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Food security and agricultural structural adjustment in Yarkant River Basin, northwest China

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Abstract

This paper presents an analysis of the cultivated pressure and the benefit of cultivated land in Yarkant River Basin. Minimum area and deficits/surplus of cultivated land are used to describe the cultivated pressure, and reasonable range of agricultural structural adjustment is discussed under food security baseline. The results show that the cultivated land area of the Yarkant River Basin increased in 1978-2009, following per capita cultivated land area declined, while it showed an icreased warily of cultivated surplus in this basin, which is varied in different counties. The structure of land use affects its benefit, that the higher the percentage of grain crops sown area, the lower the per capita agricultural gross output value and annual per capita net income of rural households. It is effectively increasing agricultural output to adjust the agricultural structure and reduce the percentage of grain crops sown area. Considering the control of cultivated land and the requirement of stock consumption ratio in more than 30%, the minimum percentage of grain crops sown area of this basin in 2015 and 2020 is predicted, which are both lower than that in 2009. The differences among counties lead to the rationally readjust of the predicted values. The implementation of grain growing subsidies policy should strengthen to improve the enthusiasm of farmers to expand the area of grain crops.

Key words: Food security, cultivated pressure, deficits/surplus, agricultural structural adjustment, Yarkant River Basin.

Introduction

As a country of large population, food security affects significantly on socio-economic development of China, while cultivated land resources is the foundation of ensuring food security [1]. Land use, cultivated land protection and food security become hot topics of research [2, 3]. Change trend and driving mechanism of cultivated land area were analyzed by researchers from multiple levels such as countries, provinces and counties [4-7]. Minimum area of cultivated land, deficits/surplus and other indexes were used to describe the cultivated pressure of multiple levels [2, 8-10]. There are differences in quality and utilization degree of cultivated land, demand and grain self-sufficient ratio of grain, so unified standard on cultivated land threshold has not significance [11], and analyzing cultivated pressure in small regions is necessary. Resource of cultivated land affects significantly on agriculture and socio-economic development because of its scarcity [12], and cultivated land use also influence farming output value and income of farmers. It becomes important for government and researchers to ensure food security and increase income of farmers with limited resources of cultivated land [13-15]. Xinjiang is one of food strategy reserve districts of China, and Yarkant River Basin is a major production region of grain and cotton in Xinjiang [16], where food security is important particularly. The income of farmers is lower purely in Yarkant River Basin, the increasing of which is meaningful for social stability and harmony. Based on the data of cultivated land use in nearly 30 years, cultivated pressure and agricultural structural adjustment of the basin were analyzed, which provide great realistic significance on ensuring food security and increasing farmers' income.

Materials and Methods

Yarkant River, one of the tributaries of Tarim River, is located in the southwest of Xinjiang, China, and originates from the north slope of the Karakoram Mountains. The total watershed area is 120,879 km^2, covering six counties of Kashgar Administrative Offices (Yecheng, Taxkorgan, Zepu, Shache, Makit and Bachu), and with geographical coordinates of 74°28'~80°54' E, 34°26'~40°31' N (Fig. 1). Annual temperature change with seasons and lower temperature appears along with higher elevation. Precipitation is scarce and uneven spatial and has temporal distribution, with typical annual rainfall of 52.7 mm and annual evaporation of 2454 mm. The total length of Yarkant River is 1,179 km, and typical annual runoff amounts to 75.71×10^8 m^3, which is composed of glacier melt water, snow melt water and base flow, where glacier melt water is most. Water resources are abundant in the Yarkant River basin, which supports the development of agriculture, and the main crops include wheat, corn and cotton. The total population of Yarkant River Basin was 210.61×10^4 in 2009, and 324.05×10^3 ha of cultivated land area and 229.05×10^3 ha of farm crops sown area. GDP was 148.85×10^8 yuan, with 67.26×10^8 yuan of primary industry (45.19%). Gross output value of farming was 80.60×10^8 yuan, and per capita net income of rural household was 3668 yuan.

Basic data used in this paper was provided by the statistical yearbooks of Xinjiang and Kashgar in 1949-2010.

