Research on Current Situation and Change of Agricultural Water Management in the Middle Reaches of Heihe River Basin

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Abstract: Taking Zhangye City in the middle reaches of the Heihe River Basin as a case study, the current situation and the background of water resources management system in this region are investigated. The current situation of agriculture water used is analyzed, and the agricultural water assignment, the irrigation management system and the organization are clear about. Then, the measures and the effects for construction of the water-saving society are analyzed, the changes in agricultural water management and agriculture industrial structure are discussed, and the question about sustainable development of the water-saving society is put forward. Finally, through the qualitative analysis on the influence of agricultural water used to the water resources of Heihe River Basin, the recent policy and the new trend of agricultural water used is appraised preliminarily.

1 Introduction

1.1 Background

In the Heihe River Basin, the problems about the drought, the water shortage and the degradation of the ecological environment are markedly deteriorated. The drastic population growth and the economic development in the past 20 decades cause that the conflict between domestic water resources supply and demand is prominent and that the environment of the downstream region grow worse. The East Juyanhai and the West Juyanhai are dried up, Ejina Oasis is disappearing, and hazards of sandstorm are getting worse.

Therefore, the State Council of the People's Republic of China approved *Heihe River Water Allocation Scheme* in 1997. The Ministry of Water Resources of China carried *General Plan of the Heihe River Basin* into execution in 2001. These ensured the discharge of river water to the downstream area. Zhangye city is constructing into a water-saving society as a model. These measures are very important to the sustainable utilization of water resources and irrigated farming in the Heihe River Basin.

Under such background, through investigating the current situation of agriculture development and the land utilization, and the internal structure and mechanism of the irrigation farming, the research on the influences of the agricultural development and irrigation to the rule of water cycle in the Heihe River Basin become an important topic to solve the water cycle question. Based on investigating the series of measures and these effects, e.g. the discharge of river water to the downstream area and the

construction of a water-saving society, and the influences of the agricultural irrigation on the middle reaches, the exploration of the sustainable pattern of agriculture management development adapting the water resources carrying capacity of the Heihe River Basin is meaningful.

1.2 Introduction of the region investigated

1.2.1 The Heihe River Basin

The Heihe River Basin is the second largest inland river basin in the arid area of Northwest China.

Its main stream, with a length of 821km, originates in the Qilian Mountains. The upper, middle and lower reaches are respectively the forming, using and vanishing areas of the runoff. The annual volumes of runoff change little, but those in a year change sharply and the transformation between the surface water and the ground water is frequent. The annual precipitation of the upper reaches is 300 mm. The annual precipitation of the middle reaches is 140 mm. This area is rich in sunlight and heat resources, and thus, it has been an important agriculture zone since ancient times. The lower reach is mainly Gobi and desert, where the annual precipitation is only 47 mm.

1.2.2 Zhangye City

Zhangye city is located the middle reaches of Heihe River. The annual precipitation of this region is 98-350 mm and the annual evaporation is 2000-2700mm. Altogether 26 rivers including Heihe River originated in the Qilian Mountains can be developed and utilized. The surface water resources amount is 2.48 billion m^3, including Yingluo Gorge Station ($1.58\times10^9m^3$), Liyuanhe Station ($2.4\times10^8m^3$), and other stations ($6.6\times10^8m^3$). The ground water resources amount is $1.8\times10^8m^3$, and the total water resources amount is 2.65 billion m^3. The mean per capita volume of water resources, $1250m^3$, is only 54.2 percent of China and closing to the lower limit of water shortage. So it is a drought region in which no irrigation and no agriculture (Fig.1).

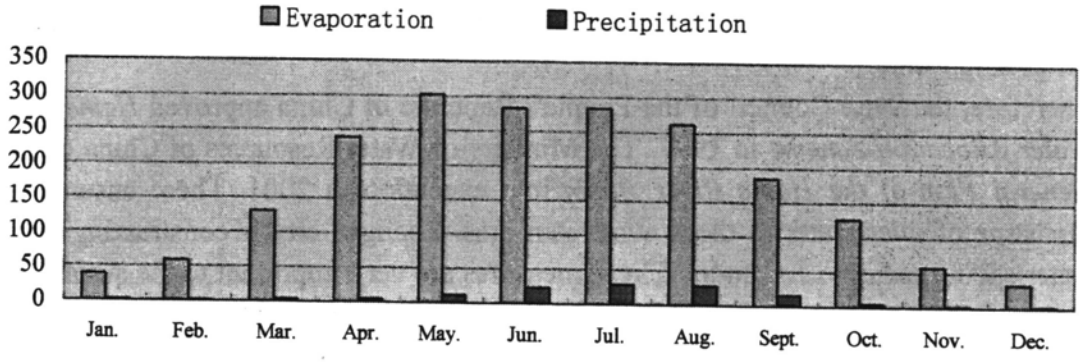

Fig.1 Average monthly evaporation and precipitation of Ganzhou Region (mm)

The city of Zhangye is the traditional irrigation region, the most developed area of agricultural economy in Gansu Province, and the national important production base of grain, rape, fruit and vegetables. And it is the famous base of transporting the vegetables from the West to the East and also has 80 kinds Chinese traditional

medicine. The city is an oasis on the middle reaches of the Heihe River, where the cultivated land, the population, the water consumption, and the GDP occupy 95%, 91%, 83% and 89% of the total amounts of the basin respectively.

Heihe River is main water source of Zhangye city and approximately 76% of the agricultural irrigation water is from this river. Therefore the situation of agricultural water used has the important influence on the water cycle of the Heihe River Basin. Thus, constructing Zhangye city into a water-saving society is very important to the sustainable development of entire river basin. Besides, the agriculture water consumption of Zhangye city occupies 95% of the total of the city, so the economization on agricultural water is the key to the construction of a water-saving society.

1.2.3 Yingke Irrigation District

The Yingke Irrigation District is one of the three big irrigation districts of Ganzhou Region, with 11 villages and towns, 104 administrative villages, 164,400 people, 20,960 ha. Wheat, corn and melon vegetable are the main crops.

