

Calculation and Analysis of Effective Utilization Coefficients of Farmland Irrigation Water in Guizhou Province

Haikuan Wu¹, Meiyun An^{2,*}, Changjun Cai³

^{1,2,3}Guizhou Provincial Water Conservancy Research Institute, Guiyang, Guizhou, China

Abstract. Effective utilization coefficient of farmland irrigation water is an important index for water-saving level evaluation. Tracked calculation of effective utilization coefficients of farmland irrigation water as well as quantitative and qualitative analyses in terms of its scientificity and rationality have a guiding role in sustainable development of water-saving irrigation. This paper sets out to calculate the effective utilization coefficients of farmland irrigation water in Guizhou Province in 2019 and evaluate rationality of the results. More than that, some internal factors influencing utilization coefficients are also investigated, and relevant proposals are put forward, in a view to providing technical support for water-saving irrigation planning and scientific water distribution.

1 Introduction

Since 2006, Guizhou Province has started to calculate and analyze the effective utilization coefficients of farmland irrigation water. Relevant results have served as important basis for evaluation of water-saving farmland irrigation work as well as relevant policy making and planning by local authorities across the province. In recent years, since water resources utilization problems have been increasingly pressing with continuous economic growth in China, the strictest ever water resources management system has been introduced. In this system, raising efficient utilization coefficients of farmland irrigation water is one of the evaluation indicators of “Three Red Lines”. In this sense, calculating and analyzing the effective utilization coefficients of farmland irrigation water is an important move to implement the strictest water resources management system, and it also has great guiding significance in water-saving farmland irrigation.

2 Overall situation of farmland irrigation

Guizhou Province located on the Yunnan-Guizhou Plateau is the only province without plain support in China. It has a complex landform which is highly mountainous and even the quite limited farmland is also mostly slope cropland. Based on this topography characterized by mountains, water conservancy projects in Guizhou Province are mainly deployed with small watershed [1] where irrigation areas are scattered and mainly small and medium-sized. Across the province, there is no irrigation area with an independent irrigation water supply serving an area more than 300,000 mu (1 mu \approx 666.67 m²). According to figures, in 2019, the actual irrigated area across the province is 15.1736

million mu [2], 2.3955 million mu for medium-sized irrigation areas and 12.7781 million mu for small-sized irrigation areas. The total irrigation water consumption across the province is 5.8517512 billion m³, 988.5421 million m³ for medium-sized irrigation areas and 4.8632092 billion m³ for small-sized irrigation areas. The area covered by water-saving irrigation projects of this province in 2019 totals 4.3649 million mu, with RMB 238 million invested to implement water-saving projects in medium-sized irrigation areas, RMB 1.037 billion in small-sized irrigation areas. New water-saving irrigated area reaches 218,620 mu.

3 Calculation and analysis of effective utilization coefficients of farmland irrigation water

3.1 Selection of sample irrigation areas

Based on the principle and requirements on selection of sample irrigation areas Instructions on Technical Guidance for Calculation and Analysis of Effective Utilization Coefficients of Farmland Irrigation Water across the Nation (hereinafter referred to as Instructions) [3], as well as the real situation of irrigation areas in Guizhou, 150 sample irrigation areas, among 118 medium-sized irrigation areas and 16994 small-sized irrigation areas across the whole province, are selected for tracked measurements. Since there is no medium-sized water-lifting irrigation areas in Guizhou Province, all selected irrigation areas are artesian water irrigation areas. Among them, there are 28 medium-sized irrigation areas, accounting for 23.7% of the total number of irrigation areas in the province. This proportion is far higher than 5%. The effective irrigated area of sample

*Corresponding author: 284978381@qq.com

irrigation areas is 454,600 mu, which is 17.16% of effective irrigated area of medium-sized irrigation areas across the province. This figure is above 10%. The number of small-sized irrigation areas is 122 (including 26 sample water-lifting irrigation areas and 96 sample artesian water irrigation areas), of which the effective irrigation area is 301,100 mu. This number takes up 0.72% of all irrigation areas of the same size, while the effective irrigation area accounts for 1.93% of that of irrigation areas of the same size (see Table 1). It is apparent that all indicators for sample irrigation areas safely satisfy relevant requirements as stated in the Instructions.

Table 1. Selected Sample Irrigation areas in 2019.

