2102	-	1250	5057
Total	26984	10588	13532	5995	1250	31365

3.3 Water Supply-Demand Balance

Table 4 shows the water supply-demand balance and seasonal sufficiency rate obtained by **Table 1** and **Table 2**. The water supply amount of the year is about 5,909×$10^4 m^3$ less than water demand amount and a shortage of water resources occurs. Here, we introduce the water sufficiency rate. The rate is defined as ratio of water supply to water demand and its maximum value is set to 1.0. The water sufficiency rates in spring, summer, autumn and winter are 0.37, 1.0, 0.70, and 1.0, respectively. It can be seen that the sufficiency rate of spring is much lower than other seasons. The annual sufficiency rate is 0.73 (Calculation process is shown in Note2 of **Table 4**).

Table 4 Water supply-demand balance and sufficiency rate of Qira County in 2009

Supply and demand	Spring	Summer	Autumn	Winter	Total
Water supply (10^4 m^3)	3938	14384	4185	2949	25456
Water demand (10^4 m^3)	10589	13531	5995	1250	31365
Supply-demand balance (10^4 m^3)	-6651	853	-1810	1699	-5909
Sufficiency rate	0.37	1.0	0.70	1.0	(0.73)

Note1: Maximum value of sufficient rate is set to 1.0.
Note2: Annual sufficiency rate (0.73) is calculated by using effective water supply.
Effective water supply is 25,456-853-1699= 22,904 (10^4 m^3)
Annual sufficiency rate is 22,904/31,365=0.73

In the area, since the harvest time of fall wheat is earlier than other crops, corn can be grown as double-cropping after the wheat harvest. In recent years, the combined cultivation of wheat and corn is expanding.

Although the total cultivation acreage of the area in 2009 is 16,988ha, the crop acreage has reached 23,196ha by the combined cultivation method. However, because of the existing water shortage problem, only 16,101ha was irrigated effectively. Complete irrigation couldn't be ensured for more than 7,000ha [2]. Therefore the production amount does not go up effectively in spite of cultivation area expanding. At the same time, the water is taken up for agricultural use and water for forestry and grass cultivation is reduced. This influences the development of stock farming and the local environment of the area.

In this paper, the crop cultivation acreage, sufficiency rate and total production amount for the proposal plan are compared with the actual data in 2009. Since the data about each crop cultivation acreage and total production amount in 2009 is available, the sufficiency rate of the actual irrigation water for each crop in the year was calculated beforehand.

The actual seasonal and annual water supply of each crop can be estimated by seasonal water requirement of each crop in **Table 3** and seasonal sufficiency rate in **Table 4**. For example, the actual seasonal and annual water supply of wheat (fall) is calculated as follows;

Spring supply $3250\ (10^4\ m^3) \times 0.37 = 1202.5\ (10^4\ m^3)$
Summer supply $929\ (10^4\ m^3) \times 1.00 = 929.0\ (10^4\ m^3)$
Autumn supply $3528\ (10^4\ m^3) \times 0.70 = 2469.6\ (10^4\ m^3)$
Winter supply $0\ (10^4\ m^3) \times 1.00 = 0.0\ (10^4\ m^3)$
Annual supply $1202.5 + 929.0 + 2469.6 + 0.0 = 4601.1\ (10^4\ m^3)$

The actual seasonal and annual water supply of all crops was calculated by the same procedure. The actual annual water supply and annual sufficiency rate for each crop in 2009 is shown in **Table 5**. The table shows that annual sufficiency rates of wheat (fall), wheat (spring), oil bearing, other crop and other grass are relatively low, which require much water in spring, whereas those of corn (spring), corn (summer), cotton, alfalfa are relatively high, which require water in summer.