Minimum area of cultivated land (MAC): Minimum area of cultivated land (MAC, ha) is the least cultivated land needed to protect for food security in certain areas [8], which is mainly affected

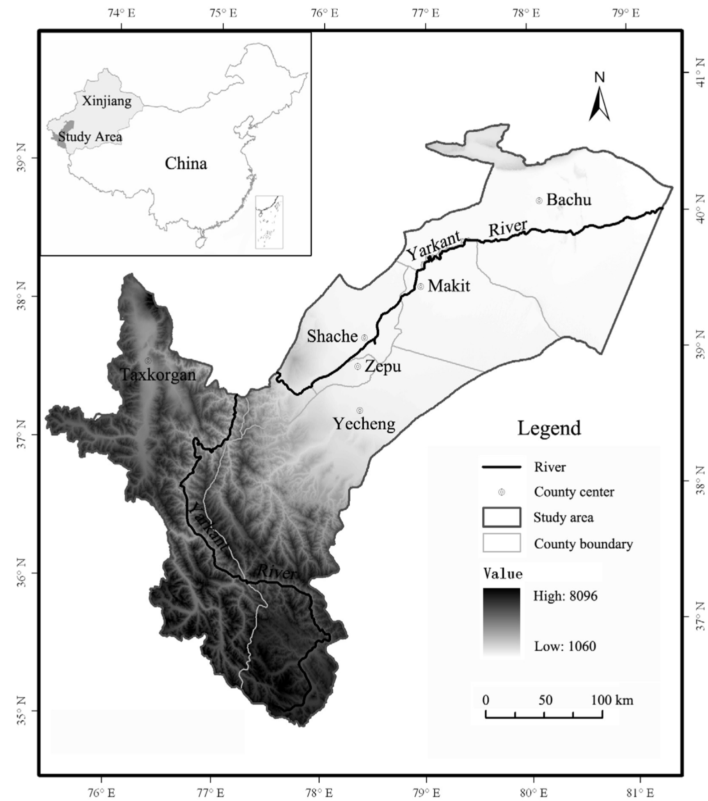

Figure 1. Location of the study area.

by population (P, person), ratio of grain self-sufficient (RGSS, %), per capita grain consumption (PGC, kg/person), grain yield per unit area (GYP, kg/hectares), ratio of grain crops sown areas (RGSA, %) and multiple cropping index (MCI, %) [2, 10]. The relationships between MAC and other components were evaluated based on the variables in Eq. (1), where GYP×RGSA×MCI reflects the comprehensive grain production capacity of the cultivated land.

$$MAC = \frac{RGSS \cdot PGC \cdot P}{\mathrm{GYP} \cdot \mathrm{RGSA} \cdot \mathrm{MCI}} \quad (1)$$

Deficits/surplus of cultivated land (DSC): Deficits/surplus of cultivated land (DSC, hectares) is the difference value between actual area of cultivated land (AAC, hectares) and MAC, with expressing as Eq. (2) [10]:

$$DSC = AAC - MAC \quad (2)$$

DSC is used to measure the pressure of cultivated land resources. V>0 means surplus of cultivated land and a well situation on food security, and V<0 means a deficit of cultivated land and with pressure on cultivated land, and V= 0 is the food security cordon.

Trend forecasting: The natural growth method is used to predict the future population of the basin, and model expresses in Eq. (3) [17, 18]:

$$Y_t = Y_{t_0} \times (1+r)^{t-t_0} \quad (3)$$

where Y_t is population in forecast year, Y_{t_0} is population in initial year, and r is the annual rate of population change, which is instead by the average rate over the years.

Results

Change on cultivated land scale: Cultivated land area of Yarkant River Basin is on the rising in nearly 30 years, which increased from 247.23×10^3 in 1978 to 324.05×10^3 ha in 2009, with an annual growth rate of 0.88%, while per capita cultivated area declined slightly. Stably changed of cultivated land area and continued growth population led per capita cultivated area to decline, which decreased from 0.23 ha in 1978 to 0.13 ha in 2005. Because the price of cash crops (such as cotton) increased since 2006, cultivated land area increased rapidly, with an annual growth rate of 6.86%. Per capita cultivated area also increased a little bit, which arrives at 0.15 ha in 2009 (Fig. 2).

