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Research Article

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Unlocking Excellence: Khageri Irrigation System Benchmarking in Chitwan

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ABSTRACT

The objective of the study was to assess the present service delivery, financial and productivity indicators. The performance of five branch canals i.e. Branch Canal 1, Branch Canal 4, Branch Canal 6, Branch Canal 7 and Branch Canal 8 of the Khageri Irrigation System was evaluated for 2023 AD using fifteen performance indicators under water supply, financial performance and agricultural productivity categories suggested by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID). 331 farmers were interviewed in respective five branch canals from head, middle, and tail portions of the command area in order to get a representative sample. The data obtained from the interview was analysed and interpreted to calculate the values of the performance indicators. It was also found that the canal capacity and scheme infrastructure was not the limiting cause of this observation according to the calculation of water delivery capacity (1.08). The irrigation service fee charged was not sufficient to pay for the Operation and Maintenance (O&M) cost according to the calculation of revenue collection performance (0.5, 50%). Land productivity in this system was found to be unsatisfactory according to the calculations of output per unit command area (13084.76 Rs/ha), ouput per unit irrigated area (13216.93 Rs/ha) and output per unit irrigation supply (1.82 Rs/m3).

Keywords: Benchmarking, evaluation of performance, performance indicators, irrigation system

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Introduction

Water is a critical input for agricultural production and plays an important role in food security. Agriculture is the basis of life and a necessity for the world's food supply. The irrigation system is a fundamental part of agricultural production, which can be defined as "an assembly of equipment and facilities that distributes water to crops to increase yield". Agricultural irrigation systems help provide food to meet the growing demands of the global population.

Irrigated agriculture represents 20 percent of the total cultivated land and contributes 40 percent of the total food produced worldwide. Irrigated agriculture is, on average, at least twice as productive per unit of land as rainfed agriculture, thereby allowing for more production intensification and crop diversification. Due to population growth, urbanization, and climate change, competition for water resources is expected to increase, with a particular impact on agriculture. Population is expected to increase to over 10 billion by 2050, and whether urban or rural, this population will need food and fiber to meet its basic needs. Combined with the increased consumption of calories and more complex foods, which accompanies income growth in the developing world, it is estimated that agricultural production will need to expand by approximately 70% by 2050.

However, future demand on water by all sectors will require as much as 25 to 40% of water to be re-allocated from lower to higher productivity and employment activities, particularly in water stressed regions. In most cases, such reallocation is expected to come from agriculture due to its high share of water use. Currently, agriculture accounts (on average) for 70 percent of all freshwater withdrawals globally.

Resolving the challenges of the future requires a thorough reconsideration of how water is managed in the agricultural sector, and how it can be repositioned in the broader context of overall water resources management and water security. Moreover, irrigation and drainage schemes, whether large or small, represent prominent spatially dispersed public works in the rural spaces. Thereby, they represent a logical vehicle for mobilizing employment opportunities into communities. (Water in Agriculture, 2022)

Irrigation development is one of the most commonly practiced strategies to increase agricultural production, food security, rural livelihood, and rural development. However, food security issues in developing nations have always been aggravated by the rapid population growth and the consequent demand for food (Galkate, 2020). Some of the key challenges that categorise irrigation development in Nepal are old infrastructure and poor performances of the existing irrigation systems, poor system efficiency and under–utilisation of canal water, weak participation of Water Users Associations (WUAs), weak institutional capacity; weak linkages between agriculture and irrigation and continuation of subsistence agriculture practices in command area. Additionally, due to riparian issues, in Nepal, it has not been possible to tap the major river systems for irrigation development, which discharge substantial amount of water even during the dry season. Most of the irrigation systems are thus fed by medium or small rivers, which almost entirely depend on the rain. Moreover, water use efficiency and agricultural productivity remain low in both the traditional farmer-managed schemes and the large public irrigation systems (World Bank Group, 2014).

