

Research Article

Evaluating the Financial Viability of Irrigation and Drainage Projects Through Cost Recovery: A Case Study of Ahero Irrigation Scheme in Kenya

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Abstract

Irrigation plays a vital role in enhancing crop production yet many public irrigation schemes continue to face persistent financial challenges that undermine their long-term performance. Sustainable operation of irrigation and drainage systems rely on effective cost recovery mechanisms that ensure sufficient revenue is generated to meet the full cost of managing, operating, and maintaining irrigation and drainage infrastructure. It is important for the scheme's managers to understand how to make these systems sustainable by implementing effective cost recovery measures. This study evaluated the financial viability of irrigation and drainage projects through cost recovery using the Ahero Irrigation Scheme in Kenya as a case study. The research applied the cost recovery ratio to assess the extent to which the scheme was able to recover the irrigation and drainage expenses. The ratio was determined by dividing the annual operation and maintenance revenue collected from farmers by the annual irrigation and drainage costs incurred in service delivery. The calculated cost recovery ratio of 0.22 showed that the operation and maintenance revenue collected from farmers covered only 22% of the irrigation and drainage costs. The low cost recovery was mainly attributed to undercharged operation and maintenance revenue which was inadequate to cover the high irrigation and drainage cost. The energy cost emerged as the largest cost component in irrigation and drainage. The study highlighted the need to review and adjust operation and maintenance charges while also integrating solar energy systems to supplement or replace the costly electrical energy to reduce the energy cost.

Keywords

Cost Recovery in Irrigation, Operation and Maintenance Revenue, Operation and Maintenance Costs, Irrigation Water Charges, Irrigation Water Pricing, Irrigation and Drainage Costs, Financial Viability of Irrigation Schemes, Energy Cost in Irrigation

1. Introduction

Rainfed agriculture accounts for nearly 80% of cultivated land and produces about 60% of the world's food [1, 2]. Irrigated agriculture covers about 20% of cultivated land and contributes up to 40% of the global food output [1, 2]. From these

statistics irrigated agriculture has a big potential of increasing agricultural production to meet the food demand of the world's growing population. In Sub-Saharan Africa about 5% of cultivated land is irrigated which is far below what is

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needed to meet the rising demand for food [3, 4]. There is need to establish more irrigation schemes to meet the rising demand for food.

Irrigation schemes rely on irrigation and drainage systems to sustain crop production. These systems ensure that crops receive sufficient water to meet their needs while also removing excess irrigation water and wastewater from the scheme [5, 6]. The continuous maintenance of these systems is essential for them to function effectively [7, 8]. The operation and maintenance services carried out on these systems are usually recurrent. These services include; routine inspections, canal rehabilitation, pump operation, staff support, repairs, water supply, and energy supply [9, 10]. Irrigation water users usually pay operation and maintenance fee to sustain these activities [8, 11, 12].

The operation and maintenance revenue collected from water users serves two main purposes. The first is to cover irrigation and drainage costs and the second is to ensure water users use less irrigation water in crop production to prevent wastage [13]. The scheme's management commonly impose irrigation water charges using either area-based pricing or volumetric pricing methods. Area-based pricing method sets a fixed fee per unit of irrigated land regardless of the volume of irrigation water used [14]. Volumetric pricing approach charges farmers based on the actual volume of irrigation water they consumed [14]. Volumetric pricing is generally more effective for promoting irrigation water conservation and for applying fair and transparent charges. Volumetric pricing approach directly links payment to the volume of irrigation water used and provides stronger incentives for efficient irrigation water management [15].

The irrigation and drainage activities in many public schemes are financially unsustainable because the operation and maintenance revenue collected from water users who are the primary beneficiaries does not match the actual cost of service delivery [16, 17]. The collected revenue in some schemes is usually little because the operation and maintenance revenue is undercharged [18]. Some irrigation schemes employ unreliable revenue collection mechanisms resulting to partial revenue collection [13]. When the revenue collected is lower than the actual cost of offering irrigation and drainage services financial deficits emerge [19]. When irrigation schemes are unable to fully collect this revenue the irrigation and drainage infrastructure deteriorates, water supply becomes unreliable, and crop productivity declines [20]. This financial imbalance also increases dependency on government subsidies to sustain the cost of service delivery in irrigation and drainage [21].

