

Study on countermeasures for water resources shortage and changes of ecological environment in Shiyang River basin

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Abstract The Shiyang River basin is a special inland river basin in China, in which the population density is the biggest, per capita GDP is higher, and the water resources average per person is the least. This paper shows that the basin water resources have already been seriously overloaded, and the basin comprehensive governing programme ought to be more urgent, by analysing the present water supply volume, groundwater equilibrium, the present water consumption level, the water use efficiency, and the present supply and demand balance of the Shiyang River basin. Using countermeasures to reserve the source in the southern basin, developing the oasis in the middle part, controlling the sandstorms in the northern part by protecting the headwater, and reforming the middle river, it will support the sustainable development of society, and promote the harmonious relationship between man and nature.

Key words Shiyang River basin; GDP; water resources; sustainable development

INTRODUCTION

The backward economy of the northwest endorheic drainage basins and the development of urbanization (Fang *et al.*, 2004) following the ecological environment security problem (Cheng *et al.*, 2002) was threatened by the shortage of water resources, but its sustainable development received people's attention (Shao *et al.*, 2005). The Shiyang River basin was a special inland river basin in China, of which the population density was the biggest, per capita GDP was higher, and the average per person water resources possession was the least.

The ecology question caused by "lack of water" was mainly concentrated downriver of Minqin oasis, which was highly regarded by the central leader authorities. Many scholars also studied the question from different angles in the Shiyang River basin in recent years: Feng (1963) researched into the problem of water system evolvement of Minqin oasis; Chen (1982) studied water and soil resources and their utilization in the Shiyang River basin; Xiao (1988) researched Minqin land degeneration; Yang (2002) studied human mechanism research of Minqin Oasis change in the lower reaches of the Shiyang River; Tang (1994) used the multi-stratum fuzzy comprehensive evaluation of strategies for exploitation and utilization of water resources in the Shiyang Watershed; Gao (1995) analysed the multiple transformation characteristics of water resources and proposed the mathematical model about transformation relations of water resources; Liu (2001) took the Minqin Basin of Shiyang River as an example to conduct research on water resources development and oasis evolution; Zhong (2002) conducted the research into the water resources and environment protection of downstream Shiyang River in Minqin downstream; Chang (2005) had done research on the natural and artificial factors and their transfer on sandy desertification of lower reaches of the Shiyang River basin.

The basin is situated at the important location of the Silk Road and Europe-Asia continental bridge; the development of agriculture and animal husbandry history is old. It has been a rich, well populated place since ancient times. The downriver Minqin oasis extends to the crevice between the Tengger and Badain Jaran desert. It has prevented the two deserts closing up and has become a natural barrier over Wuwei, Lanzhou and even the north of China. The eco-environment protection and construction in Shiyang River basin not only have something to do with the basin of living space and economy development, but also have a bearing on the northwest and north of China. Therefore, it is extremely significant to study the question of water resources in the Shiyang River basin.

RESEARCH TECHNIQUES

Areas survey

Shiyang River, emanating from the Qilian mountains, is one of three big river systems in Hexi inland river basin. It begins at Wu Shaoling in the east, stops at Dahuangshan in the west, and links up Tengger and Badain Jaran desert in the north. The entire basin is constituted of eight tributaries upstream, including the Dajing River, Gulang River, Huangyang River, Zamu River, Jinta River, Xiying River, Dongda River, Xida River from east to west, and main current of Shiyang River downriver (Fig. 1). The total area of this basin is 41 600 km². The total population was 2 230 000 and its urbanization level was 27.1% in 2000. GDP was 9 470 000 000 Yuan. Average GDP per person was 4243 Yuan. Gross industrial output value was 10 020 000 000 Yuan. Total cultivated area was 368 550 ha², irrigated area was 309 800 ha², total agricultural output value was 4 290 000 000 Yuan, gross foodstuff output was 997 000 t (2004).