Irrigation benchmarking is a process of comparative analysis of irrigation performance that enables scheme managers to understand the performance of their irrigation services. To better understand the process of monitoring irrigation performance, this study will use Nepal as an illustrative example. Irrigated rice production in Chitwan has significant potential, yet performance of the sector lags behind surrounding countries, such as India and China. In addition, there are limited resources available and published data in Nepal, making it difficult to analyse the current and changing state of irrigation in the country, the productivity levels, or irrigation's contribution to poverty alleviation and economic growth. (Tucker, 2023)

The development in agricultural productivity is directly related with the sustainable development of irrigation system and practices. Without sustainability in irrigation system, the development in agriculture is impossible as irrigation and agriculture are interrelated to each other. To accelerate the agricultural productivity, development of irrigation project is necessary in parallel (Khadka, 2021).

Hence, the inefficient water use, sustainability and low crop productivity in Nepalese irrigation systems is a major concern. It is, therefore, necessary to periodically monitor and evaluate the performance of irrigation systems. In this regard, benchmarking in the irrigation sector has been identified as a suitable technique for proper monitoring and evaluating the performance of irrigation system. The general objective of this study is to develop and introduce a simple benchmarking approach by evaluating the performance of Khageri Irrigation System whereas the specific objectives are to assess the present service delivery, financial and productivity indicators and to create baseline data on the system performance, water delivery, financial and productivity status of Khageri Irrigation System.

The performance of the Khageri Irrigation System was evaluated using fifteen comparative indicators classified in three groups, Service Delivery, Financial Performance and Productive Efficiency suggested by the International Program for Technology and Research in Irrigation and Drainage (IPTRID).

This paper consists of four sections and is organised as follows: Section 1 gives a brief introduction about the importance of irrigation system in tackling the food security issues, general concept of irrigation benchmarking, research's general and specific objectives. The irrigation scheme that was chosen as the study area where the suggested benchmarking approach was applied is introduced in Section 2, which focuses on the materials and methods. Section 3 explains about discussions and results that were obtained in the study and Section 4 concludes the paper with conclusions, recommendations and future works with the concise message of the whole research paper.

Mishra and Dahal (2022); Mishra (2022); Dahal, Mishra & Aithal (2022a&b) have conducted research on the effects of design review on selected irrigation projects in the Dang Valley of Nepal. However, their studies do not directly address the application of SSP scenarios or the comprehensive assessment of irrigation system performance using the IPTRID indicators. This research gap presents an opportunity to contribute to the existing body of knowledge by providing a more detailed and up-to-date analysis of the Khageri Irrigation System's performance under different climate change scenarios.

By filling this research gap, the current study aims to offer valuable insights into the potential impacts of climate change on water availability and irrigation system performance in Nepal. The findings can inform policymakers and stakeholders in developing targeted adaptation strategies to ensure the long-term sustainability and resilience of irrigation systems in the face of climate change challenges.

Objective

The objective of this study was to assess the present service delivery, financial performance, and agricultural productivity of the Khageri Irrigation System in 2023 AD. The performance of five branch canals - Branch Canal 1, Branch Canal 4, Branch Canal 6, Branch Canal 7, and Branch Canal 8 - was evaluated using fifteen performance indicators suggested by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID). These indicators were categorized into water supply, financial performance, and agricultural productivity metrics to provide a comprehensive assessment of the irrigation system's efficiency and effectiveness in serving the local community.

Methodology

Study Area

The study was carried out in five branches i.e. Branch Canal 1, Branch Canal 4, Branch Canal

6 Eastern, Branch Canal 7 and Branch Canal 8 of Khageri Irrigation System. Khageri Irrigation System is one of the oldest gravity irrigation systems of Nepal located in Chitwan with a command area of 3900 ha. It is located at 27.630 North Latitude and 84.480 East Longitude. Major crops grown in the command area are Paddy, Wheat, Mustard and Lentils. The location map and network of canals are shown in Figure 1.

