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Development Potentials and Benefit Analysis of Efficient Water-saving Irrigation in Lixin County

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Abstract On the basis of analyzing water resources, crop planning structure, and irrigation mode in Lixin County, potentials and benefits of developing efficient water-saving irrigation in the county were explored to provide references for its future water-saving irrigation.

Key words Efficient water-saving irrigation, Potential, Benefit

1 General situation

1.1 Natural conditions Lixin County is located in the middle west of Huabei Plain, Anhui Province, covering the geographical coordinates of $115^{\circ}54' - 116^{\circ}31' E$ and $32^{\circ}51' - 33^{\circ}27' N$. It lies at southeast of Bozhou City, has Guoyang County in the north and Mengcheng County in the east, Taihe County and Yingdong District of Fuyang City in southwest, Yingshang County and Fengtai County in southeast. Its land area totals $1\ 950\ km^2$, arable land about $1\ 187\ km^2$, the overall terrain declines from northwest to southeast with a ground elevation about $25 - 30\ m$. The highest elevation is $31\ m$ located nearby Chengtaoyuan in the northwest, and the lowest is $21\ m$ along the West Fei River in southeast, the ground average gradient is $1/10\ 000$.

Situated in the transitional area between northern subtropical zone and warm temperate zone, the county enjoys semi-humid monsoon climate, distinctive seasonal characteristics, a multi-year mean rainfall of $876.6\ mm$. But the annual and interannual distribution of rainfall is extremely uneven, the maximum annual rainfall is $1\ 215.7\ mm$, and the minimum is $496\ mm$, and annual mean rainfall days are 93.3 . Influenced by alternative winter and summer monsoon, the rainfall concentrates in June, July and August, accounts for 53.5% of the year total. Annual mean temperature is $14.9^{\circ}C$, annual mean cumulative temperature above $0^{\circ}C$ is $5\ 424.4^{\circ}C$, and that above $10^{\circ}C$ is $4,875^{\circ}C$. The multi-year mean evaporation capacity is $1\ 161.8\ mm$, the frost-free period is 226 days, and annual mean total solar radiation is $122.6\ kilocalorie/cm^2$. There are 3 types of soil in Lixin County, specifically, fluvo-aquic soil about $27\ km^2$ (2.3% of the total), brunisolic soil about $61\ km^2$ (5.3% of the total), Shajiang black soil $1\ 071\ km^2$ (92.4% of the total). Its crop farming includes wheat, soybeans, coarse cereals and oil crops, and the field crops mainly include wheat, corn, rice and soybean.

1.2 Social economy There are 23 townships under the jurisdiction of Lixin County. There are 357 villager committees, and the county government is located in Chengguan Town. Lixin Coun-

ty enjoys convenient transportation, Beijing – Kowloon Railway, Suixi – Fuyang Railway, Jieshou – Bengbu Highway, provincial roads 202, 224 305 and 308 run through the county. It is only 30 km away from Fuyang Airport, and also accessible via West Fei River and New Cihuai River all the year round. Total population of the county is 1.58 million in 2011, agricultural population 1.44 million (91.3% of the county total), natural increase rate of population is 9% .

In 2011, GDP of Lixin County achieves 9.52 billion yuan, and per capita GDP $6\ 040$ yuan. The primary industry accounts for 3.23 billion yuan, increase value of the secondary industry 2.37 billion yuan, the tertiary industry 3.92 billion yuan, and increase value ratio of the three industries is $34.0: 24.9: 41.1$. The grain output in 2011 achieves 1.13 million tons, cotton yield $1\ 148$ tons, oil crop output $5\ 288$ tons, meat output $91\ 200$ tons, aquatic products $11\ 400$ tons, vegetable yield $475\ 600$ tons, melons and fruits 63.25 million tons. The government revenue is 441 million yuan, and per capita income of peasant is $3\ 487$ yuan. Restricted by natural conditions, grain yield of the county is low and unstable, agricultural production costs too much but turns out limited profits, so rural economic development remains at a slow pace, and the county is a national poverty county.