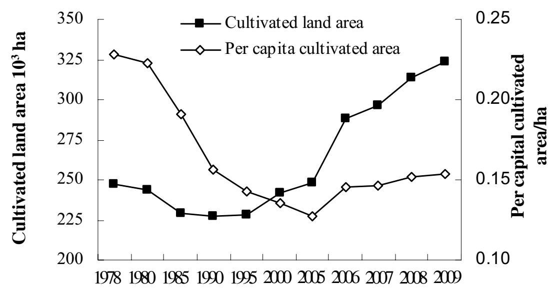

Figure 2. Cultivated land area and per capita cultivated land area in the Yarkant River Basin (1978-2009).

The change of cultivated land varied in different counties. Shache, Makit and Bachu County lie at the middle-lower reaches of basin, whose utilization of cultivated land is limited by water resources, and with a relatively higher proportion of desert area (19.24%, 79.25% and 44.13%, respectively). A sufficient number of reserved cultivated land and cultivated land reclamation bring by the increasing of population led to the expansion of cultivated land area, with average annual growth rate of 0.67%, 2.00% and 1.82% in 1978-2009, respectively, in Shache, Makit and Bachu County. The per capita cultivated area of the three counties decreased firstly and then increased, which was respectively 0.20, 0.29, 0.23 ha in 1978, 0.12, 0.19, 0.11 ha in 2005 and 0.15, 0.26, 0.14 ha in 2009, while the largest one is that of Markit County. Sufficient water resources of Yecheng County, the upstream of basin, caused a relatively smaller change of cultivated land area, where the average annual growth rate is 0.23%. However, because of the significant increasing on population, the per capita cultivated land area decreased from 0.22 ha in 1978 to 0.13 ha in 2009. Cultivated land of Taxkorgan County is the least in Yarkand River Basin, and Zepu County owns small land area, which leads to an inadequate reserved cultivated land. The cultivated land reduced in both counties, and the average annual decrease rate is 0.19% and 0.51%, respectively, in Taxkorgan and Zepu County, while the per capita cultivated area decreased, respectively, from 0.24 and 0.28 ha to 0.11 and 0.13 ha in 1978-2009.

Cultivated land press index: Per capita grain consumption (PGC) of China was 382.1 kg in 1990-2008, which is stabilized at more than 390 kg currently [19-21]. Based on the data of grain consumption in the Yarkand River Basin over years, statistical software of SPSS was used to calculate PGC in 1978-2009. Ratio of grain self-sufficient (RGSS) of China remained over 95% over the last decades [22]. The aim of food production in Xinjiang is regional self-sufficient, and RGSS maintains at 130% basically, with minor interannual variability. Using Eq. (1) and (2) to calculate minimum area of cultivated land (MAC) and deficits/surplus of cultivated land (DSC) of Yarkant River Basin at different scenarios (RGSS = 100% or RGSS = 130%), and cultivated land pressure was analyzed (Table 1).

The cultivated land of Yarkand River Basin has always been in surplus since 1978, and the surplus amount increased in volatility. The cultivated land increased, and the grain yield per unit area (GYP) rising with the increasing of inputs and the improving of farming technology, which protected the food security of the watershed. Food self-sufficient ensures in every year, with a least surplus amount of 28.58×10^3 ha in 1980 and the surplus amount was 142.02×10^3 ha in 2009. Keeping inventory consumption ratio (ICR) over 30% (as RGSS>130%), there also retains surplus in Yarkand River Basin after the year of 2000, and the surplus amount was more than 20×10^3 ha after 2005, which shows that deficits was not existed in the basin, and ICR was over 30% since 2000.