Irrigation district scale	Irrigation	Number of irrigated areas		Effective irrigated area (10,000 mu)	
		Total	sample irrigation areas	Total	Sample irrigation area
Medium-sized irrigation areas (total)	artesian water	118	28	264.90	45.46
Small-sized Irrigation areas	water-lifting	165	26	60.752	4.37
small-sized irrigation areas (total)	artesian water	16829	96	1499.023	25.74

3.2 Calculation of effective utilization coefficients

Calculation and analysis of effective utilization coefficients of irrigation water in Guizhou Province are done in strict accordance with the Instructions. All calculations are based on the end-to-end method. See the formulas for calculating effective utilization coefficients of sample irrigation areas, irrigation areas of all sizes and all irrigation areas in the province as follows:

$$\eta_s = W_{sn} / W_{sg} \quad (1)$$

Type:

η_s —effective utilization coefficient of irrigation water in sample irrigation areas;

W_{sn} —net irrigation water consumption in sample irrigation areas, m^3 ;

W_{sg} —gross irrigation water consumption in sample irrigation areas, m^3 .

$$\eta_m = (\eta_{1-5} \cdot W_{g1-5} + \eta_{5-15} \cdot W_{g5-15} + \eta_{15-30} \cdot W_{g15-30}) / (W_{g1-5} + W_{g5-15} + W_{g15-30}) \quad (2)$$

Type:

η_m —effective utilization coefficient of irrigation water in medium-sized irrigation areas of the province;

η_{1-5} , η_{5-15} , η_{15-30} —effective utilization coefficient of irrigation water in sample irrigation areas of 3 different sizes: 10,000~50,000 mu, 50,000~150,000 mu and 150,000~300,000 mu;

W_{g1-5} , W_{g5-15} , W_{g15-30} —annual irrigation water consumption (10,000 m^3) of irrigation areas of 3 different sizes: 10,000~50,000 mu, 50,000~150,000 mu and 150,000~300,000 mu.

$$\eta_i = (1/n) \cdot \sum (\eta_{si})_{i=1 \sim n} \quad (3)$$

Type:

η_i —effective utilization coefficient of irrigation water in small-sized irrigation areas of the province;

η_{si} —effective utilization coefficient of irrigation water in the small-sized sample irrigation areas of the province;

n —number of small-sized sample irrigation areas of the province.

Effective utilization coefficients of irrigation water cross the province can be calculated based on the average effective utilization coefficient of irrigation water in irrigation areas of all sizes and total gross irrigation water consumption across the province in 2019.

$$\eta_t = (\eta_m \cdot W_m + \eta_i \cdot W_i) / (W_m + W_i) \quad (4)$$

Type:

W_m , W_i —gross irrigation water consumption of medium-sized, small-sized irrigation areas of the province, 10,000 m^3 ;

η_m , η_i —effective utilization coefficients of irrigation water in medium-sized, small-sized irrigation areas of the province.

See consumptions and effective utilization coefficients of irrigation water in irrigation areas of all sizes across the province in 2019 in Table 2.

Table 2. Calculation of effective utilization coefficients.

Irrigation district scale	gross irrigation water consumption (10,000 m^3)	Effective utilization coefficients of irrigation water
Medium-sized irrigation areas	98854.2	0.4715
small-sized irrigation areas	486320.92	0.4809
total	585175.12	0.4793

4 Analysis on rationality of effective utilization coefficients of farmland irrigation water

4.1 Analysis on rationality of effective utilization coefficients of farmland irrigation water in irrigation areas of all sizes

Since there is no large-scale irrigation area or irrigation area with only motor-pumped wells, only small and medium-sized irrigation areas are selected. According to the calculated coefficients for 2019, effective utilization coefficients of farmland irrigation water in medium-sized irrigation areas is 0.4715, while this figure for small-sized irrigation areas is 0.4809, higher than the former by 0.0094. Similarly, according to comparisons between effective utilization coefficients of farmland irrigation in irrigation areas of all sizes during the past 5 years and between effective utilization coefficients of irrigation areas of the same size during the past years (see Fig.1), coefficient of small-sized irrigation areas is higher than that of medium-sized irrigation areas, and coefficient of small and medium-sized irrigation areas in

current year is also higher than that in the previous year. A fact to be noted here is large water losses during delivery associated with a large number of canal systems and long canal lines in medium-sized irrigation areas despite the fact that the local government has been investing increasingly in improving irrigation area building over the past few years. Obviously, this leads to higher consumption of irrigation water, reducing the effective utilization coefficients. In this sense, the variation tendency of effective utilization coefficient of irrigation water in irrigation areas of all sizes is basically reasonable.