2 Introduction to local water resources and balance analysis

2.1 Total amount and available amount of water resources

According to Investigation and Evaluation of Water Resources and Development in Bozhou City, the multi-year mean water resource amount of Lixin County is 763 million m^3 , 50% hydrological year is 680 million m^3 , 75% hydrological year is 517 million m^3 , 95% hydrological year is 395 million m^3 . Multi-year mean available water is 582 million m^3 , 546 million m^3 in 50% hydrological year, 454 million m^3 in 75% hydrological year, 334 million m^3 in 95% hydrological year.

2.2 Water supply capacity and available water forecast of water conservancy projects

Beneficial reservoir capacity of small reservoirs in Lixin County is 4.14 million m^3 , that of rivers and channels under control is 46.71 million m^3 , suppose repeated

storage coefficient is 2.5, the available surface water supply is 127 million m^3 . There are 9 300 motor-pumped wells (including deep wells) in the county, including 6,410 electromechanical wells, available underground water 264 million m^3 . Other water conservancy projects supply water 3 million m^3 , so the total water supply capacity of all water conservancy projects in the county is 394 million m^3 .

Planning of water supply projects should first retain surface runoff, fully use natural rainfall, renovate original ponds and dams, and expand their flood-retaining capacity. Ground water table should be raised, and ground water reserve improved. Moreover, riverfront low-lying land should be controlled, channels and rivers dredged, all sluices operated as the designed water level, beneficial reservoir capacity expanded; old irrigation stations should be renovated, and new ones built to increase the capacity of pumping water from rivers and lakes. More motor-pumped wells can be built and old ones restored to fully use shallow groundwater.

According to the calculation, available water in 2015 is: 459 million m^3 in 50% hydrological year, 422 million m^3 in 75% hydrological year, 304 million m^3 in 95% hydrological year. Available water in 2020 is: 498 million m^3 in 50% hydrological year, 440 million m^3 in 75% hydrological year, 325 million m^3 in 95% hydrological year.

Table 1 Current water supply capacity and available water forecast of Lixin County

Unit: $10^8 m^3$

| Target year | Current | 2015 | | | 2020 | | | |
|--------------|---------------|------|------|------|------|------|------|------|
| | | 50% | 75% | 95% | 50% | 75% | 95% | |
| Lixin County | Surface water | 1.27 | 1.57 | 1.23 | 0.30 | 1.82 | 1.26 | 0.33 |
| | Ground water | 2.64 | 2.98 | 2.95 | 2.70 | 3.12 | 3.10 | 2.88 |
| | Other | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| | Total | 3.94 | 4.59 | 4.22 | 3.04 | 4.98 | 4.40 | 3.25 |

2.3 Water resource supply-demand balance analysis According to the forecasted available water and water demand, supply-demand balance of water resources in different target years is

Table 2 Supply-demand balance analysis of water resources in target years

Unit: $10^8 m^3$

| Target year | Guarantee rate | Water demand | | Available water | | Water deficit | | Remark |
|-------------|----------------|-------------------------------------|------------------|----------------------------------|--------------------------------|-------------------------------------|------------------|--------|
| | | Industry and agriculture and others | Living water use | Surface and shallow ground water | Middle and deep phreatic water | Industry and agriculture and others | Living water use | |
| 2015 | 50% | 2.75 | 0.50 | 4.00 | 0.59 | 1.25 | 0.09 | |
| | 75% | 3.74 | | 3.63 | | -0.11 | | |
| | 95% | 4.76 | | 2.45 | | -2.31 | | |
| 2020 | 50% | 3.12 | 0.64 | 4.39 | 0.59 | 1.27 | -0.05 | |
| | 75% | 4.23 | | 3.81 | | -0.42 | | |
| | 95% | 5.39 | | 2.66 | | -2.73 | | |

3 Crop planting structure and irrigation mode and composition

The arable land in Lixin County achieves 1 187 km^2 , among which

calculated as listed in Table 2. In available water, middle and deep phreatic water as the major water supply resource for rural residents and livestock needs independent balance analysis.