Research Design

In this study, quantitative approach was used since it measures and gives values to different type of performance indicators. The type of research design used was descriptive design since it describes the characteristics and effect of the values of the performance indicators. Random sampling technique was used to collect the representative sample which represents the population mean. Interview method was used to collect the data of the performance indicators.

Sample Size

The samplings for benchmarking indicators were done for the five branch canals i.e. Branch Canal 1, Branch Canal 4, Branch Canal 6 Eastern, Branch Canal 7 and Branch Canal 8. The two parameters; area and production were considered as normal distribution. Since, area and production for the five branch canals could be considered as normally distributed, random sampling technique was used to collect the representative sample which represents the population mean. For random sampling, Slovin's formula was used to estimate the sample size and stratified random sampling was used to randomly select the members from different branch canals. Slovins's formula is written as (Altares, 2003):

$$n = \frac{n}{(1+Ne2)} \quad \dots (1)$$

Where,

n = Number of samples,

N = Total population = 1934 (Source: KWUA, 2023)

Error margin/Margin of error (e) = 0.05

The sample size was calculated as 331.

Sample size distribution for different strata was calculated by using proportionate distribution and is shown in Table 1.

Figure 1

Map of Study Area (Source: Department of Survey, GoN, 2011)

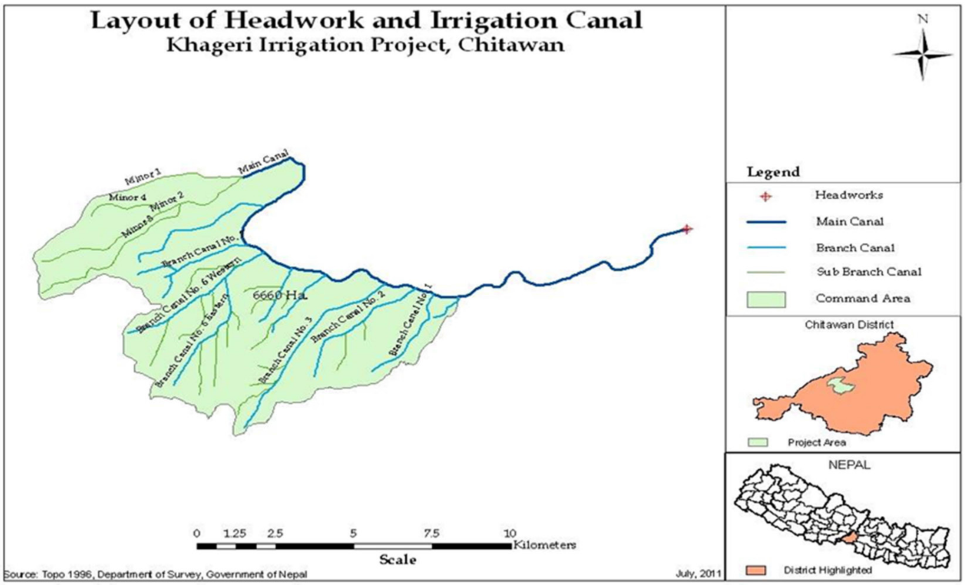

Table 1

Sample size Distribution for Different Strata (Source: KWUA, 2023)

S.N.	Description of Strata	Population Size (N)	Sample Size (n)
1	Branch Canal 1	N1 = 483	n1 = 82
2	Branch Canal 4	N2 = 295	n2 = 51
3	Branch Canal 6	N3 = 531	n3 = 90
4	Branch Canal 7	N4 = 329	n4 = 57
5	Branch Canal 8	N5 = 296	n5 = 51
	Total	N= 1934	n=331

Data Collection

The study involves significant data collection such as crop area of each crop in command, yield of each crop in command area, local price of each crop, command area, irrigated cropped area, , surface diversions, rainfall, irrigation supply, diverted irrigation supply, canal capacity to deliver water at system head.