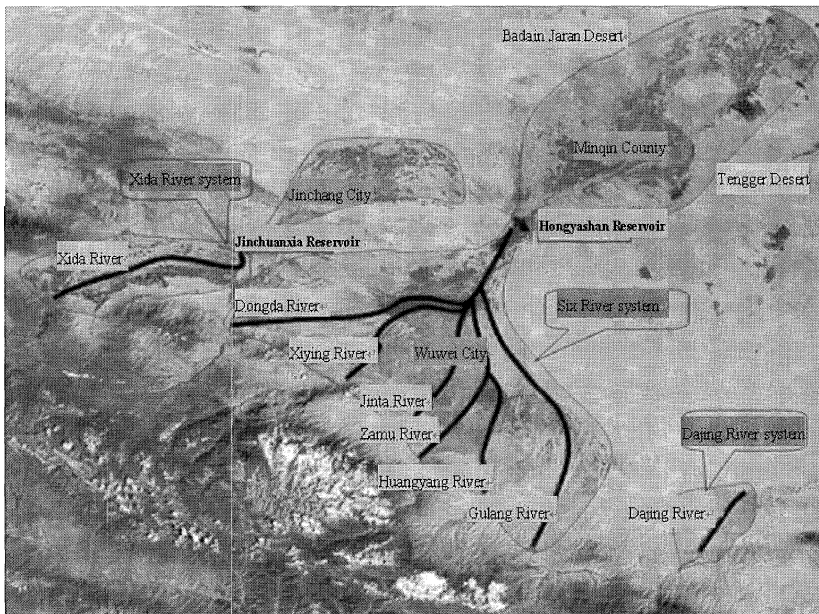


Fig. 1 Shiyang River basin map.

Table 1 Contrast between water supply in Shiyang River Basin in 1980, 1995 and 2000.

Year	Project	Surface water supply				Groundwater Water supply	Other Water supply	Total
		Storage reservoir	Water diversion	Water-lifting	Sub-total			
1980	Water volume (10 ⁸ m ³)	10.32	5.62	—	15.94	9.8	—	25.74
	Ratio(%)	40	21.8	—	62	38	—	100
1995	Water volume (10 ⁸ m ³)	9.2	4.32	0.24	13.76	12.1	0.007	25.87
	Ratio(%)	35.6	16.7	0.9	53.2	46.78	0.002	100
2000	Water volume (10 ⁸ m ³)	9.95	3.94	0.01	13.9	14.47	0.17	28.54
	Ratio(%)	34.86	13.81	0.05	48.7	50.7	0.58	100

Assessment of current situation development and utilization of water resources

Present situation of water supply There were many water supply projects in this basin, the water supply capacity of which was 3 100 000 000 m³. The types of projects mainly contain storage reservoir works, water diversion works, and water-lifting works. The actual water supply was 2 854 000 000 m³ in 2000, increased by 10% and 9.4% compared to 1980 and 1995, respectively, caused by the exploitation of groundwater (Table 1).

Analysis on groundwater balance After calculating the groundwater balance in this plain in 2000, the total groundwater recharge was 1 193 000 000 m³. If deducting 251 000 000 m³ regression water quantities from wells, the recharge of groundwater will become 942 000 000 m³. Total output water is 1 667 000 000 m³, if subtracting the regression of irrigation from spring water; the actually groundwater consumption become 1 416 000 000 m³, so the overdraft quantity of groundwater is 474 000 000 m³. The groundwater resources efficiency of Shiyang River basin is 121%. It means the groundwater has been seriously overexploited.

Analysis on the present situation of water consumption level Total water consumption was 2 135 000 000 m³ in the entire basin in 2000. Water consumption was 46 000 000 m³ in the mountainous area. Production, life, and ecological water consumption was 1 718 000 000 m³. The natural ecological and evaporation of nullity water consumption was 368 000 000 m³. Actual water resources consumption was 769.6 m³ per person and 1975.0 m³ per acre. Water consumption was 742.1 m³ per person and 1911.8 m³ per acre in Liangzhou area. Water consumption was 1653.8 m³ per person and 2800.6 m³ per acre in Minqin. It is 2.2 times and 1.5 times more than the middle reaches areas, respectively. Its water resources consumption level of per person and per acre was the highest endorheic drainage (2002).