It has a typical arid climate. In this irrigation district, the rain is scarce, the evaporation is intense and the illumination is sufficient. The annual precipitation of this region is 124.9 mm and the annual evaporation is 1291mm. There are 13 main channels (121 kilometers long), 54 branch canals (239km), 2564 field ditches (1467km), and 900 electric-pump wells. The lining rate of branch canals is 90%, and the lining rate of field ditches is 50%.

1.3 Changes of the water and soil resources use and the agricultural development of Zhangye City in the past years

Land use structure of Zhangye City (2003)

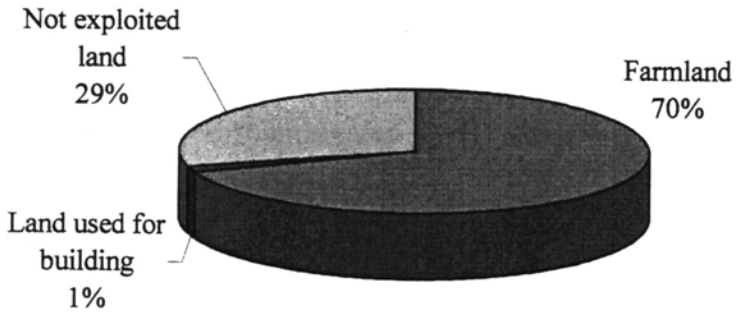

Fig.2 Land use structure of Zhangye City (2003)

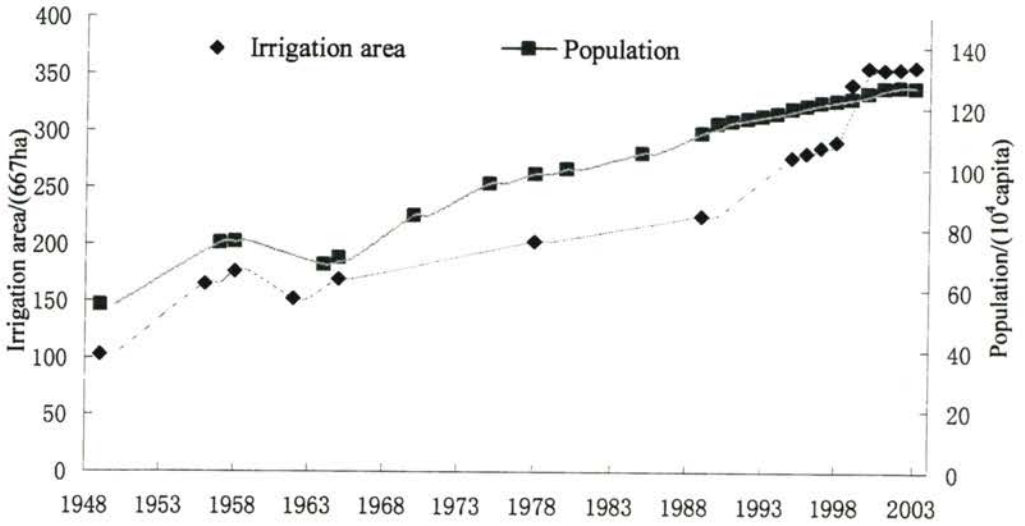

Fig.3 Population and irrigation area of Zhangye City in the past years

Fig.3 shows that the population of Zhangye City is 12,680,000 in 2003, 2.31 times as 5,492,000 in 1949, and the irrigation area is 237,640 ha in 2003, 3.5 times as 68,560 in 1949.

