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Analysis of Agricultural Water Pricing Cost Estimation in Irrigation Districts: A Case Study of the Shangpu Gate Irrigation District

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Abstract: The management of irrigation district water pricing is a critical aspect of water price administration, playing a significant role in enhancing the management of water fees and accelerating water fee reforms. Standardizing the cost estimation of irrigation district water pricing allows pricing authorities to accurately understand the true costs, identify discrepancies between current prices and cost-based prices, and provide a reliable basis for governmental pricing decisions. Through accounting, the full-cost water price for agricultural water use in the Shangpu Sluice Irrigation Area, including fixed asset depreciation, major repair costs, engineering maintenance costs, and public expenses, is 0.159 yuan/m³, and the operation and maintenance cost water price is 0.128 yuan/m³.The results provide a reference for the agricultural water pricing mechanism in the Shangpu Gate Irrigation District.

1. Introduction

The cost accounting of agricultural water pricing is a crucial prerequisite for setting agricultural water prices. Effective accounting of agricultural water supply costs plays an important role in advancing comprehensive reforms in agricultural water pricing. Establishing a scientific water pricing mechanism to form control and dynamic price adjustment mechanisms is beneficial for promoting agricultural water price reforms[1]. Conducting water supply cost accounting and proposing a suggested water price that reflects the operation and maintenance costs of irrigation districts serve as a basis for pricing authorities to approve[2] . Dinar's research[3] found that agricultural water pricing significantly impacts agricultural water consumption, and adjusting agricultural water prices can control water use to achieve water conservation. Ghassemi and White[4], in their study on inter-regional water transfer pricing methods in Canada, combined cost pricing and affordability pricing methods. They comprehensively considered the total cost of water supply, the users' ability to pay, and their willingness to pay, encouraging public participation in the pricing process to maximize cooperation with water users and achieve sustainable water resource utilization.

Currently, the water price accounting methods used by domestic scholars mainly include the marginal cost method, the planned pricing method, and the cost accounting method. Most of the current accounting for water prices of hydraulic engineering supplies and urban tap water adopts the cost accounting method[5]. Wu[6] summarized the water pricing systems of several foreign countries and the policies, regulations, standards, and methods of water fee collection in China. He analyzed the shortcomings of the current water pricing system in China and, considering China's economic development status, suggested that full-cost accounting should primarily be used for agricultural water pricing. Yu[7] theoretically explored the value and pricing of water resources, deducing the full-cost pricing method for agricultural irrigation water. He then conducted a rational analysis of irrigation water pricing using externality theory and performed an empirical analysis of the irrigation water price in the Tongshanyuan Reservoir Irrigation District in Quzhou City. In exploring the comprehensive benefits arising from the adjustment of agricultural comprehensive water price reforms, Lu's research[7] found that within a certain range, the operational capacity of irrigation districts gradually increases with the rise in agricultural water prices, while the water consumption in irrigation districts gradually decreases.

Agricultural water pricing has been operating at low costs for an extended period, resulting in a lack of water conservation awareness among users[8]. Consequently, the potential for efficient utilization of water resources and agricultural water savings in irrigation districts has not been fully realized. Based on this, this paper conducts water price estimation for the Shangpu Gate Irrigation District through processes such as sample surveys, itemized verification, and comprehensive estimation. The estimation results can serve as a reference for similar irrigation districts.

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2. Estimation Methodology

The pricing of agricultural water is determined based on the principle of compensating for the costs and expenses of water supply production, excluding profits and taxes. The assets, costs, and expenses of water conservancy projects should be reasonably allocated and categorized for compensation among various uses such as water supply, power generation, and flood control. According to relevant regulations, such as the *Water Conservancy Project Water Supply Pricing Calculation Standard*, the water supply price of water conservancy projects is divided into operation and maintenance (O&M) cost water price and full cost water price. Therefore, estimating the agricultural water price in irrigation districts involves calculating the depreciation of fixed assets, major repair costs of fixed assets, maintenance and repair costs of projects, labor costs of water supply, and public expenses of water supply.

The depreciation and major repair costs of fixed assets mainly include the depreciation and major repair costs of irrigation district channels, canal structures, water source projects allocated to the irrigation district, supporting equipment, and information technology projects.

(1) Depreciation cost:

Given the actual situation of water conservancy projects in Zhejiang Province, the estimation of fixed asset depreciation cost adopts the straight-line depreciation method. This method assumes that the value of fixed assets is transferred uniformly to the product over its useful life, meaning the book value of the fixed assets decreases linearly over time. The calculation formula is as follows:

$$\mathrm{D_p} = \frac{K - V_s}{n}, \quad (1)$$

where $\mathrm{D_p}$ is the depreciation cost of fixed assets, K is the original value of the fixed assets, $\mathrm{V_s}$ is the residual value of the fixed assets, and n is the useful life.