As Table 2 shows, water supply of 50% guarantee rate in 2015 will meet the needs of agricultural and industrial production, that of 75% and 95% guarantee rate will fail to meet the water need, leaving a gap of 11 million m^3 and 231 million m^3 respectively, water deficient ratio is 3% and 48%. Water supply of 50% guarantee rate in 2020 will meet the needs of agricultural and industrial production, that of 75% and 95% guarantee rate will fail to meet the water need, leaving a gap of 42 million m^3 and 273 million m^3 respectively, water deficient ratio is 10% and 51%.

Middle and deep phreatic water in Lixin County will be able to meet the living water use of the locals in 2015, but not in 2020. In 2020, water deficit will achieve 5 million m^3 , water deficient ratio will be 8%.

By analyzing supply-demand balance of water resources, water deficient ratio for short-term and long-term industrial and agricultural irrigation is 3% and 10%; middle and deep phreatic water supply cannot meet living water use of residents, and the long-term water deficient ratio is 8%. Therefore, water-saving facilities should be reformed, and more facilities built, water storage projects constructed to retain surface water and raise the water table; more surface water or shallow ground water can be used as water for life; agricultural planting structure should be adjusted according to actual conditions, except rice nearby New Cihuai River, dry farming should be developed in other locations, and more crops with stronger resistance to drought and less water demand should be planted; water-saving irrigation should be promoted, water-saving agriculture developed, water-saving techniques and channel seepage prevention techniques promoted, more water-saving irrigation modes explored such as low-pressure pipe irrigation, spray irrigation and drip irrigation, to improve water use efficiency and reduce agricultural water consumption; industrial projects consuming too much water should be controlled, water resources saved and more water sources explored. Only in this way, sustainable use of water resources will be guaranteed.

river-irrigated arable land occupies 313 km^2 , well-irrigated arable land 874 km^2 . According to water resource statistical yearbooks of Lixin County, the local crop planting structure consists of grain

crops (such as wheat, corn, soybean, rice, 906 km^2), cotton (23 km^2), oil crops (such as rapeseed and peanut, 20 km^2), herbs (about 53 km^2), vegetables (about 173 km^2), melons and fruits and other cash crops (about 11 km^2). The current effective irrigation area is 787 km^2 , among which river-irrigated area occupies 87 km^2 (pump station + channel irrigation), well-irrigated area 700 km^2 (motor-pumped well + hose irrigation). Current water-saving irrigation area is 100 km^2 , among which the efficient water-saving irrigation area (spray and micro irrigation) occupies 28 km^2 , includes facility agriculture such as vegetables, melons and fruits (the constructed facility agriculture 20 km^2).

In recent years, agricultural restructuring has been put on the top agenda of Lixin County, by increasing the input, applying science and technology, fully playing the driving force of leading crops, characteristic industries such as wheat production, greenhouse fruit and vegetable production, herb production, and tourism industry have been gradually formed. Agricultural structure has been optimized, economic benefits improved, construction of new countryside promoted. More funds should be input in agricultural production, construction of agricultural parks facilitated, scale of facility agriculture and cash crop production broadened, scientific and technological contents of agricultural products improved, agricultural industrialization promoted.

According to *Overall Land Use Planning of Lixin County* (2006–2020) and the "12th Five-year Plan" of Lixin County, 6 agricultural parks have been constructed (*i.e.* Yongxing Circular Economy Park, Wangren Eco-park, Madianzi Tourist Park, Wangtuan Grain Production Park, Liujiabi Fruit and Vegetable Park, Gongdian Herb Park). Local planting structure will be adjusted as herb planting (66.7 km^2), vegetable, melon and fruit planting (200 km^2), grain, cotton, oil crop planting (920 km^2).