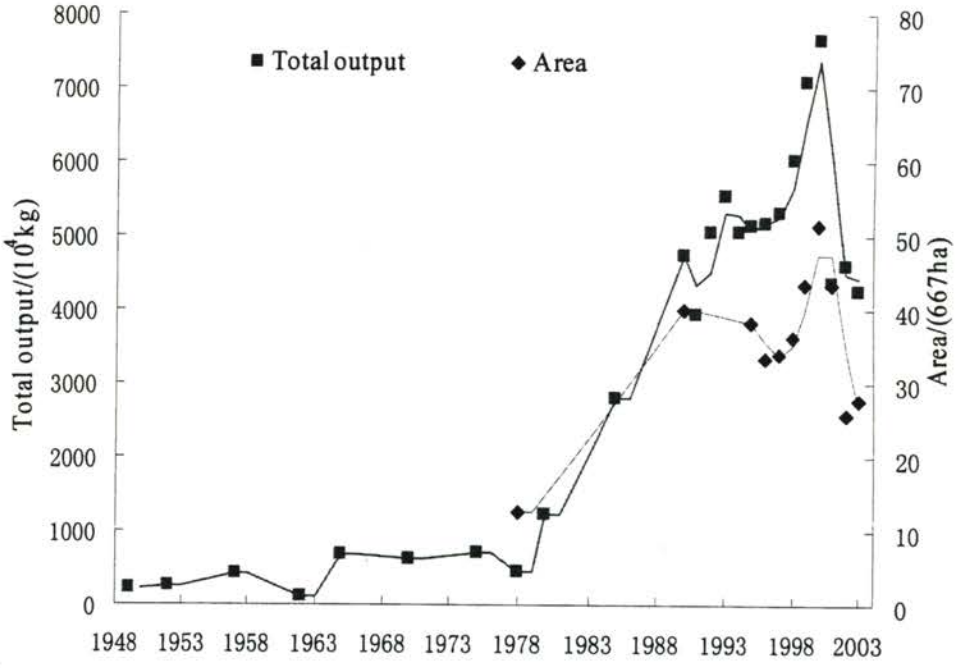

Fig.4 Area and total output of the oil crops of Zhangye City in the past years

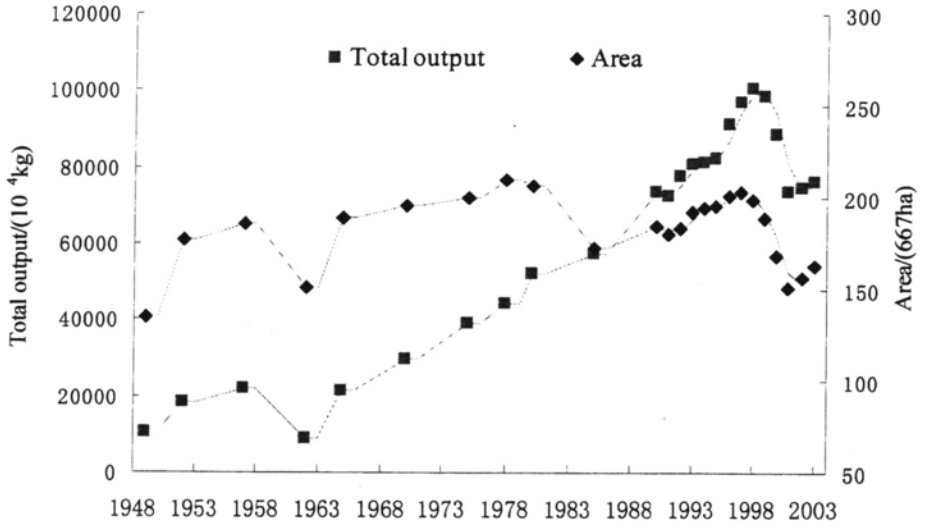

Fig.5 Area and total output of the grain crops of Zhangye City in the past years

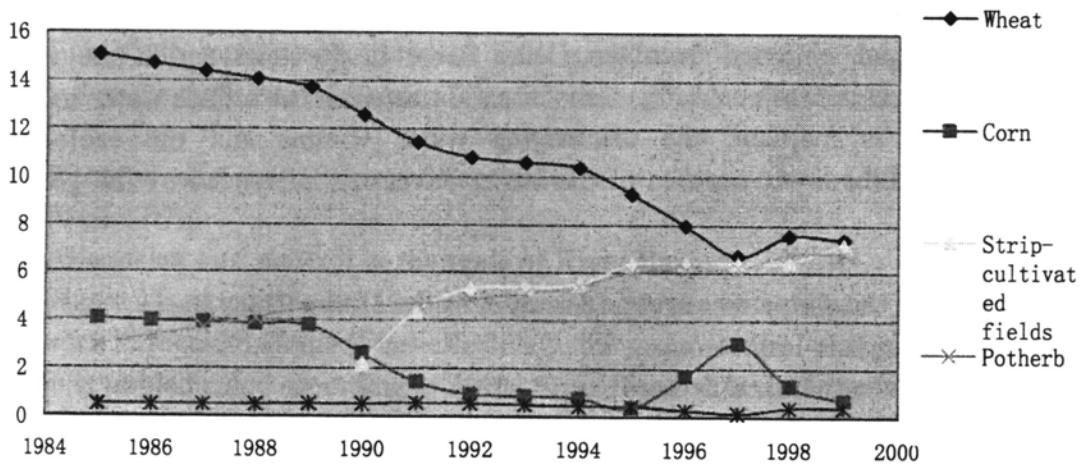

Fig.6 Area of the crops of Zhangye City in the past years

Since the 1980's, the areas of grain continued to drop and the areas of vegetables and other cash crops rise. The 'strip-cultivated fields' refers to wheat-maize intercropping. The research indicate the method is effective for water saving.

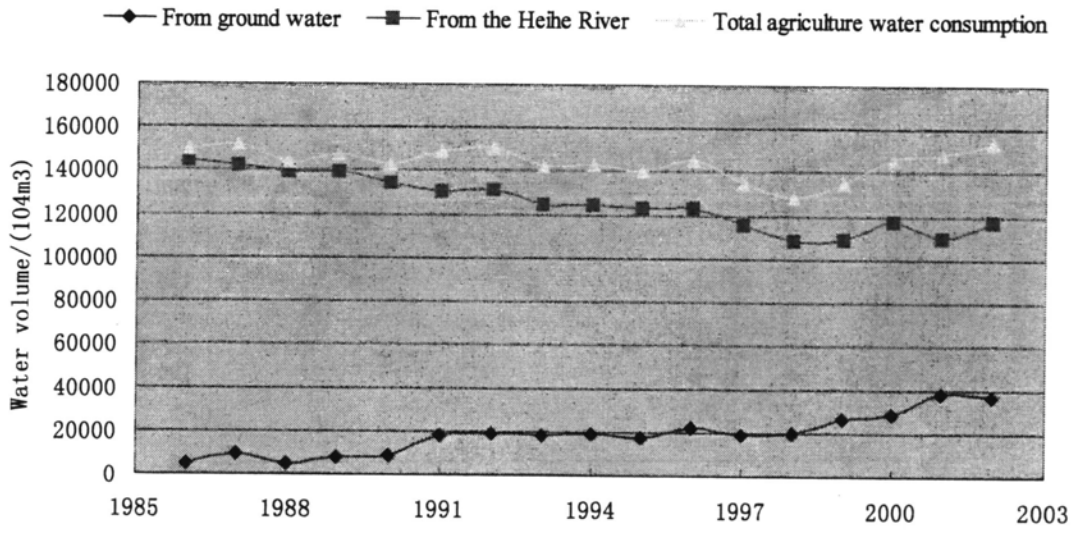

Fig.7 Agricultural water consumption structure of Zhangye City (1986-2002)

Fig.7 shows that the water consumption from ground water is sharply increasing and the total Agriculture water consumption is also increasing, though the proportion of the water volume obtained from the Heihe River in the total agriculture water consumption decreases. Because the transformation between the surface water and the ground water is frequent, the discharging water volume and the ecological environment of the lower reaches of the Heihe River are influenced by the ground water overdraft.

1.4 Problem of the water resources utilization in the Heihe River Basin

1.4.1 Hydro-meteorological factors

In the Heihe River Basin, with a typical arid climate, the precipitation is far less than the transpiration, the allocation of precipitation in space and time is uneven, usually concentrating in July, August and September. The least discharge of Heihe River appears in January and February. The discharge from January to March occupies 7.1% of the whole year water volume, from April to May is 11.8%, and from June to September is 68.5%. The flow of the upper reaches in May and June interrupts, about 22.4 days occupying 63% of the total days. It is the peak of irrigation water used of the middle reaches in May and June. The discharge of Yingluo Gorge occupies 20.2% of that in the whole year, but the irrigation water required in irrigation districts of the middle reaches occupies 35% of that in the whole year. Lacking key projects storing and regulating water causes to flow interrupting frequently in this period.