Cost recovery refers to the extent to which the revenue collected from farmers is sufficient to cover the full cost of managing, operating, and maintaining irrigation and drainage infrastructure [22]. One of the key measures of cost recovery is the cost recovery ratio which assesses the economic performance and financial viability of projects [23]. The cost recovery ratio is calculated by dividing the value of the operation and maintenance revenue by the total value of the irrigation

and drainage cost [24]. A high cost recovery ratio demonstrates that a scheme can reliably fund its irrigation and drainage costs using internally generated revenue without relying on external subsidies. A low cost recovery ratio indicates financial vulnerability and unsustainability where irrigation and drainage expenses exceed the income collected as operation and maintenance revenue. Achieving effective cost recovery is essential for ensuring long-term system performance and sustainability [22].

Energy cost is one of the most significant components of irrigation and drainage expenditure particularly in irrigation schemes that rely on pumping to abstract or distribute irrigation water [25]. Pumping systems often operate continuously for long hours to deliver large volumes of irrigation water consuming substantial amounts of energy and resulting in high electricity and fuel expenses [26]. These costs are further magnified when pumps operate at low efficiencies requiring more energy than necessary to supply the needed irrigation water [27, 28]. Many irrigation schemes are increasingly exploring the use of solar energy for pumping to address the challenge of the high energy cost [29]. Pumping systems that are powered by solar can significantly reduce dependence on grid electricity and diesel lowering long-term energy costs especially in regions with high solar potential [30].

Irrigation and drainage systems in many public irrigation schemes continue to face financial constraints that limit their long-term performance and sustainability. It is therefore important for scheme managers to understand how to make these systems sustainable by identifying effective cost recovery mechanisms. While previous studies have examined the financial performance of irrigation projects limited attention has been given to scheme level cost recovery in public irrigation schemes in developing countries. This study aims to evaluate the financial viability of irrigation and drainage projects through cost recovery using the Ahero Irrigation Scheme in Kenya as a case study. The findings are expected to provide valuable insights to guide strategies for enhancing the financial sustainability of irrigation and drainage projects in irrigation schemes facing similar challenges as those of the Ahero Irrigation Scheme.

2. Research Methods

2.1. Study Area

The Ahero Irrigation Scheme is located in Kisumu County in western Kenya as shown in Figure 1. The scheme has a command area of about 2,183 acres. Rice is the main crop grown under irrigation. Water used in irrigation is abstracted from the River Nyando using four electrically driven pumps. The water is conveyed to the scheme through a network of earthen canals. The water flows in the earthen canals by gravity to the rice fields. The scheme is managed by the National Irrigation Authority (NIA). The farmers are organized and supported through the Irrigation Water User Associations

(WUAs). The scheme uses an area-based pricing method to collect operation and maintenance revenue where farmers are

charged according to the size of land cultivated rather than the volume of irrigation water consumed [31].