Table 5 Sufficiency rate of irrigation water in 2009 (actual)

Crop	Cultivation acreage (ha)	Total water demand (10^4 m^3)	Total water supply (10^4 m^3)	Sufficiency rate
Wheat (fall)	6190	7707	4601.10	0.60
Wheat (spring)	700	673	388.24	0.58
Corn (spring)	2916	3543	2834.25	0.80
Corn (summer)	3706	3836	3635.90	0.95
Cotton	1738	2007	1078.77	0.84
Oil bearing	1379	1096	659.41	0.60
Vegetables	1045	1145	764.75	0.67
Melon	344	454	356.71	0.79
Other crop	1616	1551	894.54	0.58
Alfalfa	2512	3052	2423.41	0.80
Other grass	1050	1244	676.13	0.54
Forestry	3788	5057	3982.85	0.79
Total	26984	31365	22896	0.73

4. ADJUSTMENT OF CROP PRODUCTION PATTERN

4.1 Reason of Adjustment

Results of current water usage analysis are summarized as follows; 1) 57% of annual water supply concentrates in summer. 2) Total water requirement of irrigation concentrates in spring and summer and water requirement of wheat (a main food crop) is high in spring and autumn. 3) The water sufficiency rate of all crops in spring and autumn is low and specially the rate in spring is very low. 4) The annual sufficiency rate of wheat is low, which requires water in spring, whereas the rates of corn and cotton are high, which require water in summer. The results show clearly that the high water demand of wheat in spring and autumn is a main cause of the water shortage problem in the Qira County.

The wheat cultivation acreage and water usage takes up quite large portion of the area, but the value of production per unit area of wheat is 14,100 Yuan/ha and it's not so high. The value is half of cotton's value of production, 27,800 Yuan/ha. The water usage of cotton is concentrated in summer, so the cotton cultivation fits in with the seasonal distribution of water resources of the area. Therefore, we examined the adjustment of crop production pattern by replacing wheat cultivation with cotton.

4.2 Adjustment Proposal

In this study, the wheat acreage replacements of 2,000 ha and 4,000 ha with cotton were examined. The detail of proposal is as follows.

4.2.1 Current cultivation of wheat, corn and cotton

The cultivation acreage of fall wheat was 6,190 ha, spring wheat was 700 ha, summer corn is 3,706 ha and cotton was 1,738 ha in 2009 (see **Table 3**). The cultivation acreage of fall wheat consists of 4,531 ha of plain oasis and 1,659 ha of mountain oasis, and the later does not suit cotton cultivation and cannot to be cotton area. Moreover, the combined cultivation of fall wheat and summer corn is not done in fall wheat area in mountain oasis of 1,659 ha and that is done in only plain oasis of 3,706 ha. It means the combined cultivation is not done in fall wheat area of 825 ha in plain oasis (825 ha=4,531 ha-3,706 ha). Since the combined cultivation is carried out in the area, if the cultivation area of wheat decreases, summer corn area will also decrease.

4.2.2 Adjustment plan A (replacement of 2,000 ha)

In the plan A, 2,000 ha of wheat cultivation acreage is replaced with cotton. Here, 1,300 ha of fall wheat and 700 ha of spring wheat are replaced with cotton cultivation. In the replacement of 1,300 ha, the non-combined cultivation area of 825 ha and the combined cultivation area of 475 ha are replaced with cotton to keep summer corn area. Therefore, the decrease of summer corn area is not 1,300 ha and is only 475 ha. After the adjustment, the cultivation acreage of fall wheat is 4,890 ha, spring wheat is 0 ha, summer corn is 3,231 ha and cotton is 3,738 ha (see **Table 8**).

4.2.3 Adjustment plan B (replacement of 4,000 ha)

In the plan B, 4,000 ha of wheat cultivation acreage is replaced with cotton. 3,300 ha of fall wheat and 700 ha of spring wheat are replaced with cotton cultivation. In the replacement of 3,300 ha, the non-combined cultivation area of 825 ha and the combined cultivation area of 2,475 ha are replaced with cotton. After the adjustment, the cultivation acreage of fall wheat is 2,890 ha, spring wheat is 0 ha, summer corn is 1,231 ha and cotton is 5,738 ha (see **Table 8**).