Cultivated pressure index of each county was analyzed based on deficits/surplus of cultivated land (Fig. 3). Yecheng, Zepu and Shache County all ensured food self-sufficiency in 1978-2009, while the surpluses were growth continued with a fluctuation in Yecheng and Sahche, the surpluses of which increased from 12.64×10^3 ha and 12.15×10^3 ha in 1978 to 32.38×10^3 ha and 52.26×10^3 ha in 2009, and that of Shache County is the largest in the basin since 1980. The surpluses of Zepu County stabilized at about 10×10^3 ha, with declining slightly. Markit County was below the food security cordon line in 1990, with a deficit of 0.11×10^3 ha, and showed surplus of cultivated land in the rest years, the surplus of which increased year by year and reached 25.35×10^3 ha in 2009. DSC of Bachu County showed a greater fluctuation, where always deficits in most years, and Taxkorgan County has been in deficits of cultivated land, which was 5.30×10^3 ha in 2009. There was a larger cultivated pressure in the two counties.

Utilization benefit of cultivated land: Per capita farming output value (PFV, gross output value of farming divided by agricultural population, converted to the comparable prices of 1990) was used to represent the utilization benefit of cultivated land, per capita cultivated area (cultivated land area divided by agricultural population) to represent the resource of cultivated land, and ratio of grain crops sown areas (RGSA) to represent cultivated land use structure. Using the data of 1980-2009, the relationship of utilization benefit with resources and structure of cultivated land were analyzed. Data of each county was divided by the average of Yarkant River Basin, and then the logarithm was calculated. The results of three indicators were used to draw coupling diagrams (Fig. 4).

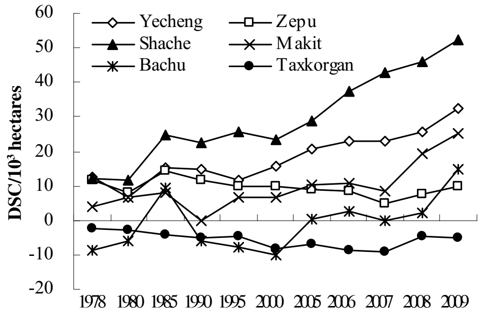

Figure 3. Change of cultivated land deficits/surplus in different counties of Yarkant River Basin.

The relationship between PFV and per capita cultivated area is not obvious, which shows that there has not strong correlation between utilization benefit and resources of cultivated land in the basin. Regularity between PFV and RGSA is existence, the higher the RGSA, the lower the PFV, which shows that structure of cultivated land affect utilization benefit to some extent.

In Zepu, Shache, Markit and Bachu County, there are larger proportions of cotton in cash crops. RGSA of Markit County is the lowest in the basin, and per capita cultivated area is relatively large, that leads to a higher utilization benefit of cultivated land, and PFV is highest in the basin with a trend of increasing in last 30 years. Smaller land area in Zepu County and larger population in Shache County lead to a smaller per capita cultivated area, so their utilization benefit of cultivated land was slightly lower than those in Markit and Bachu County. The least cultivated land, the minimum proportion of cash crops sown and the lowest grain yield per unit area result in the lowest PFV and per capita net income in Taxkorgan County, where PFV was 705 yuan, only took a percentage as 9.41% of that in Markit County (7487 yuan), and per capita net income was 2017 yuan, 46.69% of that in Markit County (4320 yuan).

Discussion

The adjustment of agricultural structure and the increasing of cash crops sown areas are conducing to improve the farming output value and income of farmers. Per capita grain production is about 400 kg in China, and that of Xinjiang was 534 kg in 2009, while 701 kg in Yarkant River Basin, which was much higher than the average of Xinjiang and China. A certain surplus amount of cultivated land provides possibility to adjust the agricultural structure under food security.

Based on population data in 1978-2009, Eq. (3) was used to predict that of each county in 2015 and 2020. Because constraints of water resources, in order to maintain stability of oasis and

Table 1. Cultivated land deficits/surplus in the Yarkant River Basin (1978-2009).

