ISSN : 0974 - 7435 Volume 10 Issue 6

BioTechnology
An Indian Journal

FULL PAPER

BTAIJ, 10(6), 2014 [1599-1604]

Water resource balance analysis in the comprehensive development of agriculture: A case study of yanjin country, henan province

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ABSTRACT

The comprehensive development of agriculture project in Yanjin country, Henan province was taken as a typical example to quantificationally evaluates available surface water quantity, ground water quantity, irrigation water quantity and water quantity for living use in order to discuss a methodology on water resource balance analysis in northern drought region of China.

KEYWORDS

Agriculture;
Comprehensive development;
Water resource;
Balance between supply and demand.

INTRODUCTION

Analysis of water resource balance is the premise and basis of irrigation and water conservancy projects. Analysis results not only decide the scale of the demonstration area but also directly indicate the feasibility of the demonstration projects[1]. Only when the status of soil and water resources in the demonstration area is found out, can the demonstration project area be scientifically planned according to local conditions, can an overall improvement in land use efficiency be achieved, and can the economic benefit, the social benefit and the ecological benefit be coordinated and unified and can benefits be maximized[2]. The project demonstration area in Yanjin County is an agricultural comprehensive development project, aiming to accelerate the improvement of agricultural fields with low or moderate yields so that the construction of the food production core area can be driven forward. Performing water resource balance analysis on this project has important strategic implications in implementing the construction planning of the food production core area in Henan Province and raising the agricultural productivity in the Yanjin area.

THE OUTLINE OF THE YANJIN PROJECT DEMONSTRATION AREA

Yanjin Country is located in the Central Plains. The country has a warm temperate continental monsoon climate with an average annual temperature of 14 °C, an average annual precipitation of 614.2 mm concentrating in summer and autumn, an average frost-free period of 216 d and an average annual sunshine duration of 2504.83 h. The agricultural comprehensive development project area is located in the east of Yulin Village which consists of 8 administrative villages, including

Jiadi, Laorenzhuang, Wanquanzhuang, Wangcun, Donglouzhuang, Zaozhuang, Xiaohanzhuang and Dahanzhuang. The terrain is flat and transportation is convenient with Provincial Highway S227 and S226 running by. The project area is about 8.996 km in the north-south direction and approximately 5.894 km in the east-west direction and about 2292 hm^2 of the area is fields with low or moderate yields. The close sites were selected and joined into a large project demonstration area where well irrigation is the major irrigation method. The soil in the project area is sandy with loose texture and good aeration. After years of soil improvement, crops planted there are mainly rain fed crops such as winter wheat, corn and peanut. The project demonstration area is one of the key target counties in the National Food Productivity Project for Additional 50 Trillion Kilograms. The county is rich in resources and has convenient transportation and prominent regional advantages.

THE CURRENT SITUATION OF WATER RESOURCE IN THE PROJECT DEMONSTRATION AREA AND ANALYSIS AND PREDICTION OF WATER DEMAND AND AVAILABLE WATER SUPPLY

The current situation of water resource

The hydrogeology in Yanjin Country has Quaternary features. Its aquifer is 15-30 m thick with fine (powder fine) sand or middle-grained (coarse) sand and usually separated by 1-3 clay (or sandy) soil sublayers with a unit water discharge of 10-16 $m^3/(h \cdot m)$. According to statistical data of recent years, the groundwater table is at a depth of 6-9 m. The groundwater has a pH of 7.7-8.3 and a salinity of 0.9-1.5 g/l. Therefore, the groundwater is extremely weakly mineralized and suitable for agricultural irrigation and people and animal consumption. Currently, the prevalent irrigation method is furrow irrigation where water lost during delivery is great.

According to water resource evaluation, the county has 2.10×10^8 m^3 of available water resource. Based on the population and cultivated land in 2008, the water resource per person is 430 m^3, and water resource per hm^2 is 3733 m^3, which are far lower than the provincial level of 445 and 6105 m^3, respectively. The water conservancy projects have severely aged and degraded. Although exploitation of surface water holds certain potential, it is of great difficulty and high cost. Farm irrigation still mainly adopts the traditional flood irrigation whose water use efficiency is low. The main drainage river is seriously silted up. Its current drainage capacity cannot deal with three-year floods, far lower than the designed capacity for five-year floods. The major tributaries have prominent problems in drainage with drainage capacities all lower than three-year floods. As a result, the farmlands have poor flood-resistant ability.