(2) Major repair cost:

The annual extraction of major repair costs is calculated similarly to depreciation cost by extracting a certain proportion of the original value of fixed assets annually. The calculation formula is as follows:

$$\mathrm{R_p} = \mathrm{K} \times \delta, \quad (2)$$

where R_p is the annual major repair cost, K is the original value of the fixed assets, and δ is the major repair rate.

The depreciation rate and major repair rate are determined based on the engineering grade of canal structures and water source projects, referring to the “Depreciation Rate and Major Repair Rate Table for Water Conservancy Project Water Supply Parts.” Reasonable engineering useful life is determined, thus obtaining the annual basic depreciation rate and the annual average major repair rate.

(3) Engineering maintenance and repair costs:

According to the *Standards for Water Conservancy Project Maintenance and Repair Quotas* issued by the Ministry of Water Resources and the Ministry of Finance in October 2004, in tandem with the *Standards for Water Conservancy Project Maintenance and Repair Quotas of Zhejiang Province* (2018), maintenance and repair costs for channel projects and canal structures in irrigation districts are calculated item by item. First, based on the designed flow rate, project scale, etc., of the irrigation district, the basic maintenance and repair grade is determined according to the *Standards for Water Conservancy Project Maintenance and Repair Quotas of Zhejiang Province* (2018), and the corresponding itemized maintenance and repair content and quota values are identified. Second, adjustment coefficients for each itemized maintenance and repair content are determined, primarily including the designed lifespan adjustment coefficient and the designed flow rate adjustment coefficient. Each itemized maintenance and repair content cost is then calculated by multiplying the quota value by these adjustment coefficients. Third, the total maintenance and repair cost is obtained by summing the costs of all individual maintenance and repair items. The main engineering maintenance and repair cost calculation formulas are as follows:

(a) Calculation formula for maintenance and repair cost of channels

$$■(Q = A * M * N * P * R + B * M * S * P * R + C * M * P * R, \# \quad (3)$$

where Q is the total maintenance and repair cost of the channel project; M is the designed flow rate adjustment coefficient of the channel; N is the road surface adjustment coefficient of the canal top; S is the channel adjustment coefficient; P is the lifespan adjustment coefficient; R is the length of the channel, with the base unit being km; A is the quota for earthwork maintenance for the corresponding grade; B is the quota for the repair of damaged masonry for the corresponding grade; C is the quota for the maintenance and repair of the anti-seepage engineering project for the corresponding grade.

(b) Calculation formula for maintenance and repair cost of inverted siphon

$$■(Q = A * M * N * S * P + B * M * N * S * P + C * M * N * S * P, \# \quad (4)$$

where Q is the total maintenance and repair cost of the channel project; M is the designed flow rate adjustment coefficient of the inverted siphon; N is the structure adjustment coefficient of the inverted siphon; S is the length adjustment coefficient of the inverted siphon, with the base unit being 100 m; P is the lifespan adjustment coefficient; A is the quota for handling concrete erosion, cavitation, and wear for the corresponding grade; B is the quota for surface crack treatment for the corresponding grade; C is the quota for maintenance and repair of water stops and expansion joints for the corresponding grade.

(c) Calculation formula for maintenance and repair cost of tunnels

$$Q = A * M * N * P + B * M * N * P + C * M * N * P, (5)$$

where Q represents the total maintenance and repair cost of the tunnel engineering; M stands for the tunnel design flow rate adjustment coefficient; N represents the tunnel length adjustment coefficient, with the base unit being 100m; P is the usage lifespan adjustment coefficient; A denotes the quota for concrete erosion, cavitation, and wear treatment project corresponding to its grade; B

represents the quota for surface crack treatment project corresponding to its grade; C stands for the quota for maintenance and repair of water stops and expansion joints corresponding to its grade.

(d) Calculation formula for maintenance and repair costs of sluice gates

$$Q = A * P * T * U + B * M * N * O * S * T + C * N * O * R * U + D * U + E * N * O, \quad (6)$$

where Q represents the total maintenance and repair cost of the sluice gate engineering; M is the adjustment coefficient for the sluice gate opening area; N stands for the adjustment coefficient for the number of sluice gate openings; O is the adjustment coefficient for the net width of the sluice gate opening; P represents the adjustment coefficient for the design flow rate of the sluice gate; R is the adjustment coefficient for the type of sluice gate opening and closing mechanism; S represents the adjustment coefficient for the type of sluice gate; T stands for the adjustment coefficient for the contact with the water body; U is the adjustment coefficient for the service life; A denotes the quota for maintenance and repair projects of hydraulic structures corresponding to their grades; B represents the quota for sluice gate projects corresponding to their grades; C stands for the quota for maintenance and repair projects of opening and closing mechanisms corresponding to their grades; D denotes the quota for maintenance and repair projects of electromechanical equipment corresponding to their grades; E represents the quota for material consumption projects corresponding to their grades.