331 farmers were interviewed in respective five branch canals i.e. Branch Canal 1, Branch Canal 4, Branch Canal 6 Eastern, Branch Canal 7 and Branch Canal 8 from head, middle, and tail portions of the command area in order to get a representative sample. The data obtained from the interview was analyzed and interpreted to calculate the values of the benchmarking indicators.

Data Analysis

Field data was first processed to obtain variables for calculating performance indicators.

The variables were computed as follows:

a) Crop water requirement

Crop pattern, transplanting date and weather data was used in calculating crop water demand and crop irrigation water requirement using CROPWAT 8.0 software (developed by FAO, Rome, Italy).

Computation of reference crop water demand (ETo) is based on the Penman Monteith equation.

The effective rainfall was computed using USDA-Soil Conservation Method, in-built in CROPWAT 8. Number of sunshine hours, temperature, humidity, rainfall data, wind speed, soil type, transplanting date and crop pattern were used as input for the model. The total volume of water consumed by all crops in the system was computed using the following equation (Malano, 2001):

"VET=∑" ("ET-Re")"*A" ………….. (2)

Where,

VET = Total volume of water consumed by crops less effective rainfall (m3);

ET = Crop evapotranspiration from planting to harvesting (m3);

Re= Effective rainfall over crop area from planting to harvest (m3);

A = Area planted to crop (ha)

b) Total seasonal volume of irrigation supply (m3)

The daily water flow level was measured with gauge readings installed at the head of main canal, which was later converted into daily discharge (m3/s) with the help of calibration sheet. The daily discharges were converted into daily delivery using the actual delivery time. The daily volume was calculated by multiplying the daily discharge with the delivery time. Hence, the total volume of water delivered was calculated by adding the monthly volume of water supply.

c) Total seasonal volume of irrigation water supplied in the branch canals (m3)

The average daily discharges were converted into daily delivery using the actual delivery time. The total volume of the delivery was computed for five branch canals using these average daily discharges to compute the total seasonal volume of irrigation water supplied in these branch canals.

d) Total seasonal irrigated cropped area (ha)

The area cultivated during monsoon and winter season i.e. Area of paddy, wheat, mustard, and lentils were obtained from the interview. The land area in hectare was calculated based on the payment provided by the farmers per unit hectare of their land in the respective branches.

e) Total command area of the system (ha)

This is the net area serviced by the scheme less the right of way for canals, drains, roads and villages. It was obtained from the related departmental office.

Performance Indicators

The performance indicators used were obtained from the IPTRID benchmarking indicators and fifteen performance indicators were computed as shown in Table 2.

Table 2

Computation of Performance Indicators (Malano, 2001)

Domain	Performance Indicators	Definition/Calculation
Service Delivery	Irrigation Water Supply per Unit Command Area	$\frac{\text{Total seasonal volume of irrigation supply}}{\text{Total command area of the system}}$
	Irrigation Water Supply per Unit Irrigated Area	$\frac{\text{Total seasonal volume of irrigation water supplied in branch canals}}{\text{Total seasonal irrigated crop area”}}$
	Relative Irrigation Supply	$\frac{\text{Total seasonal volume of irrigation supply}}{\text{Net Crop Water Requirement”}}$
	Water Delivery Capacity	$\frac{\text{Canal capacity to deliver water at system head}}{\text{Peak irrigation water consumptive demand}}$
Financial Performance	Cost Recovery Ratio	$\frac{\text{Gross revenue collected}}{\text{Total MOM cost}}$
	Maintenance Cost to Revenue Ratio	$\frac{\text{Maintenance cost}}{\text{Gross revenue collected}}$
	Total MOM Cost per Unit Irrigated Area	$\frac{\text{Total MOM cost}}{\text{Total command area}}$
	Total Cost per Person Employed	$\frac{\text{Total cost of personnel}}{\text{Total number of personnel}}$
	Revenue Collection Performance	$\frac{\text{Gross revenue collected}}{\text{Gross revenue invoiced}}$
	Staff Persons per Unit Irrigated Area	$\frac{\text{Total number of personnel}}{\text{Total command area}}$
	Total MOM Cost per Unit Volume Supplied	$\frac{\text{Total MOM cost}}{\text{Total seasonal volume of irrigation supply}}$