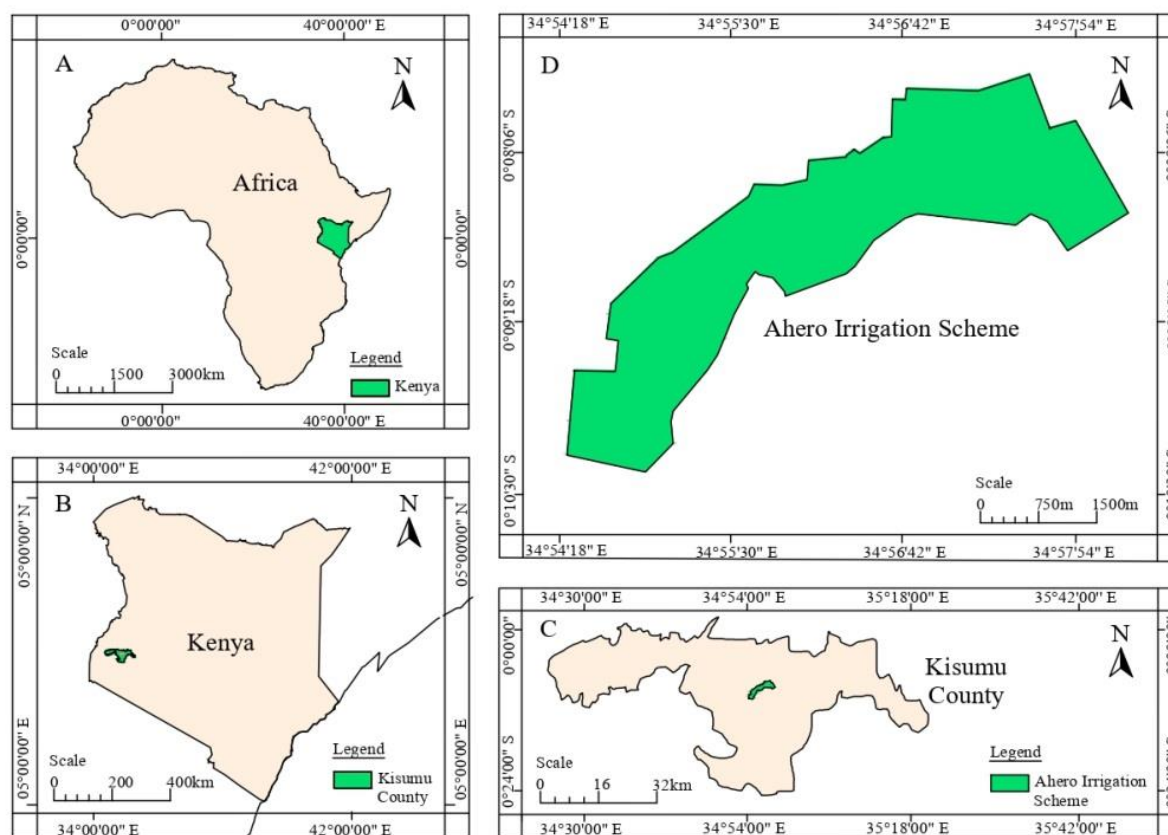


Figure 1. Geographical Location of Ahero Irrigation Scheme.

2.2. Irrigation and Drainage (I&D) Cost

The irrigation and drainage cost represented the operation and maintenance expenditure incurred by the scheme to supply water to the irrigated fields and to dispose excess or wastewater from the scheme after irrigation [9]. The components of this aggregate cost included; energy cost, water abstraction cost, maintenance cost, staff cost, and overhead costs [9, 10].

2.2.1. Energy Cost

The energy cost refers to the amount of money spent on electrical energy consumed in operating the four electric pumps that supplied irrigation water to the scheme [25, 26, 32]. The annual energy cost was determined by summing the electricity bill paid each month over a period of one year.

2.2.2. Water Abstraction Cost

Water abstraction cost refers to the fee paid by the scheme to the national water resources management authority in Kenya for drawing irrigation water from surface water sources

[33]. The fee charged was based on the volume of water abstracted from River Nyando. The annual water abstraction cost was calculated by multiplying the applicable volumetric water tariff by the total volume of irrigation water diverted into the scheme at the abstraction point.

2.2.3. Maintenance Cost

The maintenance cost refers to the expenditure incurred in rehabilitating and preserving the functionality of irrigation and drainage infrastructure [34]. These rehabilitation activities included; canal desilting, reshaping of earthen canal embankments, removal of aquatic weeds in the canal, repair of pumps, and restoration of water control structures [34]. The annual maintenance cost was determined by summing the total amount of money paid over one year to contractors engaged in carrying out these maintenance works within the scheme.

2.2.4. Staff Cost

The staff cost refers to the salaries paid to the scheme's personnel involved in offering irrigation and drainage services [9]. The staff directly involved in operation and management of irrigation and drainage infrastructure included; engineers,

technicians, pump attendants, water guards, and administrative personnel. The annual staff cost was computed by summing the monthly gross pay for all personnel for a period of twelve months.

2.2.5. Overhead Cost

The overhead cost represented the administrative and operational support expenses necessary for running the irrigation and drainage infrastructure. These costs included; office operations, communication, transport, insurance, and taxes [10]. The annual overhead cost was obtained by summing the monthly expenditures for a period of twelve months.