(4) Common expenses for water supply

Common expenses for water supply refer to all consumable expenditures incurred by the irrigation district management unit in the current year for irrigation production, as well as various expenses incurred for organizing and managing professional and auxiliary matters. These expenses can be accounted for based on the actual expenses incurred in the previous year.

(5) Personnel expenses

Personnel expenses include employee salaries, trade union expenses, employee education expenses, housing provident fund, medical insurance premiums, endowment insurance premiums, unemployment insurance premiums, work-related injury insurance premiums, maternity insurance premiums, and other basic social insurance premiums. These expenses can be accounted for based on the actual expenses incurred in the previous year.

(6) Allocation coefficients

Irrigation district water supply projects have various comprehensive utilization functions such as flood control, drainage, and irrigation. To accurately calculate the cost of agricultural irrigation water supply, according to relevant regulations, various project expenditures and operating expenses should be reasonably allocated among these functions.

According to the “Regulations for Water Supply Price Calculation of Water Conservancy Projects (Trial Implementation),” water supply for irrigation purposes is divided into agricultural water supply and non-agricultural water supply. Shared assets and shared expenses for different water supply targets can be allocated using water supply guarantee rates. The specific allocation formula is as follows:

$$C = \frac{A \times A'}{A \times A' + B \times B'}, \quad (7)$$

where C is the allocation coefficient for agricultural water supply, A is the annual agricultural water supply volume; B is the annual non-agricultural water supply volume; A' is the agricultural water supply guarantee rate; B' is the non-agricultural water supply guarantee rate. Usually, A' and B' have the same value.

$$P = C' \times C, \quad (8)$$

where P denotes the agricultural water price, C' signifies the production cost of water supply in the irrigation district, and C represents the allocation coefficient for agricultural water supply.

The process of calculating the cost of agricultural water supply in an irrigation district involves several critical steps. It begins with the analysis of irrigation district water conservancy projects, gathering detailed information about the infrastructure and operations, and compiling this data into a comprehensive irrigation district project information table. Next, data on the volume of water diverted at the head of the irrigation district canal and agricultural water consumption is collected and analyzed. This is followed by a thorough expense analysis, which includes material and power expenses, employee salaries, management expenses, and other operational costs incurred by the irrigation district management unit. Maintenance and repair costs for water conservancy projects are then calculated in detail based on provincial standard quotas. Finally, all these various costs are totaled to calculate the price of agricultural water supply within the irrigation district.

3. Study Area

The Upper Putuo Gate Irrigation District has a designed irrigation area of 402,000 mu, with an effective irrigation area of 351,500 mu. Among these, the Yubei area covers 149,100 mu, the Forty Li River area covers 118,500 mu, and the Zhangzhen area covers 83,900 mu. The head of the irrigation district is equipped with a water diversion gate, with a designed water diversion flow of 50 m^3/s. The main canal extends from the water diversion gate to the northern end of the Baiguan urban area, where it connects to the Baixiong River canal in the Yubei Plain, with a total length of 13.6 km.

The scope of this cost calculation includes engineering managed by the irrigation district management unit, including one main canal, one siphon, one tunnel, 23 water gates, 16 production access bridges, and information technology and other projects (including vehicles, supporting factories and office facilities, general equipment, etc.). The water diversion volume for agricultural irrigation in the irrigation district is 30.9 million m^3. The management unit of the Upper Putuo Gate Irrigation District is the Upper Putuo Gate Operation and Management Center of Shangyu District Water Conservancy Bureau. It currently consists of offices, engineering management departments, and irrigation district offices, responsible for backbone engineering scheduling, operation and maintenance, engineering construction, and daily management tasks. Since 2008, water fees have not been collected in the Upper Putuo Gate Irrigation District, and fiscal transfers have been implemented. The Upper Putuo Gate currently employs 39 regular staff and 4 temporary staff. The management unit of the irrigation district belongs to the category of public welfare institutions, with funding fully provided by government appropriations.

4. Results Analysis

(1) Depreciation and major repair expenses

The fixed assets in the Upper Putuo Gate Irrigation District include canals, bridges, tunnels, water gates, and other hydraulic engineering structures, with supporting facilities such as vehicles, supporting factories and office facilities, general equipment, and specialized equipment. The specific calculation process is shown in Table 1 below.