Year	P (10^4 persons)	GYP (kg/ hectares)	PGC (kg/人)	AAC (10^3 hectares)	MAC (10^3 hectares)		DSC (10^3 hectares)	
					RGSS=100	RGSS=130	RGSS=100	RGSS=130
1978	108.54	1529	280	247.23	209.83	272.78	37.40	-25.55
1980	109.55	1672	300	243.59	215.00	279.51	28.58	-35.92
1985	119.79	2879	320	229.00	156.81	203.86	72.19	25.14
1990	145.10	2818	350	227.51	178.57	232.14	48.94	-4.63
1995	160.21	3669	370	228.57	177.01	230.11	51.56	-1.54
2000	178.20	3817	380	241.56	187.36	243.57	54.20	-2.01
2005	194.86	6432	388	248.55	174.98	227.47	73.57	21.08
2006	198.22	6591	392	288.60	198.83	258.47	89.77	30.13
2007	202.05	6860	392	296.49	208.23	270.70	88.26	25.79
2008	206.22	6722	394	313.36	206.54	268.50	106.82	44.86
2009	210.61	6449	394	324.05	182.03	236.64	142.02	87.41

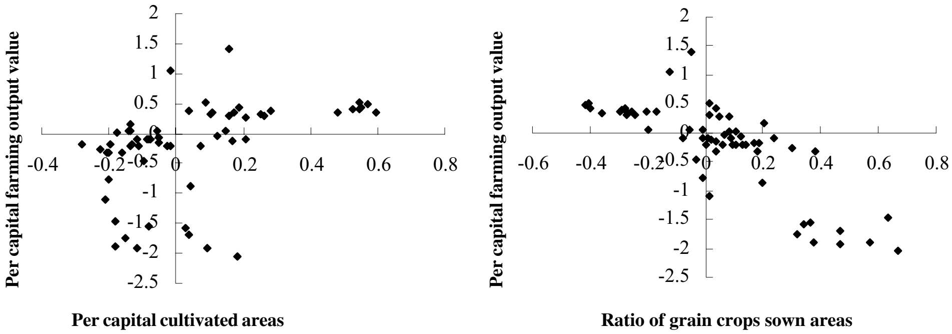

Figure 4. Relationships between land use benefit and its influencing factors.

achieve sustainable development in the region, the notion that arid area is the reserved cultivated land of China should be adjusted appropriately, and the scale of cultivated land in arid area should be controlled strictly [23,24]. Rapidly increasing of cultivated land in Yarkant River Basin would bring serious harm to land resources and ecological environment. For controlling cultivated land area of the basin, the average annual change was set as -0.5%, and area in 2009 was as the base, which could keep the cultivated land area in 2015 as the level in 2008 and in 2020 as the level in 2007, respectively. Larger changes in GYP in recent years, but it should not retain a rapid growth under more factors, so the growth rate of GYP was set as 2%, and the forecast base was the average value of that in 2005-2009. MCI in 2015 and 2020 is instead as the average value in 2005-2009. The results shows that population of Yarkand River Basin will reach 240.56×10^4 and 269.10×10^4 persons, respectively, in 2015 and 2020, and area of cultivated land will reach 314.45×10^3 and 306.66×10^3 ha, respectively, in 2015 and 2020.

Using per capita grain consumption (PGC) in 2009 (394 kg) as the base, and according to an average annual increase of 1.5-2 kg, PGC of 2015 and 2020 will be 403-406 kg and 411-416 kg, respectively. Inventory consumption ratio (ICR) is 17-18% in China and 20-30% in Xinjiang. For ensuring food security of basin, setting ICR as 30%, then per capita grain production of Yarkant River Basin will be 524-528 kg in 2015 and 534-541 kg in 2020.

According to predictive values of population, cultivated land area, MCI and GYP, and per capita grain production are 528 kg and 541 kg, respectively, in 2015 and 2020 the minimum grain crops sown area (MGSA) and available grain crops sown area (AGSA) were calculated, which are 175.59×10^3 and 451.87×10^3 ha in 2015, 182.22×10^3 and 440.69×10^3 ha in 2020 (Table 2).

Under the requirements of controlling cultivated land, ensuring food security, and with 30% of ICR, the predictive values of RGSA in Yarkant River Basin will be 38.86% in 2015 and 41.35% in 2020, which are lower 4.36% and 1.87%, respectively, than that of 2009 (43.22%), and provide the possibility of adjusting agricultural structure.