4.3 Results of Adjustment

The water supply-demand balance and sufficiency rate of irrigation water after the adjustment was calculated. The calculation procedure of the sufficiency rate is the same as the above-mentioned actual case in 2009. Firstly, the sufficiency rates in each season for the adjustment plan A and B were calculated. The calculation result is shown as **Table 6** and **Table 7**. According to the sufficiency rate of each season, the sufficiency rate of each crop was calculated. The calculation result is shown as **Table 8**. In both plans, the water shortage in spring was not resolved, however the water shortage in autumn was resolved completely in plan B.

Table 6 Water supply-demand balance and sufficiency rate (Adjustment plan A)

Supply and demand	Spring	Summer	Autumn	Winter	Total
Water supply (10^4 m^3)	3938	14384	4185	2949	25456
Water demand (10^4 m^3)	10053	14420	5168	1250	30891
Supply-demand balance	-6115	-36	-983	1699	-5435
Sufficiency rate	0.39	1.0	0.81	1.0	(0.77)

Note1: Maximum value of sufficient rate is set to 1.0.
Note2: Annual sufficiency rate (0.77) is calculated by using effective water supply.
Effective water supply is 25,456-1,699= 23,757 (10^4 m^3)
Annual sufficiency rate is 23,757/30,891=0.77

Table 7 Water supply-demand balance and sufficiency rate (Adjustment plan B)

Supply and demand	Spring	Summer	Autumn	Winter	Total
Water supply (10^4 m^3)	3938	14384	4185	2949	25456
Water demand (10^4 m^3)	9603	14120	3669	1250	28642
Supply-demand balance	-5665	264	516	1699	-3186
Sufficiency rate	0.41	1.0	1.0	1.0	(0.80)

Note1: Maximum value of sufficient rate is set to 1.0.
Note2: Annual sufficiency rate (0.80) is calculated by using effective water supply.
Effective water supply is 25,456-264-516-1,699= 22,977 (10^4 m^3)
Annual sufficiency rate is 22,977/28,642=0.80

Table 8 Adjusted cultivation acreage and sufficiency rate (Adjustment plan A, Adjustment plan B)

Crop	Adjustment plan A		Adjustment plan B	
	Cultivation acreage (ha)	Sufficiency rate	Cultivation acreage (ha)	Sufficiency rate
Wheat (fall)	4890	0.66	2890	0.75
Wheat (spring)	-	-	-	-
Corn (spring)	2916	0.82	2916	0.85
Corn (summer)	3231	0.97	1231	1.00

Cotton	3738	0.84	5738	0.85
Oil bearing	1379	0.61	1379	0.63
Vegetables	1045	0.69	1045	0.73
Melon	344	0.81	344	0.87
Other crop	1616	0.59	1616	0.60
Alfalfa	2512	0.83	2512	0.88
Other grass	1050	0.57	1050	0.61
Forestry	3788	0.79	3788	0.80
Total	26509	0.77	24509	0.80

Secondly, based on the actual value of production in 2009, cultivation acreage and sufficiency rate of each crop in 2009 and two adjustment plans, the designed value of production for adjustment plans were calculated. In this calculation, the following assumption is adopted; (1) The value of production of each crop is proportional to cultivation acreage. (2) The value of production of each crop is proportional to sufficiency rate. Therefore, the value of production in an adjustment plan is estimated by the following equation.

$$VP_{plan} = VP_{actual} \times \frac{CA_{plan}}{CA_{actual}} \times \frac{SR_{plan}}{SR_{actual}} \tag{1}$$

Where, VP_{actual}: actual value of production (Yuan) in 2009 , VP_{plan}: value of production (Yuan) in a adjustment plan, CA_{actual}: actual cultivation acreage in 2009, CA_{plan}: cultivation acreage in a adjustment plan, SR_{actual}: sufficiency rate of irrigation water in 2009, SR_{plan}: sufficiency rate of irrigation water in a adjustment plan.