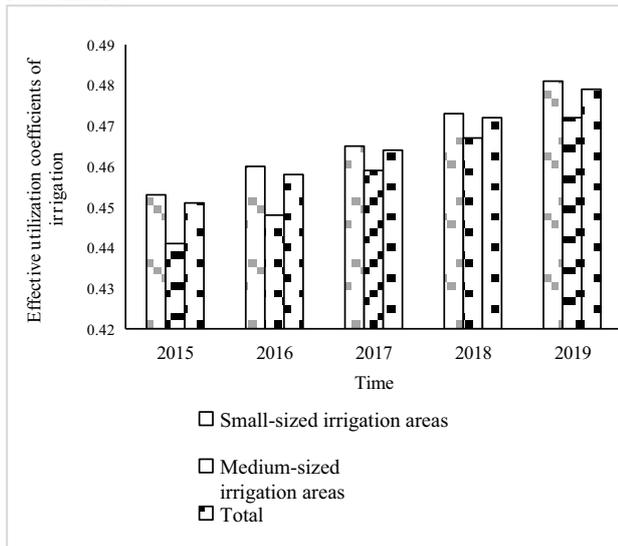


Figure 1. Annual effective utilization coefficient of irrigation water in irrigation areas of all sizes.

4.2 Analysis on rationality of effective utilization coefficients of farmland irrigation water across the province

In terms of calculation of effective utilization coefficients of farmland irrigation water in Guizhou Province in 2019, the selection of sample irrigation areas and typical farm fields takes also natural conditions as well project status, project scale, management level, irrigation technologies and agrotypes in irrigation areas into account. This ensures good representativeness and typicality. More than that, rigid inspection and double check for all water measuring facilities in sample irrigation areas are also conducted to reduce errors and ensure more accurate measurements. In addition, among the 150 sample irrigation areas selected in 2019, there are 28 medium-sized irrigation areas, accounting for 23.7% of the total number of irrigation areas. This is far higher than 5%. The number of small-sized irrigation areas is 122, taking up a proportion of 0.72%, also higher than 0.5%. All this means that the calculated net irrigation quota for farm fields is more reasonable. The methods and formulas used to do such calculations are exactly the same as those specified in the Instructions. For example, calculations of annual gross irrigation water consumption and annual net irrigation water consumption. In this sense, both calculation methods and measurement indicators ensure good rationality of the measuring results.

5 Analysis on influence factors of effective utilization coefficients of farmland irrigation water

5.1 Analysis on effect of investments on effective utilization coefficients of farmland irrigation water

Among medium-sized irrigation areas selected in 2019, the irrigated ground area of seepage-proofing canals in irrigation areas with a scale of 10,000-50,000 mu registers 146,300 mu. Investments in improving irrigation areas of all types in 2019 totals RMB 41.5 million. The irrigated ground area of seepage-proofing canals in sample medium-sized irrigation areas with a scale of 50,000-150,000 mu is 58,000 mu. In 2019, there is no investment in water-saving projects. The irrigated ground area of seepage-proofing canals in sample small-sized irrigation areas reaches 86,800 mu, and the total investments in improving irrigation areas in 2019 is RMB 34.542 million. With the capital invested in water-saving projects of irrigation areas in 2019 taken into consideration, it can be seen that such investments did contribute to the rise of effective utilization coefficients of irrigation water in Guizhou Province. Seepage-proofing improvements of channel works in irrigation areas greatly reduces water losses during delivery and raise the effective utilization coefficients. Effective utilization coefficient of irrigation water in irrigation areas of all sizes.