Domain	Performance Indicators	Definition/Calculation
	Average Revenue per Cubic Meter of Irrigation Water Supplied	$\frac{\text{Gross revenue collected}}{\text{Total seasonal volume of irrigation supply}}$
Productive Efficiency	Output per Unit Command Area	$\frac{\text{Total value of agricultural production}}{\text{Total command area of the system}}$
	Output per Unit Irrigated Area	$\frac{\text{Total value of agricultural production}}{\text{Total seasonal irrigated area}}$
	Output per unit irrigation supply	$\frac{\text{Total value of agricultural production}}{\text{Total seasonal volume of irrigation water supplied in branch canals}}$

Results and Discussion

Irrigation Water Supply per Unit Command Area (m3/ha)

Irrigation water supply per unit command area was found to be 7226.02 m3/ha. The quantity of water supplied per unit area varies with the availability of water, climate, soil type, cropping pattern, system conditions and system management. In Kenya, the annual water supply per unit command area varied between 2269 m3/ha (West Kano in 2014/2015) to 11,089 m3/ha (Bunyala , 2016/2017). The water supply per unit command area was 4389 m3/ha to 7586 m3/ha in Ahero, 2269 m3/ha to 8583 m3/ha in West Kano and 6050 m3/ha to 11,089 m3/ha in the Bunyala irrigation scheme. In the Susurluk river basin in Turkey, water supply per unit command area values varying from 1465 m3/ha to 13,086 m3/ha and values ranging from 2169 m3/ha to 22,098 m3/ha were obtained. A high amount of water was supplied to irrigation schemes in the Sursurluk basin because rainfall was limited during the irrigation period. (Muema, 2018)

Therefore, the value of 7226.02 m3/ha indicated that irrigation water supply per unit command area was not sufficient as compared to the irrigation schemes of Kenya and Turkey.

Irrigation Supply Per Unit Irrigated Area (m3/ha)

Irrigation water supply per unit irrigated area was found to be 7272.01 m3/ha. The research study performed in Kenya showed that the annual irrigation supply per unit irrigated area varied from 5294 m3/ha to 7785 m3/ha in Ahero; 11,238 m3/ha to 12,310 m3/ha in West Kano and 6285 m3/ha to 12,130 m3/ha in the Bunyala irrigation scheme. Considering low irrigation efficiencies associated with surface irrigation schemes, usually 30–40%, the irrigation supply per unit irrigated area was adequate in West Kano and Bunyala irrigation schemes. The Ahero irrigation scheme, on the other hand, supplied inadequate water, which was not enough to meet crop water needs. Irrigation supply per unit irrigated area values were relatively lower compared to the 22,029.43 m3/ha, 16,026.37 m3/ha, 11,289.10 m3/ha, and 9795.96 m3/ha obtained in MARIIS, Divisoria, Lucban and Garab irrigation projects, respectively, in the Cagayan river basin, Philippines. In southern Italy, high values ranging between 6500–14,900 m3/ha were reported by the Water Users' Association (WUA's) of Calabria. Values of 5578 m3/ha were obtained in sprinkler irrigation systems and 1084 m3/ha in drip irrigation systems in Castilla-La Mancha, Spain. Drip and sprinkler irrigation systems have high water application efficiencies of 75% and 90%, respectively. Surface irrigation systems, on the other hand, have a low irrigation efficiency of 60%. Therefore, more water was supplied in surface irrigation systems compared to sprinkler and drip irrigation systems. (Muema, 2018)

Hence, the value of 7272.01 m3/ha indicated that Khageri irrigation system supplied insufficient water, which was not enough to meet crop water needs compared to the above values of different irrigation systems.