4 Development potentials and benefit analysis of efficient water-saving irrigation

According to water resource balance analysis of Lixin County, water deficit will achieve 11 million under the guarantee rate of 75% by 2015. Therefore, water-saving irrigation should be promoted, water-saving agriculture enhanced, efficient water-saving irrigation modes such as spray and micro irrigation popularized, to improve water use efficiency and reduce agricultural water consumption. Efficient water-saving irrigation is suitable for cash crop planting such as herbs, vegetables, melons and fruits. By 2015, the potential water-irrigation area is 240 km^2 (deducting the already-developed efficient water-saving irrigation area 28 km^2). Peony is the major herb planted in the local area, spray irrigation, especially semi-fixed spray irrigation is suitable for the convenience of management, so the semi-fixed spray irrigation for newly-planted herbs will be 66.7 km^2 . Semi-fixed spray irrigation is adopted for the open field vegetables, drip irrigation for grape production and facility agriculture, so the semi-fixed spray irrigation will be 140 km^2 , and drip irrigation 33.3 km^2 . Efficient water-saving irrigation is distributed in both river-irrigated area and well-

irrigated area, but considering the high guarantee rate of water resources, only statistics of the well-irrigated area are used for the calculation.

4.1 Project cost assessment By referring to similar projects in the county and adopting comprehensive index evaluation method, investment for water-saving irrigation projects (including well house, water supply and discharge, water pumping and irrigation facilities) is calculated by using investment per mu as the index (mu is a traditional Chinese measurement unit, $1 \text{ mu} \approx 666.7 \text{ m}^2$), specifically, drip irrigation investment is 3,000 yuan per mu, semi-fixed spray irrigation 800 yuan per mu, so the static total investment for the total $360\,000 - \text{mu}$ (240 km^2) efficient water-saving irrigation is 398 million yuan, and annual investment is about 100 million yuan (2012–2015). Current investment of the county in farmland water conservancy is about 130 million yuan, among which efficient water-saving irrigation accounts for 30 million yuan, so there will be a financing gap of 70 million yuan.

4.2 Project benefit analysis Economic benefits of applying efficient water-saving irrigation are mainly demonstrated as promoting the yield, saving water resources and labor forces. In addition, application of efficient water-saving irrigation has also social and ecological benefits.

(a) Saving water.

The projects will improve and restore irrigation area about 240 km^2 after the completion, the original irrigation mode is annual hose irrigation with a water efficiency of irrigation of 0.75, after adopting spray and drip irrigation, the water efficiency of irrigation will increase to 0.85 and 0.9. According to the calculation, gross rating of drip irrigation for grape and facility agriculture is about $18.5 \text{ m}^3/\text{mu}$, 10 times per year, and irrigation area is 50,000 mu (about 33.3 km^2); gross rating of drip irrigation for open field vegetables and herbs is $24.8 \text{ m}^3/\text{mu}$, 4 times per year, irrigation area 310,000 mu (about 207 km^2). Therefore, annual spray irrigation quantity per mu will decrease from current 222 m^3 to 185 m^3 , and annual drip irrigation quantity per mu from 114 m^3 to 100 m^3 , and total saved water quantity will be 6.19 million mu per year for the $240 - \text{km}^2$ arable land. Even if efficient water-saving irrigation is adopted for the planting of all cash crops, the saved water quantity will be less than 11 million m^3 under the guarantee rate of 75%, so spray and drip irrigation should be further promoted in field crops cultivation.

(b) Saving land and labor forces.

Application of pipes will reduce the occupation of land by 1% or so, so after the wide application of efficient water-saving irrigation, the saved arable land will be 2.4 km^2 . According to the current output of crops in Lixin County (mean net output value per mu of field crops is 2,000 yuan), so the annual land saving benefits will be 7.2 million yuan. In addition, efficient water-saving irrigation projects will improve agricultural production conditions, agricultural productivity and production efficiency improved, labor intensity and input will be reduced, energies saved for the change of mode of labor and reduction of irrigation water, so the produc-

tion cost will be reduced, and economic benefits improved.