1.4.2 The unreasonable economic structure

The primary industry, secondary industry and tertiary industry of Zhangye city occupy 42%, 29%, 29% respectively (the nation is 17.6%, 49.4%, 33% respectively). The proportions of water for agricultural, industrial domestic and ecologic uses are 87.7:2.8:2.2:7.3. The output value of agriculture in the economic structure is higher

than others, and the urbanization rate is low.

1.4.3 The hydraulic engineering construction lacking the unified plan, the random water used and the low irrigation efficiency

In the middle reaches of the Heihe River Basin, the economy is booming and the degree of water resources development is high. The massive water resources are used in the agricultural irrigation. There are 62 water intakes and 28 plain reservoirs from Yingluo Gorge to Zhengyi Gorge, so the excessive canals are crowded and disordered. And then, for these plain reservoirs the capability of storing and regulating water is low, and the transpiration rate is big. Agricultural water management is random. And the water used efficiency is low, only 0.522 in the irrigation districts of the middle reaches.

1.5 General Plan of the Heihe River Basin

The main contents of *General Plan of the Heihe River Basin* are: 1) to achieve the water diversion goal by closing all water intakes and draining water together; 2) to complete the plans of engineering construction, e.g. agricultural water saving plan and the water saving transformation projects of irrigation districts, including enhancing the lining rate, merging several water intakes, and stopping some plain reservoirs. It is clear that the main aim of the plan is to decrease agricultural water used.

2 Allocation and management of agricultural water used in the middle reaches of the Heihe River

2.1 Allocation and control in the scale of River Basin

(1) The macro-control water allocation according to the water allocation Scheme

In order to regulate Heihe River effectively, the macro-control plan in the entire river basin is implemented according to *Heihe River Water Allocation Scheme.* Considering the need of the production and the environment water used, the characteristic of water required in the middle and lower reaches of Heihe River, and the current condition of projects, the Scheme is approved and carried on by the State Council of the People's Republic of China. On the different guarantee rate of flow at Yingluo Gorge, the discharges of river water are controlled (Table 1). In 2002, the volume is enhanced from $8.30\times10^9 m^3$ to $9.5\times10^9 m^3$ based on the annual means volume. Water allocation scheme of water volume of Yingluo Gorge with a year can be found in Table 2.

Table 1 Water Allocation Scheme of Zhengyi Gorge (revised in 2002) (10^9 m^3)

Different guarantee rate	Water volume of Yingluo Gorge	Discharging Water volume of zhengyi Gorge	Usable water volume of the middle reaches
10%	19.0	13.2	5.8
25%	17.1	10.9	6.2
Annual means	15.8	9.5	6.3
75%	14.2	7.6	6.6
90%	12.9	6.3	6.6

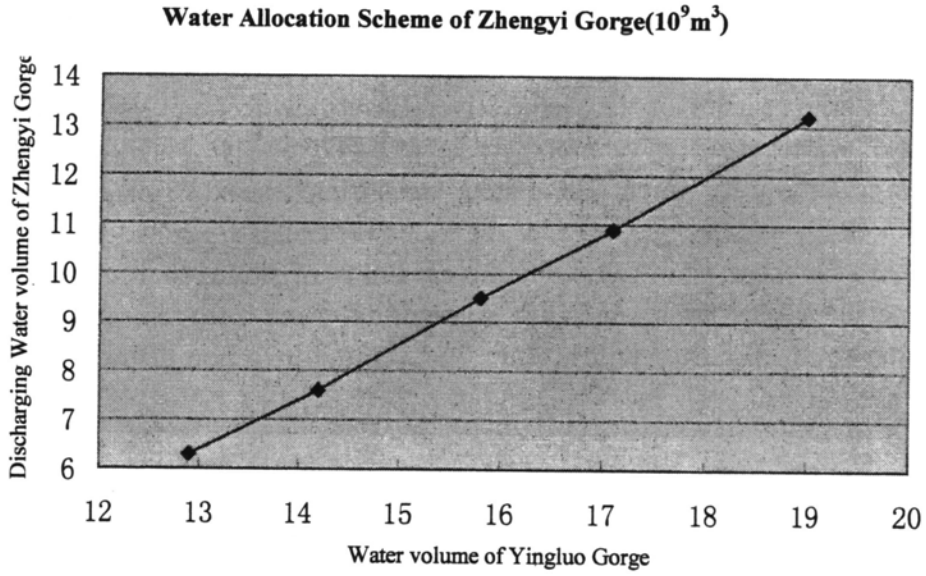

Fig.8 Relation between water volume of Yingluo Gorge and discharging Water volume of Zhengyi Gorge

Table 2 Water allocation scheme of water volume and the days of water transferring of Yingluo Gorge with a year (Annual means) (10^4 m^3)

Items	A year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
①	158001	3407	3398	4247	6701	11802	20028	35083	31350	21592	10231	5937	4225
②	187	31	28	10	3	2	10	20	20	17	5	10	31
③	57710	0	0	1913	4011	7866	10148	9461	8454	7111	6117	2632	0
Coefficient	Loss factor	0.3	0.3	0.3	0.3	0.25	0.2	0.2	0.2	0.2	0.25	0.3	0.3
	use factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95

①Water volume of Yingluo Gorge

②Days for water transferring

③Usable water volume of Ganzhou Region

(2) There are three time intervals of water allocation in a year as following, spring-summer irrigation period (from March 11to on June 30), summer-winter irrigation period (from July 1 to November 10) and non-irrigation period (from November 11 to March 10) (Table 3).

Table 3 Water Allocation Scheme of Yingluo Gorge (10^9 m^3)

Time intervals	Different guarantee rate	Water volume of Yingluo Gorge	Discharging Water volume of zhengyi Gorge
Spring-summer irrigation period (from March 11to on June 30)	10%	5.6	2.35
	25%	5	1.9
	50%(Annual means)	3.5	0.75
	75%	2.9	0.7
	90%	4.25	1.3
Summer-winter irrigation period (from July 1 to November 10)	10%	13.6	8
	25%	10.9	5.2
	50%(Annual means)	8.6	2.7
	75%	7.6	1.6
	90%	10	4.2
Non-irrigation period (from November 11 to March 10)	10%	13.6	4.5
	25%	10.9	4.05
	50%(Annual means)	8.6	3.65
	75%	7.6	3.45
	90%	10	3.9

The total water allocation in whole year is the key guideline, and those of different intervals are only the reference standard. We can adjust the allocation quota of the same year's surplus time interval according to the total water allocation in this year.