2.3. Operation and Maintenance (O&M) Revenue

The operation and maintenance revenue refers to the amount of money collected from farmers as irrigation service fees [35]. This revenue was intended to contribute to the cost of operating and maintaining the irrigation and drainage infrastructure [35]. The total annual operation and maintenance revenue was calculated by summing the monthly farmers' contributions over a period of twelve months.

2.4. Cost Recovery Ratio (CRR)

The cost recovery ratio was used to assess the financial viability of irrigation and drainage operations within the scheme [22, 23]. The cost recovery ratio was computed by dividing the total annual operation and maintenance revenue collected from farmers by the total annual irrigation and drainage cost incurred by the scheme as illustrated in Equation (1) [22, 23]. A cost recovery ratio below 1 indicates that the operation and maintenance revenue collected from farmers was insufficient to cover the total irrigation and drainage cost. A cost recovery

ratio above 1 indicates that the operation and maintenance revenue collected from farmers was sufficient to cover the total irrigation and drainage cost.

$$CRR = \frac{\text{O\&M Revenue}}{\text{I\&D Cost}} \quad (1)$$

3. Results

3.1. Computation of O&M Revenue and I&D Cost

The computation of operation and maintenance revenue and irrigation and drainage cost was based on the monthly financial data collected from the scheme for the period ranging between April 2022 and March 2023. The scheme collected a total of Ksh. 8,411,665 as operation and maintenance revenue as shown in Table 1. The irrigation and drainage cost consisted of five major cost components: water abstraction cost, staff cost, energy cost, maintenance cost, and overhead cost. The total annual irrigation and drainage cost was calculated and found to be Ksh. 37,926,398 as shown in Table 1.

3.2. Computation of Cost Recovery Ratio (CRR)

The cost recovery ratio was computed to assess the extent to which the operation and maintenance revenue collected from farmers was sufficient to cover the total irrigation and drainage cost incurred during the study period. The cost recovery ratio was determined using Equation (2). The values of operation and maintenance revenue and irrigation and drainage cost applied in this computation were obtained from Table 1. The cost recovery ratio was calculated and found to be 0.22.

$$CRR = \frac{8,411,665}{37,926,398} = 0.22 \quad (2)$$

Table 1. Operation and Maintenance Revenue and Irrigation and Drainage Cost.

No.	Month	Gross Revenue Collected	Irrigation and Drainage Cost				
			Water Abstraction Cost	Staff Cost	Energy Cost	Maintenance Cost	Overhead Cost
1.	April 2022	215,320		240,850	1,733,069		121,960
2.	May 2022	763,300		240,850	1,113,325		414,893
3.	Jun 2022	1,390,460		240,850	1,267,265		264,854
4.	Jul 2022	1,171,800	10,854,154	240,850	1,216,424	600,000	161,659
5.	Aug 2022	1,450,150		240,850	1,676,316		204,198
6.	Sep 2022	260,400		240,850	1,499,889		183,088
7.	Oct 2022	1,292,700		240,850	1,189,841		147,234

No.	Month	Gross Revenue Collected	Irrigation and Drainage Cost				Overhead Cost
			Water Abstraction Cost	Staff Cost	Energy Cost	Maintenance Cost	
8.	Nov 2022	1,271,425		240,850	1,783,796		493,098
9.	Dec 2022	85,000		240,850	2,588,382		134,623
10.	Jan 2023	272,110		240,850	2,557,879		205,021
11.	Feb 2023	211,100		240,850	2,461,463		115,578
12.	Mar 2023	27,900		240,850	1,659,426		288,400
Total			10,954,517	2,890,200	20,747,075	600,000	2,734,606
			37,926,398				

4. Discussion

A cost recovery ratio of 0.22 indicates that the operation and maintenance revenue collected from farmers covered only 22% of the total irrigation and drainage costs. The irrigation and drainage costs far exceeded the operation and maintenance revenue as illustrated in Figure 2. This shows that the scheme remained heavily dependent on government subsidies to sustain water delivery services. The low cost recovery ratio aligns

with observations from many irrigation schemes in Sub-Saharan Africa where water delivery fees rarely match the actual cost of service provision [36-38]. Similar findings have been reported in Ghana and Tanzania where low irrigation water charges failed to meet the cost of pumping, canal maintenance, and staffing [39, 40]. The low-cost recovery has also been reported in Indus Basin Irrigation System in South Asia in Pakistan where irrigation charges remain heavily subsidized and insufficient to meet the irrigation costs [41]. Under-pricing irrigation water charges undermines the long-term sustainability of irrigation systems [15].