Water demand prediction

Water demand prediction for the project demonstration area includes near-term planning (year 2010), medium-term planning (year 2015) and long-term planning (year 2020). There are no industries in the project demonstration area. Therefore, water use mainly includes agricultural irrigation, domestic water use and other water use. And domestic water use is associated with water used by residents and by animals.

Determination of agricultural water demand

According to data obtained from the Ministry of Agriculture and the Ministry of Water Resources, the representative crops in the project demonstration area are winter wheat, corn and peanut. Well irrigation combined with low pressure pipeline irrigation is going to be used. As irrigation well groups are independent with relatively high irrigation water use efficiency, an irrigation water use coefficient of 0.9 was adopted in calculations.

The water demand in agricultural production in the project demonstration area was calculated using the following equation:

$$W_d = MA/\eta$$

where W_d is the total water demand in agricultural production (m^3); M is irrigation amount (m^3/hm^2); A is irrigation area (hm^2); and η is irrigation water use coefficient and 0.9 was used in calculations.

The designed planting system in the project demonstration area was double cropping of wheat-corn or wheat-peanut with a cropping index of 1.9. According to the *Local Standard Irrigation Quota of Henan Province* (DB41T385-2009), the irrigation quotas for major crops in Henan Province were obtained and agricultural water demands with different assurance rates were calculated using the above equation for the demonstration area. The results are shown in TABLE 1.

Determination of domestic water demand and other water demands in the project demonstration area

The majority is agricultural population in the project demonstration area. Taking into account such factors as natural population growth rate and peasant-worker shift, a population annual growth rate of 5‰ was adopted. The calculation results showed that the total population in the project demonstration area was 9810 and total livestock was 800 heads. According to the *Local Standard Irrigation Quota of Henan Province* (DB41T385-2009), for a water supply assurance rate of 95%, resident water demand is:

$$Q = \frac{pq}{10^7} \times 365$$

$$P = P_0 (1 + r)^n + P_1$$

Where Q is resident water demand ($\times 10^4$ m^3/year); P is projected water using population (person); P_0 is the current permanent resident population in the water supplying (person); q is the highest daily water quota (L/(person·d)) with 65 L/(person·d) and 50 L/(head·d) for people (q_p) and animal (q_a), respectively; r is the natural growth rate for the design period with r_p=5‰; n is the design period; and P_1 is the total mechanical increase of population in the design period and is determined with the average increment method (person). Other water demand is mainly the basic flow that is needed to sustain the natural eco-environment and is calculated as 2% of agricultural irrigation water demand. The predicted water demands from calculation in the project demonstration area are shown in TABLE 2.

Determination of available water resource amount

Available water resource amount is the part of the water resource that can be utilized after taking into account the constraint of natural, technical and economical conditions and after meeting eco-environmental water demand.

TABLE 1 : Agricultural water demands with different assurance rates for the project demonstration area

Project	Crop	Assurance rate	Planting ratio	Water use coefficient	Net irrigation quota (m^3/hm^2)	Gross irrigation quota (m^3/hm^2)	Cultivated land area hm^2	Irrigation water demand ($\times 10^4$ m^3)
Water-saving irrigation zone	Wheat	P=50%	0.95	0.95	2025	2131.58	2292	464.13
	Corn		0.30		900	947.37	2292	65.14
	Others		0.65		1350	1421.05	2292	211.71
	Total							740.98
	Wheat	P=75%	0.95	0.95	2625	2763.16	2292	601.65
	Corn		0.30		1425	1500.00	2292	103.14
	Others		0.65		1350	1421.05	2292	211.71
	Total							916.50

TABLE 2 : Predicted water demands in the project demonstration area (unit: $\times 10^4$ m^3)

Level year	Irrigation assurance rate	Crop Water demand	Domestic water demand	Others	Total
2010	*P*=50%	740.98	3.79	14.82	759.59
2015		740.98	3.93	14.82	759.73
2020		740.98	4.00	14.82	759.80
2010	*P*=75%	916.50	3.79	18.33	938.62
2015		916.50	3.93	18.33	938.76
2020		916.50	4.00	18.33	938.83

FULL PAPER

Natural precipitation

The 30-year (1979-2008) statistical data obtained from the weather station of Yanjin County were used for precipitation frequency calculation and analysis. The curve-fitting method was used to deduce the precipitation frequencies in median water years (P=50%) and drought years (P=75%). C_v=0.25 and when C_s=2C_v, the theoretical frequency curve matched the empirical data points pretty well, which is shown in Figure 1.