2.2 Water allocation of Heihe River among different regions

There are a series of related plans and the local authority regional planning, e.g. *Water Law*, Heihe River Water Allocation Scheme and *General Plan of the Heihe River Basin*, as the disposition basis of the water allocation of Heihe river among different regions. The factor of agricultural water lacking, water used per ten thousand Yuan GDP, water used per capita, and water used per a Chinese acre are basic indexes (Table 4).

Table 4 Water Allocation Scheme of Yingluo Gorge in the three regions (10^9 m^3)

Different guarantee rate	Volume of surface water resources				Discharging Water volume of zhengyi Gorge	Volume of surface water resources		
	Total	Heihe	Liyuanhe	Others		Ganzhou	Linze	Gaotai
90%	16.7	12.9	2.31	1.49	6.3	6.25	3.61	2.48
75%	18	14.2	2.31	1.49	7.6	6.25	3.61	2.48
Annual means	19.6	15.8	2.31	1.49	9.5	6.05	3.5	2.52
25%	20.9	17.1	2.31	1.49	10.9	5.98	3.47	2.45
10%	22.8	19	2.31	1.49	13.2	5.73	3.31	2.27

The allocation principle is as following: 1) The demand of the domestic water used and the ecology water used is firstly considered. 2) Based on the coordination of the relation between the water required and the water used in different regions, the ground water and the surface water, the local water and the transiting water are

allocated together. 3) The aim is high water use factor of the life, the production and the ecology. 4) The highly effective water use is first. 5) The degrees of water lacking in different regions are approximately balanced. 6) The average water used per capita draws close gradually.

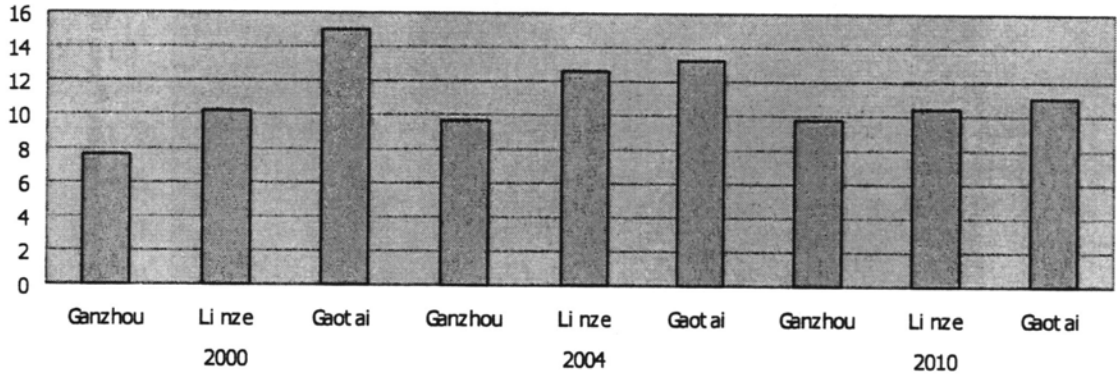

Fig.9 Degrees of water lacking of three regions in annual means

Fig.9 shows that the degrees of water lacking of the three regions are approximately balanced.

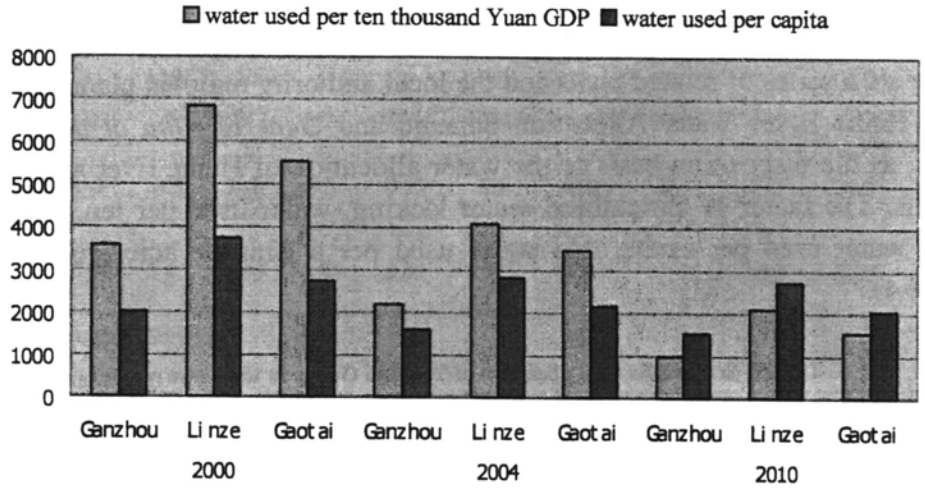

Fig.10 Contrasts of water used per ten thousand Yuan GDP and water used per capita

Fig.10 shows that water used per ten thousand Yuan GDP and water used per capita are all decreasing. Ganzhou's degree of water lacking is the lowest than other two countries, and its water use factor is also high, so it has the priority in water allocation.

2.3 Allocation of agricultural water of Zhangye City

The total water which is allocated to agricultural use of Zhangye City according to the water allocation scheme is the base to further allocate. The first step is to count the various irrigation districts. The second is to count the water demand according to

quotas and water efficiency of irrigation. If the water demand is more than the estimated water supply, the crops areas should be adjusted to decrease the water demand in the scope of the water supply.

2.3.1 Establishment of water allocation plan (from top to bottom, taking Ganzhou as a case)

(1) Water allocation plan of Ganzhou Region

The water allocation plan is established by Ganzhou Water Resources Bureau. According to former experiences and the policies, considering the approximate irrigation areas, the frame of the water allocation plan in that year is decided by forecasting the water volume and discussing with Hydrology Bureau.