Analysis of the water use efficiency Water volume per 10 000 Yuan GDP was approximately 3014 m³ in the Shiyang River basin, which was four times more than the national average level. Stere water produced 0.41 kg/m³ grain, which was lower than the national average level and ranged from 0.6 kg/m³ to 1.0 kg/m³. Water volume per 10 000 Yuan GDP reached as high as 8487 m³ in Minqin downriver, which was 12 times more than the national average level. Stere water only produced 0.23 kg/m³ grain. From these data, it explained that Shiyang River basin water resources allocation was mainly on low output of industry and Stere water use efficiency was somewhat low.

Development and use factor of water resources

According to the water supply gauge in 2000, the development and use factor of water resources (the ratio of water supply and total water resources), which was 20.0% in China, 53.3% in northwest China, 52.5% in inland river basin, 92% in the Hexi Corridor, and 162% in Shiyang River. It is shown that the development and use factor of water resources in Shiyang River basin was the highest because of the water resources recycling and groundwater over-exploiting without completely considering water for environment.

Table 2 Major index of synthesis assessment.

Evaluation index	Unit	Numerical value
Irrigation rate of infield	%	84.1
Average per person cultivated area in countryside	(ha ² per person)	0.23
Average per person irrigated area in countryside	(ha ² per person)	0.19
Average per person water resources	(m ³ per person)	789
Average per person annual water consumption	(m ³ per person)	1278
Storing and regulating rate of reservoir project	%	21.85
Development and use factor of surface water	%	89
Development and use factor of groundwater	%	121
Use factor of total water resources	%	162
Mining potential index of groundwater resources	%	52.1

Comprehensive evaluation

Based on the research achievements on exploitation and use of water resources, unifying the characteristics of Hexi inland river basin and the Shiyang River water resources exploitation and use, 10 targets has been put forward to take comprehensive evaluation on exploitation and use of the present water resources in Shiyang River basin (Table 2).

PROMINENT PERFORMANCE AND ORIGIN ANALYSIS OF WATER RESOURCES

Prominent performance of water resources

Scarcity of water resources, contradiction of supply and demand Total water resource of Shiyang River basin is only 1 661 000 000 m³ and available water is 1 762 000 000 m³. Water resource is 789 m³ per person and 52 m³ per acre, which is lower than 1150 m³ per person and 62 m³ per acre in Gansu province. So it is typical of water resource shortage areas. Water requirements status is 3 186 000 000 m³, available water is 2 661 000 000 m³ and total water consumption is 2 135 000 000 m³. The water deficit is 525 000 000 m³ and the lack of water degree is as high as 31%. The supply and demand contradiction is incisive. With the development of the social economy, the contradiction of for water resources supply and demand will be greater.

Sudden dropping of groundwater table, sharp degrading of ecological environment Along with the enhancement of water resources development and use degree in upper and middle reaches, the water entering into the downriver of Minqin oasis was reduced year by year. The present oasis area of Hongyashan reservoir in Minqin was 1312.66 km², which was 288.94 km² less than that in the 1950s. The groundwater was over-exploited in the middle and lower reaches of the basin. In recent years, 9000 ha² narrow-leaved oleaster forests got spike top and downfall, natural vegetation such as 23 330 ha² Bai Ci, the Chinese tamarisk, etc., was dead or half dead condition in Minqin. Sandbreak forest and farmland protection forest in the north of the basin have reduced by nearly 200 000 ha². The desert pushed 8–10 m to the oasis every year. The average desertification area reached 15 000 ha² every year. Sandstorm and dust storm harm is aggravated as a result of shrinkage and desertification of Minqin oasis, which not only seriously threatened people's production and living in Shiyang River basin, but also underestimated the influence on the ecological environment of the entire province and even the northwest area of north China.

Degeneration of the Qilian mountainous area ecology, the weakness of water source self-control function Forest vegetation and the alpine steppes of the Qilian mountains is a water source self-control area in the Shiyang River basin. Prominent contradiction among the forest worker, forest herd and forest mine is created as a result of the population increase and of overdevelopment and overgrazing. The lower Qilian mountainous bush forest line has moved up 40 m since the 1950s, 30% bush forests appear as grassland desertization and desertification. The forest land and percentage of vegetation coverage is reduced. The natural grassland degenerates. The water source self-control ability continues to decline.