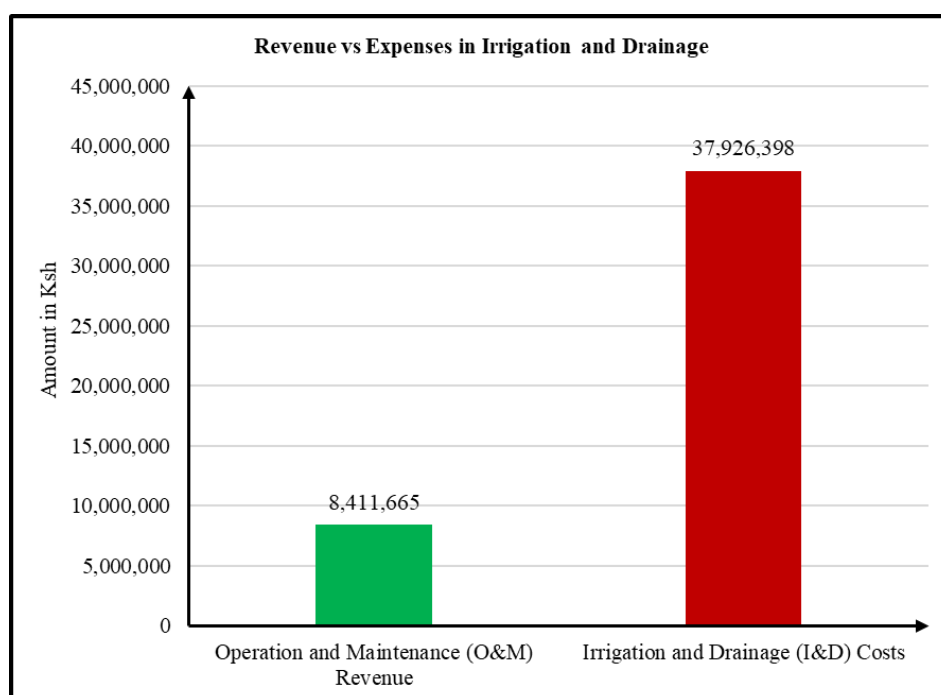


Figure 2. Revenue vs. Expenses in Irrigation and Drainage.

The amount of operation and maintenance revenue collected from farmers in Ahero Irrigation Scheme remained fixed because the charges were based on the size of land cultivated rather than the volume of irrigation water consumed. This area-based pricing approach did not reflect the fluctuating nature of the operational costs driven by variations in water abstraction volumes, energy consumption, maintenance needs, and overhead expenses. Irrigation schemes that use volumetric pricing method recover costs more accurately because the charges adjust with the actual volume of water used and the associated variable costs [42]. Irrigation projects in Shandong Province China routinely achieve close to 100% cost recovery due to the volumetric pricing approach and the effective revenue collection systems [13]. Evidence from Turkey in Kayacık Irrigation Scheme further shows that the volume-based pricing method led to higher cost recovery and improved irrigation service delivery [24]. The international best practice recommends full cost recovery to support effective system operation, routine maintenance, and long-term service delivery [35, 43].

The energy cost emerged as the largest cost component of the Ahero Irrigation Scheme as illustrated in the cost distribution pie chart in Figure 3. The high energy cost was due to the low efficiency of the four electrically driven pumps and the large volume of water abstracted to satisfy the water demand. Irrigation systems that use pumps commonly incur high electricity expenses and many studies confirm that pumping cost is one of the most significant barriers to financial sustainability in such schemes [44, 45]. Farmers in Bhakra irrigation scheme in India incur substantial pumping expenditures due to deep groundwater levels and aging pumps [46]. Kemubu Irrigation Project in Malaysia has high irrigation and drainage costs because of high pumping costs [44]. Bagarasi and Turkelli irrigation systems in Turkey have a challenge of financial sustainability because of high electricity expenses hindering the economic viability of the irrigation schemes [47]. The gravity irrigation systems typically achieve higher cost recovery because they avoid the cost of energy which results to lower irrigation and drainage costs [48, 49].