5.2 Analysis on effect of rainfalls on effective utilization coefficients of farmland irrigation water

Located on the Yunnan-Guizhou Plateau, Guizhou Province boasts of abundant rainfalls, but this is not evenly distributed among different areas. An analysis on rainfall frequency for counties where sample irrigation areas cover within the province shows that rice growth duration mainly falls in normal water, and the rainfall frequency is between 38.6%~61.2%. However, rainfalls are not well distributed across the province, which means that there are less rainfalls than needed in high water demand seasons and more rainfalls than needed while crops have low water demand. As a result, waterfalls that are not utilized flow into underground rivers, lowering the overall amount of effectively used water. In 2019 alone, water consumed for farmland irrigation stands at 58.51751 trillion m³, an increase of 2.991373 trillion m³ compared to that of the year before. In short, the effective utilization coefficients of farmland irrigation water witnessed a slight rise.

5.3 Analysis on effect of management on effective utilization coefficients of farmland irrigation water

Enhancing management of irrigation areas is an effective way to raise the effective utilization coefficients of

farmland irrigation water[4-5].Scientific water distribution and “scientific storage-based” irrigation regime as formulated according to crop-growing seasons helps a lot in increasing water utilization efficiency. For small-sized irrigation areas with relatively lower effective utilization coefficients of irrigation water and less management experience, in particular, strengthening water management and raising water-saving awareness among agricultural water users in irrigation areas can significantly improve the effective utilization coefficients of irrigation water in small and medium-sized irrigation areas, so as to increase the overall coefficient across the province.

5.4 Analysis on effect of adjustments to sample irrigation areas on effective utilization coefficients of farmland irrigation water

In line with the economic restructuring and planting structure adjustments in Guizhou Province during the last few years, proper adjustments were also made for selection of sample irrigation areas according to the principle of “More addition and less subtraction, gradually tending to normal”. The goal is to fit the planting structure in this province. Such adjustments, on the one hand, make sure that the sample irrigation areas cover not only all major grain producing areas across the province, but also cover areas of water-saving projects recently invested by the local government; on the other hand, the calculated effective utilization coefficients of farmland irrigation water helps better reflect the existing situation of all irrigation areas within the province and also the economic benefits of increased capital investments by the provincial government in irrigation areas. In this sense, it also helps raise the coefficient by adding typical sample irrigation areas while reducing those with less representativeness.

6 Conclusions and Suggestions

Calculation and analysis of effective utilization coefficients of farmland irrigation water in Guizhou Province in 2019 show that the effective utilization coefficient is determined by multiple factors, both objective factors and human factors. However, as to how to raise the coefficient in a scientific and reasonable manner while ensuring reliability and accuracy of relevant data, all regions should adapt their own solutions to local situations and make sure the solutions are technically feasible and economically reasonable. Take Guizhou for example, based on the current situation of irrigation areas in this province as well as a summary on local experiences and an objective analysis of major principal contradictions, the following proposals are put forward to raise the coefficient:

6.1 Project measures

To increase water delivery efficiency and utilization rate by boosting investments in building small and medium-sized irrigation areas, lifting the seepage-proofing rate of

canals for water delivery in irrigation areas and reducing irrigation water leakage.

6.2 Management actions

To raise the effective utilization coefficients of irrigation water by strengthening reasonable allocation of water resources in irrigation areas, setting reasonable agricultural water pricing policies and raising water-saving awareness among users through better publicity of water-saving knowledge.

6.3 Technical solutions

To raise the effective utilization coefficients of irrigation water by demonstrating and promoting water-saving programs such as controlled rice irrigation and non-sufficient irrigation for dry crops while enhancing technical guidance and demonstration trainings.

Acknowledgements

This paper is finished with great capital support from the Scientific Research Fund of Guizhou Province, KT201819.

References

1. Wang Yang, China Water, speed up efforts to solve the problem of engineering water shortage in poor areas and lay a solid foundation for the development of water conservancy in Guizhou in the new era,24,73(2017)
2. Guizhou Provincial Water Conservancy Research Institute, Report on the calculation and analysis of effective Utilization coefficient of farmland Irrigation water in Guizhou Province in 2019, (2019)
3. Department of Agriculture and Water Resources of Ministry of Water Resources, Instructions on Technical Guidance for Calculation and Analysis of Effective Utilization Coefficients of Farmland Irrigation Water across the Nation,4-24, (2015)
4. Han Zhenzhong.et, China Water, Calculation and analysis of effective utilization coefficient of irrigation water,3,11-14, (2009)
5. Fen Bao qing, Water Saving Irrigation, Analysis on the characteristics and influencing factors of effective utilization coefficient of irrigation water in different regions of China,6,29-33, (2013).