According to the annual precipitation frequency curve of the project demonstration area, the precipitation in median water years (P=50%) is 563.2 mm, and that in drought years (P=75%) is 481.4 mm. According to curve matching results, year 1994 was selected as the P=50% representative year with annual precipitation of 583.1 mm and year 2002 was selected as the P=75% representative year with annual precipitation of 497 mm.

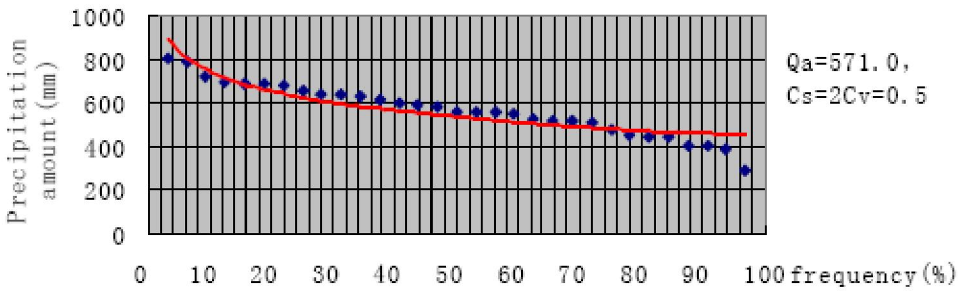

Figure 1 : Theoretical precipitation frequency curve for the project demonstration area

The water quality of deep groundwater is relatively good and suitable for drinking. Yet, as it is difficult to recharge deep wells, it is not appropriate to exploit the deep water resource at a large scale at this time. The project area is relatively rich in shallow groundwater which has been exploited at a certain level and is mainly for people and animal drinking and industrial production. Therefore, only the shallow groundwater resource is evaluated in this study.

Shallow groundwater resource

Recharging sources for the shallow groundwater mainly include precipitation infiltration recharging, surface runoff (the Yellow River) infiltration recharging and surface water body vertical infiltration recharging. In the lateral direction, recharging is almost equivalent to draining, that is, recharging offsets draining. Therefore, the lateral direction is not taken into consideration for analysis this time.

Recharging amount from precipitation infiltration (P_r)

Precipitation infiltration is one of the main recharging sources for shallow groundwater, and recharging amount can be calculated using the following equation:

$P_r = 0.1\Sigma P_i \cdot \alpha_i F_i$

Where P_r is recharging amount from precipitation infiltration (10^4 m^3); P_i is the annual precipitation in the calculation region (mm); α_i is the precipitation infiltration coefficient of the *i*th subarea, and for this estimation, α_i=0.2; F_i is the area of the calculation region with precipitation infiltration recharging (km^2).

Recharging amount from irrigation infiltration (I_r)

The irrigation method in the project demonstration area is low pressure pipeline irrigation. Part of the irrigation water evaporates while another part of the water recharges the groundwater. The following equation is used in calculation:

$$I_r = \sum_{i=1}^{n} \beta_i I_i$$

Where β_i is irrigation water infiltration recharging coefficient for the *i*th crop and for rainfed crops, β_i=0.20; I_i is the gross irrigation amount for the *i*th crop.

Lateral recharging from rivers and canals

Lateral recharging from surface runoff mainly comes from the Yellow River. In the project area, the Yellow River is a seasonal stream. During the irrigation season, as water is in great demand, basically there is no available water from the Yellow River in the project area. Therefore, water from the Yellow River is the main water recharging source.

Lateral recharging amount is one of the key factors influencing groundwater storage. According to local hydrogeological data, the groundwater in the project area goes basically in the same direction as the terrain there from northeast to southwest. In the project area, the northeast-southwest boundary is 8998 m in length. According to the regional balance method, the project area is looked on as one water storage entity when calculating regional boundary within a year. The equation for calculating the lateral runoff recharging amount[3] is as follows:

$$Q = KBIMt$$

Where t is the recharging time (d); K is the permeability coefficient (mm/d); I is the hydraulic slope of the groundwater; B is the length that the vertical groundwater goes through the flow cross-section (m); M is the average thickness of the aquifer (m); and Q is the lateral recharging amount to the groundwater from runoff (10^4 m^3).