Relative Irrigation Supply

Relative irrigation supply was found to be 0.19. It reflects that irrigation water supply was 0.19 times more than net crop water requirement at field. The RIS indicates whether crops are getting enough water and how canal irrigation supply and demand are matched. A value of RIS over one would suggest too much water is being supplied, possibly causing waterlogging and negatively impacting yields and a value less than 1 indicates that crops are not getting enough water. RIS relates supply to demand, and give some indication of water abundance or scarcity, and how tightly supply and demand are matched.

The value of more than 1.0 indicates that the irrigation supply by the canal is enough to meet the irrigation demand. In other irrigation projects, the relative irrigation supply value was found between 0.41 to 4.81 for eleven different countries, 1.55 for the Hayrabolu Irrigation Scheme in Turkey, 1.4 and 0.77 for Nura Era and Wonji estate of Ethiopia and 3.33 to 6.68 for Takez basin and the RIS Kalwande minor irrigation scheme was 1.27 (Galkate, 2020).

Therefore, the value of 0.19 indicated that the Khageri command area crops were not getting sufficient irrigation water and indicates water scarcity.

Water Delivery Capacity

Water delivery capacity was found to be 1.08. WDC is meant to give an indication of the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands. If this ratio is close to unity, then the management inputs must be effective. Value greater than one indicates that the canal capacity is not a constraint to meeting crop water demands (Galkate, 2020). It indicates additional capacity that will enable more flexible water deliveries. The water delivery capacity might recommend improvements in irrigation infrastructure or cropping patterns to maximize cropping intensity if irrigation system design is limiting agricultural productivity.

Therefore, the value of 1.08 indicated that the canal capacity was not a constraint to meeting crop water demands and there was no indication that irrigation infrastructure was constraining cropping intensities.

Financial Performance

Cost Recovery Ratio

It is the ratio of recovery of water charges to the cost of providing the service. It is imperative to devise water rates and mechanism for recovery of water charges for irrigation use in such a manner to meet, at least, annual cost of management, O & M of system and recovery of some portion of capital investment on the projects in order to make the system self-sustainable. Theoretically, the cost recovery ratio should be at least equal to one.

In India, Operation and maintenance cost recovery in irrigation was less than 5 % in the majority of the states (Reddy, 2009). The cost recovery ratio was found to be 0.02 (2%) which was far below 1 and 5%, making it very unacceptable. This means it needs financial support from supporting organization for repair and maintenance. The Khageri Irrigation System's WUA has not collected the Irrigation Service Fee (ISF) as gross revenue invoiced, according to the WUA record. So far in practice the collection of irrigation fees has become more important than the provision of irrigation service. It is critical that both fee collection and improved irrigation service be explicitly addressed. In principle, one of the strong advantages of an ISF program is that it can develop a direct relationship between fee collections and better O & M service (Sharma, 2010). ISF can be actually geared to the actual financial requirements for O & M in specific irrigation systems and can be implemented in such a way that there is a direct connection between payment of the fee and the provision of O & M service. In this case, better service means higher irrigation fees and collections. The relationship between irrigation fees and irrigation services assumes that there is mechanism for institutionalizing the fee-service relationship.

Maintenance Cost to Revenue Ratio

Maintenance cost to revenue ratio was found to be 60.43 which is greater than 1. If the ratio is less than 1, the project is regarded as maintenance budget sufficient project. Therefore, the project's maintenance expenditure was insufficient in comparison to the total revenue brought in. The WUA has been determined to have collected NRs. 200/Bigha/year in relation to the Irrigation Service Fee (ISF) according to its records. When compared to the expense of operation and maintenance, this sum was insignificant.

Total MOM Cost per Unit Irrigated Area (Rs/ha)

The MOM Cost per Unit Area of the project was found to be 3703.53 Rs/ha which is a satisfactory level. But it should be kept to a minimum. So, Care and ownership of the system should be taken so that MOM cost should be minimal.