Irrationality of economic structure, low efficiency of the water used The industry construction of the Shiyang River basin took agriculture as the primary structure, the increased value of the primary industry occupies the proportion of GDP; for Wuwei city it was 35.2% and for Minqin County was 62.9%. It is far higher than the entire province, which was 19.63%. The industrialization coefficient of Wuwei city and Minqin County were lower than the entire province average level. The water used in the farmland and forest-grass occupied almost 90.4%, and the industry, urban domestic and countryside person livestock only accounted for 9.6%. The agriculture water used was obviously high, and the primary industry was on the high side; secondary and tertiary industries were on the low side.

Dysfunction of the management system, weakness of water resources unification management In recent years, the authorities of country and province enlarged the dynamics to dangerous reservoir and water-saving transformation irrigation area, but the river basin program

authorized by the provincial government in 1990 had not been comprehensively carried out because the work of the basin unified management had not followed. The region water allocation plan was not in accord with the plan implementation, which caused the water entering downriver of Minqin to become less and less, and the oasis ecological problems to become more and more serious.

Origin analyses

Drought climate and shortage of water resources in local Shiyang River basin is located deep in the centre of the mainland. Its climate is continental temperate dry. The water resources average per person measured 789 m^3 , which was only 1/3 of the nation and far lower than the average per person 1000 m^3 for the inadequacy standard of international water resources. The Chinese Mou water resources measured 318 m^3 , which was only 1/5 of the nation. Water resources quantity of average per person and infield of unit area possess was seriously insufficient, so it was the main root for scarcely water used and deterioration of the eco-environment in the Shiyang River basin.

Consideration of water resources condition was insufficient in social area economy development, the social economy water using had occupied the eco-environment water The basin has reclaimed wasteland and planted crops to develop foodstuff production base on a large scale since the 1970s, because of the insufficient overall planning consideration of water resources condition. It pricked up the eco-environment worsening. Water used contradictory among upper, lower reaches and each national economy department was extremely incisive. The basin average volume of eight main branches' runoff at mountain outlet was $1\,456\,000\,000 \text{ m}^3$. The water volume entering into Minqin represented 31.1–31.6% of branches at mountain outlet before the 1970s. The proportion between the water volume entering to Minqin and various branches at the mountain outlet reduced year by year after the 1970s, because water volume consumption in the middle reaches increased yearly. The water volume actually entering to lower reaches did not achieve $100\,000\,000 \text{ m}^3$ in the late 1990s, which was only 8.3% of branches at mountain outlet. Drying up of the downstream riverway and the reduction of surface water volume, caused by increase of the middle reaches' water consumption, results in over-exploitation of the groundwater and the continuous decline of groundwater table. Some vegetation which depended on the groundwater gradually started to degenerate or wither away. That was why the eco-environment in the lower reaches had deteriorated.

Reclamation was disordered and ecological environment was seriously destroyed downriver of Minqin There is no self-produced surface water downriver of Minqin; the water resources is almost all foreign water from the middle reaches and its eco-environment is being

Table 3 Contrast between average yearly volume of upper branches' runoff at mountain outlet and inflow of Hongyashan Reservoir.

Year	Average yearly volume of upper branches' runoff at mountain outlet (billion m^3)	Runoff enter to downriver of Minqin (billion m^3)	Ratio of lower branches' runoff at mountain outlet (%)	Ratio of water using between lower and middle reaches
1955–1959	17.524	5.527	31.5	1:0.5
1960–1964	14.376	4.471	31.1	1:0.4
1965–1969	14.034	4.437	31.6	1:0.5
1970–1974	13.776	3.737	27.1	1:0.4
1975–1979	14.357	2.712	18.9	1:0.2
1980–1984	14.938	2.359	15.8	1:0.2
1985–1989	15.529	2.215	14.3	1:0.2
1990–1995	13.716	1.65	12	1:0.1
1996–2000	12.87	1.07	8.3	1:0.1
Average	14.56	3.131	21.5	1:0.3

worsened day by day because the discharge in the middle reaches is reduced year by year. However, the Minqin irrigated infield has developed in a disorderly way in recent years and the irrigated area scale has enlarged. Statistics have indicated that there were 40 000 ha² in the irrigated area in Minqin in the middle 1980s. The irrigated area had once achieved about 80 000–867 000 ha², driven by the economics of “heat melon seeds” actuation in the 1990s. Along with falling of the melon seed quotation, massive farmlands were abandoned, so the irrigated area still maintains about 68 000 ha² in Minqin County at present. Farmlands have been abandoned again caused by predatory exploitation of groundwater, the continuing decline of groundwater table, and the deterioration of groundwater quality. Some of the people are unable to survive in Minqin lake region at present. They are forced to leave their native home and become “ecological refugees”.