There are several essential factors considered in the establishment of water allocation plan, such as water volume forecast, the time and the days for water transferring of Heihe River. According to the above factors, the dynamic water allocation plan of each time in the whole year is established. So-called 'dynamic' refers to constantly carry on the adjustment in a month or a ten-day period according to the water volume of Yinluo Gorge.

For example, in 2004, the water volume of Yinluo Gorge is 1.58×10^9 m^3 and it is 187 days for water transferring (including non- irrigation period). So the number of days of water allocation is 178 and 9 times of rotational irrigation (including the spring, summer, fall, and winter) are planned.

(2) Irrigation plans of the irrigation districts

After investigating some basic conditions, the governors of various irrigation districts plot out the groups of rotational and continuous irrigation according to the experiences and establish the water allocation plan.

An Example - Water Allocation of Yingke Irrigation District: The total water which is allocated to Yingke Irrigation District by Ganzhou and the water allocation of each time are the base to further allocate. The balance of water supply and demand is counted and analyzed according to the irrigation areas of each time, the quotas, and water efficiency of irrigation and others. Then, the governor of Yingke Irrigation District establishes the water allocation plan.

Table 5 Irrigation plans of Yingke Irrigation District

Continuous irrigation group	Rotational irrigation group	Irrigation canal	Areas (1/15ha)			Irrigation quota ($15\ m^3$/ ha)	Net water volume in fields ($15\ m^3$/ ha)	Water use factor (%)		Gross waterdemand ($10^4\ m^3$)	
			Total	River irrigation	Well irrigation			Branch canal	Main canal	Branch canal	Main canal
0	0	Main	30520	22520	8000	80	180.16	59.9	92.4	300.71	325.58
1	1	Branch 1	3532	3532		80	28.26	61.8	100	45.73	45.73
2	0	Total	1436	1436		80	11.49	70	100	16.42	16.42
2	2	Lateral 1	1388	1389		80	11.11	69.9	100	15.89	15.89
2	3	Field canall	48	48		80	0.36	71.6	100	0.53	0.53
3	4	Main 1	6477	3948	2529	80	31.58	59.2	98.2	53.34	54.32
4	5	Embranchment 1(Ying)	2159	2159		80	17.27	59	98.2	29.27	29.81

5	0	Total	2707	2707		80	21.65	61.4	95.4	35.28	36.99
5	6	Embranchment 3(Ying)	2517	2517		80	20.14	61.4	95.3	32.8	34.42
5	7	Lateral 2	190	190		80	1.52	61.4	96.4	2.48	2.57
6	0	Total	5097	3142	1955	80	25.14	58.6	95	42.93	45.19
6	8	Branch 2	3580	2895	795	80	23.08	58.4	95.3	39.52	41.47
6	9	Branch 3	1417	257	1160	80	2.06	60.4	91.7	3.41	3.72
7	10	Embranchment 3(Ying)	1731	1205	526	80	9.64	58.3	91.7	16.54	18.03
8	11	Embranchment 4(Ying)	1404	835	569	80	6.68	63.9	85.7	10.45	12.2
9	12	Branch 5	978	716	262	80	5.73	56.2	77.3	10.2	13.11
10	0	Total	472	129	343	80	1.03	63.2	75.5	1.63	2.16
10	13	Branch 4	195		195	80		52.1	85.7		
10	14	Lateral 3	277	129	148	80	1.03	63.4	75.4	1.63	2.16
11	15	Lateral 2	4527	2711	1916	80	21.68	55.7	75.4	38.92	51.62

(3) Water allocation plan of Water User Associations

Water User Associations establish the water allocation plan of irrigation groups below branch canals according to irrigation plans of the irrigation districts.

2.3.2 Calculation of water demand (from bottom to top)

(1) Water quota of each irrigation, Irrigation water quota in whole season, Irrigation schedule

There are different indexes for water quota of each irrigation, irrigation water quota in whole season, and irrigation schedule in the arid regions and semiarid regions of China. The irrigation schedule of Yingke Irrigation District is as following.

Table 6 Irrigation schedule of Yingke Irrigation District

Crops	Irrigation times	Water quota of each irrigation ($15\ m^3$/ ha)	Water quota of each irrigation (Spring and Winter) ($15\ m^3$/ ha)	Irrigation water quotain whole season ($15\ m^3$/ ha)	Irrigation time	
					From	To
Spring rye	5	78	100	412	Apr.10	Aug.10
strip-cultivated fields	8	76	100	632	May 4	Oct.15
corn	8	76	100	632	May 20	Sept.20
coarse cereals	8	76	100	632	May 20	Sept.20
Cole	5	78	100	412	Apr.10	Aug.15
Potherb	10	75	100	775	May 10	Oct.20
Fruit tree	8	78	100	646	Mar.10	Nov.16
Two crops	8	78	100	404	Aug.1	Nov.16
Forest - grass	4	85	100	695	Mar.10	Nov.16

1) Irrigation Area is 15.02 thousand

2) Irrigation water quotas in spring and winter are constant.

Because rotational irrigation is the main characteristic of agricultural irrigation of Zhangye Ctity, the beginning and end time is different for various water use units (Taking Xiaoman Village as an example, Table 7).

Table 7 Irrigation time of Xiaoman Village (From farmers orally)

Name of turns	Irritation object	Start stop time
Spring irritation i	Open area, early vegetable, forest land	Mar.20 - Apr.5
Summer irritation i	Wheat	Apr.15 - May 10
Summer irritation ii	Wheat, corn, fiel	May 10 - May 30
Summer irritation iii	Whole area	Jun.15 - Jun. 30
Autumn irritation i	Whole area	Jul.20 – Aug.9
Autumn irritation ii	Whole area	Aug.15 - Aug.28
Autumn irritation iii	Whole area	Sept.20 - Oct.5
Winter irritation i	Fruit tree, forest-grass, open area	Oct.15 - Oct.24

Irrigation time of each turn of irrigation areas is the sum of each start stop time of various water use units.