The exploitable amount of groundwater resource

The exploitable amount of groundwater resource is the maximum quantity of water that can be withdrawn from the aquifer under the conditions that it is economically reasonable and technically feasible, that it won't cause water environmental problems such as continuous lowering of the water table, deterioration of water quality, invasion of sea water, and subsidence of land, and that it won't have negative influences on the eco-environment[4]. According to the "withdrawing-recharging balance" rule, the exploitable amount in the project area was determined using the exploitable amount coefficient method:

$$W_e = \rho W_r$$

Where W_e is the amount of exploitable groundwater; W_r is the recharged amount for groundwater; and ρ is the exploitable amount coefficie nt, and ρ=0.9.

SUPPLY-DEMAND BALANCE ANALYSES

Based on the above comprehensive analysis and calculation results of water demand and exploitable

TABLE 3 : The calculation results of the exploitable water resource amount of the project demonstration area (unit: 10^4 m^3)

Frequency	Precipitation infiltration	Irrigation input	Lateral permeation from rivers and canals	Total	Exploitable amount
P=50%	618.48	148.20	322.78	1089.46	980.51
P=75%	537.77	183.30	347.61	1068.67	961.81

TABLE 4 : Comparison of water resource supply-demand balance in the project demonstration area

Level year	Irrigation assurance rate	Water demand (×10^4 m^3)					The maximum available water supply	Water excess/deficit (×10^4 m^3)	
		Agricultural irrigation	Industry	Domestic	Other	Total	(×10^4 m^3)	Excess	deficit
2010		740.98	0	3.79	14.82	759.59	980.51	220.93	
2015	*P*=50%	740.98	0	3.93	14.82	759.73	980.51	220.78	
2020		740.98	0	4.00	14.82	759.80	980.51	220.71	
2010		916.50	0	3.79	18.33	938.62	961.81	23.19	
2015	*P*=75%	916.50	0	3.93	18.33	938.76	961.81	23.05	
2020		916.50	0	4.00	18.33	938.83	961.81	22.98	

FULL PAPER

water resource amount in the project demonstration area in Yanjin County, comparison of water resource supply-demand balance is shown in TABLE 4.

It can be seen from TABLE 4 that for the project demonstration area, when P=50%, the amount of water resource that can be utilized is greater than the amount that is needed, and available water resource can meet the agricultural production demand. If the project demonstration area has the matching water conservancy facilities which can give full performance, it is highly sure that the water demand in the project demonstration area can be met. When P=75%, water supply and demand are basically in balance with a little surplus and supply is slightly higher than demand. Comprehensive analyses showed that rational development of the water conservancy facilities in the demonstration area can change the original fields with low and moderate yieldsinto fields with high yields where irrigation can be guaranteed. At the same time, local irrigation water use coefficient can also be raised and water resource can be fully and effectively utilized.

CONCLUSIONS

Water resource balance analysis for the project demonstration area in Yanjin County showed that for the status quo year (2010), when the assurance rate is 50% or 75%, available water supply can meet water demand. For the planning years of 2015 and 2020, when the assurance rate is 50% or 75%, available water supply is slightly in surplus. In drought years, water gap can be filled by increasing water recharging from the Yellow River or water shortage can be solved by taking engineering or non-engineering measures such as raising precipitation storage and years of effective regulation.

ACKNOWLEDGEMENTS

The paper is supported by Important National Science & Technology Specific Projects of China (2012ZX07404-004).

REFERENCES

[1] Y.N.Zhao, Z.C.Wang; Adjustment of agricultural land clear up rights: issues and strategies. Resource Exploitation and Market, **3**, 222-224 **(2005)**.

[2] Y.Tang, G.L.Yang, T.Li; Water resource balance analysis in land consolidation, planning and design. Proceedings of the Annual Meeting of the Land Science Society of China, 1017-1022 **(2007)**.

[3] J.W.Wang, X.Z.Wang, D.Y.Yang; Water Resource in Henan Province (1st Edition). The Yellow River Water Conservancy Press, **(2007)**.

[4] Department of Hydrology, Ministry of Water Resource. Evaluation Guideline of Water Resources. China Water Power Press, Beijing, **(1999)**.