There is large population in Bachu County, which leads to more demand for grain, but with smaller AGSA, while RGSA in Markit County is far lower than in other counties of the watershed. In order to ensure food security to meet the needs of the population growth, the two counties should increase the ratio of grain crops sown areas appropriately. Higher RGSA in Shache, Zepu and Yecheng County, with larger cultivated land in Shache County, smaller population in Zepu County and higher GYP in Yecheng County, provide a range to reduce RGSA in the three counties. The small cultivated land is difficult to meet the demand of grain increase with population growth in Taxkorgan County, grain need to provide from other counties. As the main cash crops in Zepu, Shache, Markit and Bachu County, cotton has higher economic returns. The highest GYP is in Yecheng County, followed by Markit County. Considering a maximum economic returns in the whole basin, it should be increase in Yecheng and Markit County and reduce appropriately in Bachu County on the predictive values of RGSA. With the highest PFV in the basin, increasing appropriately on RGSA of Markit County could weaken the economic differences of it with other counties. Lower PFV and per capita net income in Yecheng County, reducing the decline degree of RGSA will help for ensuring food security, but broaden the economic differences with other counties as well. Subsidy should be increase for grain cultivation, in order to reduce economic loss and promote the enthusiasm of farmers to sown grain crops, and then ensure food security of Yarkant River Basin.

Conclusions

Cultivated land area of Yarkant River Basin tends to increase in 1978-2009, with an annual growth rate of 0.88%, while per capita cultivated area declined slightly because of population growth. Cultivated land increased in Shache, Makit, Bachu and Yecheng County and reduced in Zepu and Taxkorgan County, and it varied in different periods. It shows a surplus of cultivated land in this basin since 1978, and the surplus amount increased in volatility. Inventory consumption ratio retains over 30% in the basin after 2000. Yecheng, Zepu, Shache and Markit County all ensured food

Table 2. Predicted values of sown area in the Yarkant River Basin.

	MGSA (10^3 hectares)		AGSA(10^3 hectares)		RGSA (%)		
	2015	2020	2015	2020	2009	2015	2020
Yecheng	30.78	31.19	82.84	80.79	58.29	37.16	38.60
Zepu	16.03	16.51	33.33	32.50	53.10	48.11	50.80
Shache	60.16	60.73	165.82	161.71	44.77	36.28	37.55
Makit	18.74	19.59	64.92	63.31	28.44	28.87	30.94
Bachu	39.65	43.56	101.29	98.78	32.67	39.14	44.10
Taxkorgan	10.23	10.64	3.69	3.59	76.46	277.69	296.06
Yarkant River Basin	175.59	182.22	451.87	440.69	43.22	38.86	41.35

self-sufficiency in 1978-2009, but it showed a larger cultivated pressure in Bachu and Taxkorgan County.

The relationship between per capita farming output value and per capita cultivated area is not obvious, while structure of cultivated land affects utilization benefit to some extent, that the higher the RGSA, the lower the PFV. The lowest of RGSA and larger per capita cultivated area lead to a higher utilization benefit of cultivated land in Markit County, where PFV is highest in the basin. The highest RGSA in Taxkorgan County results in the lowest utilization benefit of cultivated land in the basin. It is effective for increasing agricultural output to adjust agricultural structure and reduce the percentage of grain crops sown area.

Under the requirements of controlling cultivated land and ensuring food security, the predicted values of the ratio of grain crops sown areas of Yarkant River Basin in 2015 and 2020 are lower than that in 2009, which provide the possibility of adjusting agricultural structure. RGSA of Bachu, Markit and Taxkorgan County should be increased and that of Shache, Zepu and Yecheng should be reduced appropriately. Considering a maximum economic returns in the whole basin, it should increase in Yecheng and Markit County and reduce appropriately in Bachu County on the predicted values of RGSA. The implementation of grain growing subsidies policy should strengthen to improve the enthusiasm of farmers to grow grain crops and then ensure food security of Yarkant River Basin.

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