Table 9 Total value of production of actual, adjustment plan A and B

Crop	**Actual**	**Adjustment plan A**	**Adjustment plan B**
	Value of production (10^4 Yuan)	**Value of production (10^4 Yuan)**	**Value of production (10^4 Yuan)**
Wheat (fall)	8703.2	7562.9	5079.2
Wheat (spring)	984.2	0.0	0.0
Corn (spring)	4547.4	4661.1	4831.6
Corn (summer)	5777.7	5143.2	2020.2
Cotton	4830.6	10389.4	16138.1
Oil bearing	933.9	949.5	980.6
Vegetables	1778.5	1831.6	1937.8
Melon	1540.7	1579.7	1696.7
Other crop	767.8	781.0	794.3
Alfalfa	157.5	163.4	173.3
Other grass	4930.0	5203.9	5569.1
Forestry	1626.5	1626.5	1647.1
Total	36578.0	39892.2	40867.8

The value of production of all crops in adjustment plan A and B is shown in **Table 9**. According to the calculated result of plan A, by replacing the wheat cultivation acreage of 2000ha, the water usage condition is not changed so much. However, the total value of production is increased 33,142,000 Yuan from the actual total value of production in 2009. The adjustment will contribute to the economic development of the area. In the plan B, the total value of production is increased 42,898,000 Yuan from the actual total value of production in 2009. But, the change of production value by additional replacement of 2,000 ha was relatively small because of the decrease of summer corn acreage due to the replacement in combined cultivation area.

Considering the food problem in the adjustment plan A, the decrease portion of wheat and corn production can be compensated by the value of production from 1,279 ha expansion of cotton. Moreover, the income from 721 ha expanded cotton area will be a net increase portion of income. In adjustment plan B, the decrease portion of wheat and corn production can be compensated by the value of production from 3,412ha expansion of cotton and the income from 588ha expansion of cotton area will be a net increase portion of income.

In the view point of water resources, the adjustment plan B is better than the plan A. But, in the view point of economy, the adjustment plan A is at the same level as the plan B because the net increase portion of income of plan A is slightly larger than plan B, but these are the same level. In any case, considering its impact on food issues, a certain amount of wheat acreage should be reserved. In addition, the environmental impact should be considered in the discussion of crop pattern adjustment.

5. CONCLUSION

In this paper, the current situation of water usage by irrigated agriculture in Qira County of Xinjiang Uyghur Autonomous Region, China was discussed. Moreover, the adjustment proposal of crop production pattern in the area was examined. Main results are summarized as follows.

(1) Analysis of current water usage shows that about 60% of annual water supply concentrates in summer and total water requirement of irrigation concentrates in spring and summer. In this study, the sufficiency rate of irrigation water was introduced and calculated results show that the sufficiency rate of all crops in spring and autumn is low, specially the rate in spring is very low and the annual sufficiency rate of wheat is low, which requires water in spring, whereas the rates of corn and cotton are high, which require water in summer.

(2) The above-mentioned results show clearly that the high water demand of wheat in spring and autumn is a main cause of the water shortage problem in the Qira County. Therefore, the wheat acreage replacements of 2,000 ha and 4,000 ha with cotton were examined as adjustment proposals. In both plans, the water shortage in spring was not

resolved, however the water shortage in autumn was resolved completely in 4,000 ha replacement. The increase of the value of production by expansion of cotton area was also shown in both cases and the net increase portion of income in 2,000 ha replacement was at the same level as 4,000 ha case. Considering its impact on food issues, a certain amount of wheat acreage should be reserved.

In future research, such adjustments will be examined among other crops, which must be rational crop production in the area. This is important for Qira County's economic development and sustainable water resource usage.

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