(c) Increasing yield and profit.

According to relevant experiments and investigation data of the county, and also research fruits of the provincial water conservancy research institute, the projects will increase the profit by 32 420 yuan per year for the increasing yield, as Table 3 shows.

Per capita arable land in Lixin County is 1.24 mu, so there will be 290 000 people benefiting from the projects, and per capita income increase will be 1 117 yuan. Taking the whole county population into consideration, per capita income increase will be 225 yuan.

Table 3 Yield and profit increase of efficient water-saving irrigation in Lixin County

| Irrigation mode and crop | Planting area// mu | Profit increase per mu// yuan | Total profit increase yuan |
|---|--------------------|-------------------------------|----------------------------|
| Open field grape, drip irrigation | 12 000 | 1000 | 12 000 000 |
| Greenhouse vegetables (melons and fruits) drip irrigation | 38 000 | 1500 | 57 000 000 |
| Herbs, spray irrigation | 100 000 | 800 | 80 000 000 |
| Open field vegetables, spray irrigation | 210 000 | 800 | 168 000 000 |
| Total | 360 000 | | 324 200 000 |

Lixin County belongs to north China planting area, sharing coefficient of irrigation benefit is calculated as 0.5, so after the completion of projects, annual direct irrigation benefit $B = 324 200 000 \times 0.5 + 720 = 169 300 000$ yuan.

(d) Social benefits and ecological environment benefits.

① Application of advanced irrigation techniques and agricultural means of production can improve working conditions, reduce labor intensity and quantity, improve production quality and productivity, promote agricultural industrialization and rural economy.

② Popularization of efficient water-saving techniques and measures saves water resources and water cost, improves agricultural water supply and water price formation mechanism, benefits peasants, improves contract management mechanism in rural areas, and also promotes the development of rural economy.

③ Popularization of efficient water-saving techniques and measures reflects the importance attached to water conservancy construction by government, and also the support to new country-side construction from water resources and financial departments, strengthens the link between government and people, and stability of rural society.

④ Application of advanced water-saving irrigation techniques saves water resources, reduces application of fertilizer and pesticide, reduces non-point water pollution and concentration of toxic substances in soil, reduces penetration of water and nutrition loss, water logging damages, facilitates the improvement of crop

growth environment, and stable, high-yield and high-quality production.

⑤ Application of efficient water-saving irrigation reduces the utilization of groundwater, facilitates the protection and development of water environment, water and soil resources, so it is significant for improving ecological environment, and facilitating the sustainable utilization of water and soil resources.

4.3 National economy evaluation

① Evaluation support and major parameters: according to *Economic Evaluation Methods and Parameters of Construction Projects* (3rd ed.) issued by State Planning Commission (current National Development and Promotion Commission) and the Ministry of Water Resources in 2006, and *Economic Evaluation Standards of Water Conservancy Projects* (SL 72-94) issued by the Ministry of Water Resources, prior and post construction conditions are compared to evaluate national economy. The projects will make profits in the same year of their completion, and operation period of the projects is supposed as 15 years, social discount rate 12%, datum point of the discount is the beginning of the first year of the construction period, all costs and profits are calculated at the end of the year.

② Project cost. Static total investment is evaluated as 398 million yuan. Annual operation cost of project includes all costs for normal operation every year, and suppose the rate is 5%, the cost is 19.9 million yuan, and is input from the first year of normal operation.

③ Project profit. After the completion and operation of the projects, annual direct profit of irrigation is 169.3 million yuan.