Table 1: Calculation of Depreciation and Major Repair Expenses for Fixed Assets in the Upper Putuo Gate Irrigation District

Category	Engineering item	Original value (Yuan)	Fixed asset depreciation		Major repair for fixed asset	
			Depreciation rate	Depreciation expense (Yuan)	Major repair rate	Major repair expense (Yuan)
Canal engineering	Canal	24133200	2.50%	603330	1.50%	361998
Canal Structure	Bridges, tunnels, water gates, others	48449776	2.0%	981034	0.6%	268159
Supporting facilities and equipment	Vehicles, factories, office facilities, general and specialized equipment	5764015	3.4%	196775	1.3%	76262

(2) Results of various engineering calculations

Through calculations, the total maintenance and repair expenses for the irrigation area projects amount to 1.59 million yuan. Details of the maintenance and repair expenses for each project are shown in the table 2 below.

Table 2: Calculation Results of Maintenance and Repair Expenses for Irrigation Area Projects

Engineering item	Description	Quantity	Total length (m)	Subtotal (Yuan)
Channel engineering	Channel maintenance and repair	1	13600	110472
Inverted siphon engineering	Inverted siphon maintenance and repair	1	250	15388
Tunnel engineering	Tunnel maintenance and repair	1	367.7	39979
Sluice gate	Sluice gate maintenance and repair	23	/	1109462
Production access bridges	Road bridges, agricultural bridges	16	/	44533
Information technology	Maintenance of video surveillance systems, operation and management platform maintenance, metering facility maintenance, and other maintenance and repairs	4	/	75952
Others	Flood control equipment maintenance, production and management building maintenance, water surface cleaning, etc.	4	/	196140
Total				1591926

(3) Public water supply expenses: The actual public water supply expenses incurred in 2019 were 954,900 yuan, including office expenses, utilities, and other miscellaneous expenses.

(4) Labor Costs: The actual labor costs incurred in 2019 were 6,812,800 yuan.

The total full-cost water price for agricultural water supply in the Shangpu Sluice Irrigation Area was 11.85 million yuan, and the operating cost for water supply was 9.36 million yuan. The water intake in the Shangpu Sluice Irrigation Area was 74.47 million cubic meters, of which the supplied agricultural water volume was 30.90x10^6 m^3. Therefore, the agricultural water supply distribution coefficient was calculated as 0.415. Accordingly, the total production cost for agricultural water supply is 4.9166 million yuan, and the operating cost is 3.9589 million yuan. The agricultural irrigation water volume in the Shangpu Sluice Irrigation Area was 30.90 million cubic meters. The full-cost water price for agricultural water use in the irrigation area is 0.159 yuan/m^3, and the operating maintenance cost water price is 0.128 yuan/m^3.

5. Conclusion and Analysis

5.1 Conclusion

The cost of water supply in the irrigation district includes depreciation and major repair costs of fixed assets, engineering maintenance costs, and public expenses. The water price of the irrigation district management unit is determined by the management of irrigation projects by the irrigation district management unit and is the scope of this cost accounting. Conduct an inventory of irrigation district engineering information, such as the project directory, design flow, scale, and service life, to form the corresponding irrigation district engineering information table. This provides basic information for subsequent calculations of fixed asset depreciation, major repairs, and maintenance costs.

Through accounting, the full-cost water price for agricultural water use in the Shangpu Sluice Irrigation Area, including fixed asset depreciation, major repair costs, engineering maintenance costs, and public expenses, is 0.159 yuan/m³, and the operation and maintenance cost water price is 0.128 yuan/m³.

5.2 Recommendations

This study did not consider the psychological affordability of irrigation users in its accounting. Future research needs to delve deeper into the factors affecting the affordability of water prices for irrigation users to comprehensively determine the water price affordability for irrigation users in the district.

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References

1. Jeong D , Sesmero J P , Reeling C .Efficiency and Equity of Posted Price Markets for Irrigation Water[C]//2022 Annual Meeting, July 31-August 2, Anaheim, California.Agricultural and Applied Economics Association, 2022.
2. Huang Y , Wang S , Li X ,et al.Agricultural irrigation water price apportionment and sharing[J].Water policy, 2023(1/6):25.
3. Dinar A, 2003. Institutional Linkage, Transaction Cost and Water Institutional Reforms: Analytical Approaches and Cross-Country Evidence. Conference Institutional Water Management Institute. Paper h033035.
4. Ghassemi F, White I, 2007. Inter-Basin Water Transfer: Contents. On Academic. (12):261-294.
5. Li X , Engel B , Duan P ,et al.Developing an agricultural water pricing model considering both physical and virtual water: A case study of an irrigation district in China[J].Journal of Cleaner Production, 2022.DOI:10.1016/j.jclepro.2022.133043.
6. Wu W., Research on Water Price Accounting and Water Price System [D]. Hohai University, 2001.
7. Yu G, Research on Agricultural Irrigation Water Price in Irrigation Districts [D]. Zhejiang University, 2012.
8. Chebil A , Soula R , Souissi A ,et al.Efficiency, valuation, and pricing of irrigation water in northeastern Tunisia[J].Agricultural Water Management, 2022, 266.