(2) Crop area

The irrigation groups send the number of total areas to Water User Associations. Each Water User Association reports to the management station. Then it is send to higher-up once more. The governors of irrigation districts respectively put forward applications of irrigation water to Ganzhou Water Resources Bureau.

(3) Irrigation water

Irrigation water of each turn = ∑Crop areas × Water quota of each irrigation

Total irrigation water = ∑ Irrigation water of each turn

(4) Agricultural water

Agricultural water = Irrigation water + Water of domestic use in the country + Water of domestic animal use

Water quota of domestic use in the country = $50m^3$/(capita· day)

Water quota of domestic animal use = 22 - $45m^3$/(capita · day)

2.3.3 Actual operation and adjustment

The methods described as above are usual and the same to those of every year. The main procedure is to adjust little according to the actual situation.

The three months of December, January, and February are the non-irrigation season, so the water volume wouldn't be forecasted. The water volume of the period from April to November can be calculated by the partition computation method.

The water volume in March is little, so various irrigation districts take the water according to the area proportions.

The water volume of the period from April to November is more, so that of the second quarter can be forecasted by the actual water volume in March. The rest may be deduced by analogy.

Finally usable water volume of one year can be calculated according to the coming

water. Various irrigation districts can get their water based on the area. In order not to surpass this target of water supply, the water volume on each month and each ten-day period should be adjusted little.

For example, in 1993, weather forecast is as following: dry in the end of spring and the beginning of summer, normal and few in August, few from September to November.

According to this forecast, the frequency of the three periods which are from April to June, from July to August, and from September to November is forecasted, 75%, 50%, and 70% respectively.

3 Irrigation Management System in Yingke Irrigation District

3.1 Management organization

The management organization consists of water management organization and water user organization (Fig.11)

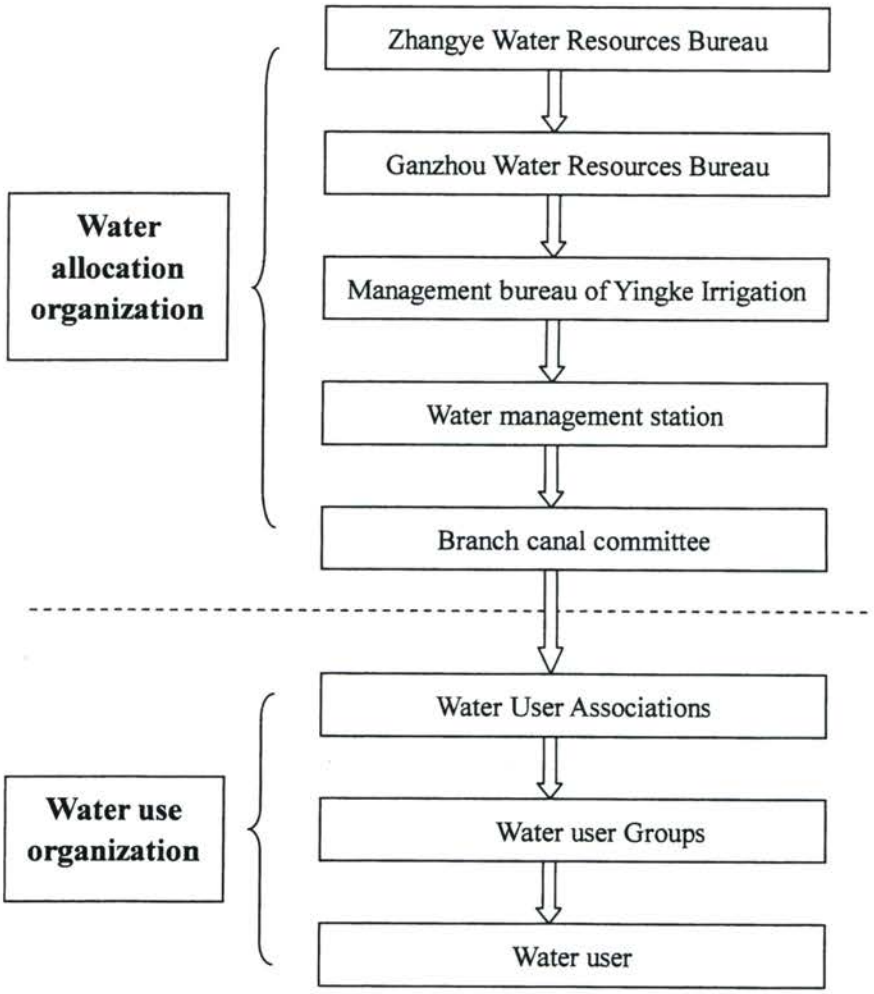

Fig.11 Management organization in Yingke Irrigation District

The management bureau of Yingke Irrigation District is one of the organizations of

Ganzhou Water Resources Bureau. The management station is established according to townships or towns. Branch canal committee consists of 2-3 committees. Above makes up of the water management organization. The organization below Water User Associations consists of water users. Branch canal committee is responsible for allocate the water to each lateral canal.

Water User Associations are responsible for establishing the water allocation plan, adjusting the allocated water among water use groups, dealing with disputes, and the maintenance work below the lateral canal. Water use groups are responsible for the water allocation below the lateral canal.

3.2 Water use management

3.2.1 Surface water resources management

(1)Water level management and water volume management: There are 34 personnel responsible for the measure work in main canal, branch canal, and lateral canal. The data are the basis for the adjustment of water allocation.

(2) Water allocation duty in the irrigation area: Above the lateral canal, the personnel of the management bureau are responsible for the water allocation duty. Below the lateral canal, it is the duty of Water User Associations.

(3) Water right license: Each farmer household has the water rights license and pays fee according to it.

(4) Water charge: If the water use is not exceeding the water quota, the water charge consists of two parts which is the basic water charge and the measurement water charge.

The basic water charge is 30 Yuan per ha, and the measurement water charge is 0.85 cent per m^3 (1 Japanese Yen per m^3).

3.2.2 Wells water management

In 2004, the total area of Yingke Irrigation District is 13,140 ha, including the well irrigation area, 3,467 ha, approximately occupying 25% of the total area. There are three types, river irrigation area, well irrigation area, and mixed water irrigation area. Therefore when wells are finished, the water use permission license is given by the water administration department after checking and accepting. The man in charge sends the water use plan very month. After the plan is approved, it would be in effect. There is a water meter for each well. The water volume is measured by brushing the card in several wells.