The pressure of the still-growing very large population The population yearly rate was 17.5‰ in this basin for the last 50 years. The population mainly concentrates in the oasis area. The oasis’s bearing population had more than 300 people per square kilometre. As a result of water resources condition limitation and land resource development potential limitation, the area suitable for human living was 10% of the total land area (2004), developing the suitable agricultural wasteland also become a much bigger pressure on water resources supply. Therefore, the increase of population is an important factor, which affects the deterioration of region eco-environment.

COUNTERMEASURES ON BASIN COMPREHENSIVE CONTROL

Basic clues

The basic clues of comprehensive administration is: insist on taking the ecological protection and the improvement as the basis, taking the water resources of the scientific management, the reasonable allocation, the high-efficiency utilization and the effective protection as the core, consolidating the engineering measures and non-engineering measures, giving attention to two or more effects of ecology benefit and economic benefit, making overall plans, and taking all factors into consideration on upper, middle and lower reaches, regulating waterways together, colluding development, corresponding to the life, production and ecological waterwell, carrying on the comprehensive administration to keep the ecosystem worsening tendency of Shiyang River basin within limits, and urging the harmonious coexistence between man and nature.

COUNTERMEASURES

Advancing water saving, establishing water saving society

We should carry out the industry and life water saving technology vigorously; expanding the region of town centralism water supply. To develop the industrial enterprise water balance test positively, to strictly restrict new high water consumption and pollution project, to popularize new water saving technology, new craft and new equipments, and to reduce unit water demand. Push agriculture convention water saving technology comprehensively; unceasingly improving its quality and standard. So we need to diligently carry out sprinkler irrigation, drip irrigation and ooze irrigation as the main content new agriculture water saving technology, construct water saving society.

Adjusting economic structure reasonably, optimizing disposition of water resources

Taking the market as a guide, take the redistribution of water resources as the core, speed up secondary and tertiary industrial development, and promote the industrial structure reasonable adjustment. Unify the readjustment of the economic structure in the basin, develop small towns vigorously, and adjust population distribution, through annex the village and spot, move town distribution in resettlement. This causes water conservation in the forest region in the south and serious desertification in the north, the local population disagrees with oasis to be suitably centralized to the middle of the corridor. Optimize agriculture industrial structure, increase forest-

grass planting area, and adjust the dual of grain and economic crop to the three-plant dimension structure of grain, economic crop and grass. Use optimal allocation to region water resources to promote industrial structure adjustment gradually and use industrial structure adjustment to promote the concatenation system of optimal allocation to region water resources.

Developing the ecology construction vigorously, improving the ecological environment diligently

Take the soil and water conservation and comprehensive administration as the key point. Persist in making, controlling, developing simultaneously, and combine with sealing and forestation. Administrate mountain water, forest, field and road comprehensively. Develop closing hillsides (sand) to facilitate afforestation (grass), return cropland to forestry, push natural forest protection effort, sands controlling and afforestation and the construction of farm-shelter forest, expand woods and grass vegetation, improve ecological environment vigorously.

Actualizing water resources unification management and attemper

Perfectly authoritative, highly effective, harmonious basin management system and the operating mechanism should be established. Take the rationally water resources allocation as the core, practice centralized management and unified allocation. First, constitute rules and regulations of Shiyang River basin, delimit the hydrant permission management system permission legally and reasonably, implement the system, and unify total quantity control and quota management by norms. Second, Shiyang River year water volume real-time scheduling plan should be established and supervised, actualized responsibly by the basin management structure. Third, close the motor-pumped well designedly, and gradually reduce the quantity of groundwater exploitation. Fourth, establish the advanced hydrological measurement and reporting and water resource information management and attemper system, according to the request of unification management Shiyang River basin water volume and water quality dispatch.

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