In this study, Total MOM cost per unit irrigated area was calculated as Rs 3703.53 (28 US$) which was above the minimum average value of 4 US$ and below the maximum average value of 190 US$ (Cornish, 2005). This indicated that this value was satisfactory.

Total Cost per Person Employed (Rs/person)

The total cost per staff person employed was found to be 171869.6 Rs/person which was more for water allocation and distribution. It requires more financial burden in operation and maintenance of canal system. Hence, government has to increase high investment for the operation of the system in comparison to the yield.

In this study, total cost per staff person employed was calculated as 1322 US$ which was above the minimum average value of 600 US$ and below the maximum average value of 1745 US$ (Cornish, 2005). This indicated that this value was satisfactory.

Revenue Collection Performance

Revenue Collection Performance was found to be 0.5 which is less than 1. So, the project has to improve the fund raising level for operation and maintenance of the canal. The WUA Constitution has defined the roles and responsibility and renewal system as per governing Rules and Regulation and can be amended with general assembly. The average of three years total annual ISF collection amount was only NRs. 225000 out of the total NRs. 452000 invoiced. It is critical that both ISF collection and improved irrigation service be explicitly addressed.

In Kenya, revenue collection performance (RCP) values obtained were 85% in the Ahero irrigation scheme, 51% in the West Kano irrigation scheme, and 94% in the Bunyala irrigation scheme. Revenue collection performance values below 70% were considered unsatisfactory. The ideal desirable value should be close to 100%. De Alwis and Wijesekara obtained an ideal revenue collection performance of 100% in the Beypazarı Ba¸sören irrigation system, Turkey. Similarly, a RCP of 103% was recorded in the Karacabey irrigation scheme in Turkey. Values of RCP equal to or above 100% show that water users are willing to pay for the cost of irrigation. RCP values above 100% are possible to obtain due to payment of accumulated arrears. Low RCP values point out an unwillingness of farmers to pay water fees, poor organisation of the Irrigation Water Users Association, poor collection programs, and financial problems within the schemes (Muema, 2018).

Therefore, the value of 50% was considered unsatisfactory and needs to be improved.

Staff Persons per Unit Irrigated Area

In this study, Staff person per unit irrigated area was calculated as 3 persons which was below the minimum average value of 27 persons (Cornish, 2005). This indicated that this value was unsatisfactory.

Total MOM Cost per Unit Volume Supplied

The total MOM cost per unit volume supplied was found to be 512.53 NRs per 1000 cubic meter. In this study, Total MOM cost per unit volume irrigation supplied was calculated as 12.63 US cents which was above the maximum average value of 5 US cents (Cornish, 2005). Greater the value, lower the performance. Hence, performance was not satisfactory. So, MOM cost must be minimized.

Average Revenue per Cubic Meter of Irrigation Water Supplied

The value 7.98 NRs per 1000 cubic meter showed very less amount of revenue was collected from the irrigation facility. If the value is greater, performance is higher, but in this case, the value was lower so the performance was also low.

In Kenya, the average revenue per unit cubic meter varied from 0.79 to 1.26 US cents in the Ahero irrigation scheme, 0.35 to 0.44 US cents in the West Kano irrigation scheme, and 0.79 to 1.45 US cents in the Bunyala irrigation scheme. These values were below the economic value of irrigation water of 7.54 US cents per cubic meter obtained in the Ahero irrigation scheme. Pricing of water is an economic aid to improving water allocation and sustainable water utilization. The water fee charged was NRs. 200/Bigha/year in the Khageri irrigation scheme. The pricing was based on area cropped per farming season and not the quantity of water consumed. There was no limit to the quantity of water that a farmer can use. This explained why the value of water per cubic meter was below 1 US$. This is a weakness and is unsuitable in terms of efficiency of water use and water conservation (Muema, 2018).