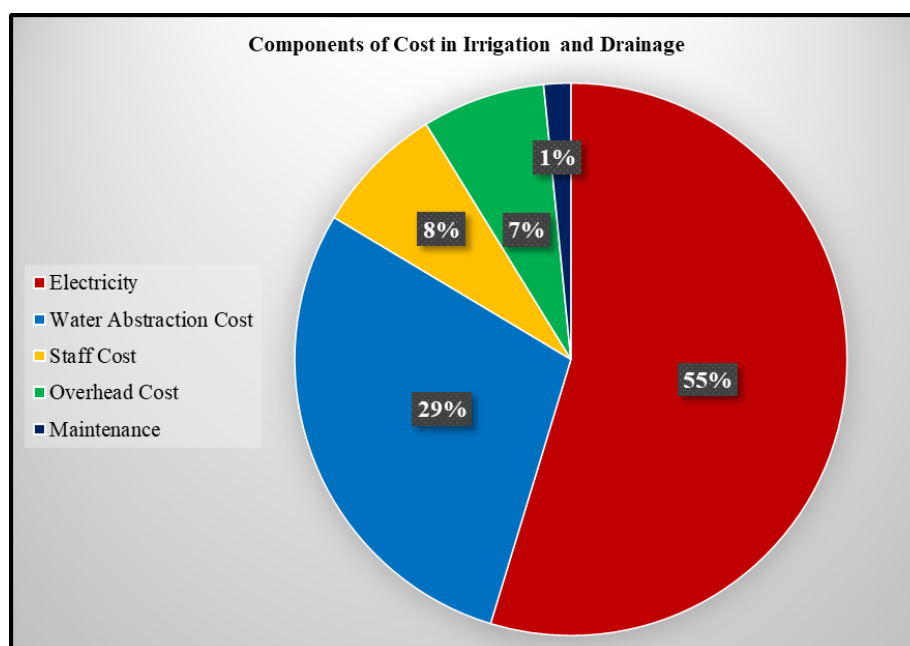


Figure 3. Components of Cost in Irrigation and Drainage.

The high cost of electricity makes solar energy a viable option for pumping irrigation water in Ahero Irrigation Scheme to lower the energy costs. Evidence from several countries demonstrates that solar irrigation systems substantially reduced pumping costs enhancing the economic viability of irrigation schemes [50, 51]. Studies in Spain show that pumps operated using solar energy in Valle Inferior irrigation system reduced energy costs thereby reducing the overall cost of irrigation service delivery [52]. Similar benefits have been documented in Philippines where large solar irrigation projects in

the provinces such as Rizal, Camarines Sur, and Laguna lowered irrigation costs while ensuring sustainable water supply [53]. The solar irrigation facility in Dinajpur in the northern part of Bangladesh reduced the energy cost lowering the overall costs of irrigation service delivery [54]. The introduction of solar energy to run the pumps in Ahero Irrigation Scheme would therefore help to reduce the financial burden of electricity costs incurred to operate the pumps.

5. Conclusion

The study established that Ahero Irrigation Scheme had a low cost recovery ratio of 0.22. The low cost recovery was mainly attributed to undercharged operation and maintenance revenue which was inadequate to cover the high irrigation and drainage cost. The energy cost emerged as the most significant cost component in irrigation and drainage expenditure.

6. Recommendations

The scheme should consider reviewing and adjusting the operation and maintenance charges to ensure that the revenue collected is sufficient to cover the actual cost of delivering irrigation and drainage services. The scheme should also work to reduce the high energy costs by integrating solar energy systems to supplement or replace the costly electrical energy currently used to operate the pumps.

Abbreviations

CRR	Cost Recovery Ratio
I&D	Irrigation and Drainage
O&M	Operation and Maintenance

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Author Contributions

Nickson Kenyoru Marita: Methodology, Data Curation, Formal Analysis, Writing – original draft, Writing – review & editing

Emmanuel Chessum Kipkorir: Conceptualization, Formal Analysis, Methodology, Supervision

Joel Kibiiy: Methodology, Formal Analysis, Supervision

Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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