④ Economic evaluation. Economic benefits evaluation indexes are given as below:

Benefit - cost ratio

$$R = \frac{(1+i)^n - 1}{i(i+1)} \times \frac{B - C}{K} = 2.55.$$

Investment recovery period (TD)

$$T = \frac{\lg(B - C) - \lg(B - C - i \times K)}{\lg(1+i)} = 3.4 \text{ years, suppose it is 4 years. Internal rate of return (IRR)}$$

Internal rate of return (IRR)

$$\frac{I(1+I)n}{(1+I)^n - 1} = \frac{B - C}{K}, IRR = 37.2\%.$$

The net present value is 618.8 million yuan, > 0 .

5 Conclusions

According to the above analysis, potential efficient water-saving irrigation area is 240 km² in Lixin County by 2015, considering only cash crops. Even if all cash crop production uses efficient water-saving irrigation, the saved water consumption is still less than the forecasted water deficit under the guarantee rate of 75% (11.0 million m³) in 2015. Thus, efficient water-saving irrigation should be further promoted in the production of field crops. By 2020, water deficit under the guarantee rate of 75% will achieve 42 million m³, so it is imperative to promote water-saving irrigation.

growth. Especially with the rising prices of rice and corn currently, on the one hand, it improves the farmers' enthusiasm for growing grain; on the other hand, it poses new challenges to the comprehensive grain production capacity.

Since the efficacy of food crops is mainly to meet the most basic needs of life, it is necessary to increase farmers' income based on meeting consumer demand. Therefore, we should promote market-oriented development of food crops, on the basis of meeting the basic needs of food consumption.

3.2 Rationally making overall arrangement of planting structure So, to develop both the staple food crops and the food crops with high added value, it is necessary to conduct planting of the growing regions, based on the principles of intensification, optimization and reasonableness. Meanwhile, different industrial structures are often directly related to some advantages, and varying advantages are an important factor influencing the formation and changes of the industrial structure of agriculture from the perspective of supply^[3].

The interaction of supply and demand requires us to rationally adjust the cultivation proportion of food crops while strengthening production capacity, based on the comparative advantages for production in various regions, such as concentrating advantages to develop the main producing areas of potatoes, rice and corn.

3.3 Paying attention to the agricultural science and technology progress In the above two points, whether it is to increase production capacity, or lay out the planting structure, it is inseparable from the progress of agricultural science and technology, and whether the quality of agriculture and rural economy can be fundamentally improved hinges in a large measure on the scientific and technological support. The progress of agricultural science and technology is the main driving force for one region to carry out transformation of traditional agriculture, and promote the transformation and upgrading of agricultural institutions toward high-class and modern structure. Increasing the technology content from the source of production means a high starting point for the farmers to

increase income. The production of food crops is low added value industry in the traditional sense, so we must develop agriculture by applying scientific and technological advances, and actively play the role of agricultural research and technology promotion in enhancing the development of agricultural production, and improving the agricultural restructuring.

For a long time, the food production in Yunnan Province is self-sufficient with low commercialization rate. Although the cultivation proportion of food crops in Yunnan Province has reached more than 70% and tended to be stable, the food is still unable to meet demand, and the prices still constantly rise. So it is necessary to focus on agricultural science and technology from the internal cultivation structure of food, to improve the commercialization of food, and conduct reasonable adjustment on the basis of high proportion planting currently. Based on the above analysis, it is necessary to continue to develop agricultural science and technology according to the principle of ensuring food security, strengthen the food production capacity, and adjust the planting proportion of rice, corn and potato based on the comparative advantages of local production.

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According to the static benefit analysis, benefit-cost ratio for applying efficient water-saving irrigation for the 240 - km² arable land is 2.55, investment recovery period is 4 years, internal rate of return is 37.2%, the net present value is 618.8 million yuan, beneficiaries will achieve 290 000, and per capita income increase 1 117 yuan. The above data show the outstanding economic benefits, social and economic benefits of efficient water-saving irrigation. Therefore, if financial capacity allows, increasing the input in efficient water-saving irrigation will bring remarkable economic, social and ecological benefits.

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