Water charge: The basic water charge is near 210 Yuan per ha. The electrical bill, the management service fee and the electromechanical device maintain fees are paid by the beneficiary.

3.3 Project management

The management bureau of Yingke Irrigation District is responsible for the maintenance and management of the irrigation projects above the branch canal. And Water User Associations are responsible for those below the lateral canal.

4 Measures, effects and problems of the construction of Water-Saving Society in Zhangye City

4.1 Measures for construction of the water-saving society

1) Control of total water consumption, management of quotas, and estimation of crops on the basis of water consumption. According to the water allocation plan for the Heihe River decided by the State Council, a fixed volume of water is allocated to the lower reaches. The available volume of water resources is allocated to each county, to each township, and finally to each village. The quotas for domestic, industrial, agricultural, and ecological uses are formulated and basic prices fixed. The actual irrigated area in 2000 taken as the basis, initial water rights are allocated. The total volume of water consumption is checked based on the quotas, and, if the total volume is deficient, the structure of crops is adjusted. Water consumption within the quota is paid for on the basic price basis; water consumption exceeding the quota is paid for on an additional price basis: for water consumption exceeding the quota by 1%-3%, additional 50% of the basic price is paid, exceeding the quota by 31%-50%, 100%, and exceeding the quota by 51% or more, 200%.

2) Public participation and water allocation to each family. Water users' associations are set up, participating in the supervision of water rights, water prices, and water consumption. The associations break soon the total volume and distribute it to each piece of land for each round of irrigation. On this base, the responsible department issues water right license to the farmers.

3) Supply by ticket and trade of water. The farmers buy water from water management institutions with the license for each round of irrigation and the water management institutions charge them on the basis of the fired prices. Surplus water can be sold, and the buyer and seller can negotiate over the price within the range of government's guiding price. The water users' associations (WUA) coordinates water supply.

Ordinary water meters are generally used to control the water volume in most well irrigation areas. And up-front cash cards are used to in several areas based on water right and volume pilot tests. When farmers put their cards on the card reader, water is started to supply. After farmers take back their cards, the card reader automatically writes down the water volume. The cost of this equipment is very high, so it isn't possible used widely in current situations.

The above measures make up of the water-saving mechanism. Through the measures of control of total water consumption, management of quotas, and distributed water to households, the water rights system in regions is established. Supply by ticket and trade of water, control of total water consumption, water charge levy truly become the main tools for construction of the water-saving society.

4.2 An Example of Implementation – Liyuanhe Irrigation District

The Liyuanhe Irrigation District is a large irrigation district of 20,000 ha on the middle reaches of the Heihe River. The construction of the water-saving society began in 2001, and the year of 2003 witnessed the following preliminary effects.

1) WUA had been popularized. 45 water users' associations had been set up, and

10,680 licenses had been issued. Farmers' awareness of using water, managing water, and saving water had been enhanced.

2) The agricultural structure had been successfully adjusted. The grain crops-economic crops-forest and grass proportion for 2000 was 56:14:30, while the proportion 2003 is 22:46:32. This adjustment only helped save 5,700,000 m^3 of water and increase farmers' income by 2101 Yuan per person on the average. The farmers had also changed, from passively accepting adjustment to actively adjusting the structure of crops according to economic benefit and market demand (Table 9).

3) The efficiency and benefit of water resource utilization had been raised. The net irrigation quota had decreased from 1275 m^3/ha to 1200 m^3/ha, and the utilization rate of the canal system had increased from 0.49to 0.54. The volume of water diverted for the irrigation area in 2003 decreased by 25,000,000 m^3.

4) The load of water fee had been lowered. The agricultural water fee had reduced by 105Yuan/ha, and the rate of water fee collection had increased obviously.

4.3 Conclusions and Discussions

1) The construction of the water-saving society at Zhangye has yielded significant effects, and it has helped the fulfillment of the plan of water allocation to the lower reaches.

2) Although water consumption is restricted and water is saved, both farmers' income and social productivity have been raised.

3) A whole set of effective ways has been found out for the operation of water rights and water markets. The previous system of governmental control is initially transformed into the system control

4) The water volume to the lower reaches of the river is increased and the ecological environment is improved.

Table 8 Achievements of water transfer projects in the Heihe River (2000-2004) (10^8 m^3)

Year	Water transfer indexes (Water volume of Yingluo Gorge is $1.58\times10^9 m^3$)	Actual water volume	Discharging water volume of Zhengyi Gorge
2000	8.0	14.62	6.50
2001	8.3	13.13	6.39
2002	9.0	16.11	9.23
2003	9.5	19.00	12.55
2004	9.5	14.98	8.55

Some problems need to be further studied.

1) Saving water is an effective way to alleviate the pressure of water shortage; however, it cannot solve all the water-related problems.

2) The construction of a water-saving society is a gradual process, and it needs long-term efforts. For example, great efforts must be made to better water users' associations and to bring their functions into full play.

3) A water-saving society must be sustainable, and thus it needs to be supported by regulations and mechanism. For example, the mechanism of compensation for saving water should be established and enforced; otherwise, the effect of saving water in the irrigation area would be in inverse proportion to the income and the enthusiasm for saving water would be affected. If things go on like this, the effect of saving water would be ruined.

4) The pilot construction under study was supported by the state policy and state input. Nationwide popularization needs both financial support and policy support.

5) Because the integrated management of surface water and ground water is not considered into the former design of the water-saving society, the water consumption from ground water is sharply increasing instead when the water volume obtained from the Heihe River is decreasing. So some watershed forests are dying down and the ecological environment of the lower reaches of the river is getting worse. How to scientifically transfer water taking account of the ecological environment of the middle and the lower reaches needs to be further studied. At present the governors of Zhangye City are applying for reducing the discharging water volume to Ministry of Water Resources of China.

6) Because the control projects along the Heihe River are extremely lacking, it is very difficult to supervise the work of closing all water intakes at the same time. Therefore the departments and grassroots units often complain.