In this study, average revenue per unit cubic meter was calculated as 0.19 US cents which was below the minimum average value of 0.26 cents.

Productive Efficiency

Output per Unit Command Area (Rs/ha)

A high value of Output per unit command area is an indication of intensive irrigation. Land productivity indicators give a reflection of crop intensity. In the analysis of Kotwal-Pillowa irrigation project, India, it was observed that the output per unit command area has increased 28,425 Rs/ha in the year 2013-14 and 51272 Rs/ha in the year 2015-16. This indicated that there was a need to develop command area and increase the cropped area in the Kotwal-Pillowa project (Galkate, 2020).

In this study, the Output per unit command area was calculated as Rs 13,084.76 which indicated that intensive irrigation was not practiced in this system.

Output per Unit Irrigated Area (Rs/ha)

A high value of Output per unit irrigated area is an indication of intensive irrigation. In the analysis of Kotwal-Pillowa irrigation project, India, it was observed that the Outputs per unit irrigated area was 13523 Rs/ha in the year 2005-06 and increased to 45220 Rs/ha in the year 2013-14 (Galkate, 2020). In this study, the Output per unit irrigated area was calculated as Rs. 13,216.93 which indicated that intensive irrigation was not practiced in this system.

Output per Unit Irrigation Supply (Rs/m3)

The output per unit irrigation supply puts into consideration the contribution of effective rainfall. In the analysis of Kotwal-Pillowa irrigation project, India, it was observed that the output per unit of irrigation supply varied between 1 to 7 Rs/m3 which indicated significant variation during the study periods. It was higher for the year 2015-16 due to less water consumed and high gross returns (Galkate, 2020).

In this study, the output per unit irrigation supply was calculated as Rs 1.82 which indicated that Khageri irrigation system does not utilize water efficiently and since, the value of agricultural production is the governing factor for output, high value cash crop and high yield crop may be used with changing cropping pattern in time. On the other hand, canal losses can be controlled by canal lining and applying water distribution system making field channel to field rather than field to field.

Conclusion

The evaluation of service delivery performance within the Khageri Irrigation System has revealed critical insights into the challenges facing irrigation management in the region. The analysis, based on four performance indicators, indicates a significant shortfall in the availability of irrigation water, which is insufficient to meet the demands of the agricultural sector. Specifically, calculations showed that the irrigation water supply per unit command area (7226.02 m^3/ha) and per unit irrigated area (7272.01 m^3/ha) were inadequate, resulting in a relative irrigation supply of only 0.19. This finding underscores the pressing need for improved water management practices to enhance the efficiency of water use in agriculture.

Interestingly, the study determined that the canal capacity and scheme infrastructure were not the limiting factors contributing to the water supply shortfall, as evidenced by the water delivery capacity calculation of 1.08. This suggests that the challenges lie not in the physical infrastructure but rather in the operational and management aspects of the irrigation system. Financially, the irrigation system demonstrated a lack of self-sufficiency, with a cost recovery ratio of merely 0.02 (2%). The irrigation service fees collected were insufficient to cover operational costs, as indicated by a revenue collection performance of 0.5 (50%). This financial inadequacy highlights the urgent need for a reassessment of the pricing structure and revenue generation strategies to ensure the sustainability of the irrigation system.

Moreover, land productivity metrics revealed unsatisfactory outcomes, with output per unit command area (13084.76 Rs/ha), output per unit irrigated area (13216.93 Rs/ha), and output per unit irrigation supply (1.82 Rs/m^3) indicating that the current agricultural practices are not yielding optimal results. This calls for a comprehensive review of crop production strategies, including alterations in cropping patterns and the implementation of soil improvement techniques to enhance agricultural productivity.

In light of these findings, several recommendations have been proposed to improve the performance of the Khageri Irrigation System. The Ministry of Water Supply, Energy and Irrigation (MoWSEI) in Bagmati Province should allocate adequate budgets for system rehabilitation, repair, and maintenance. Addressing issues such as silt deposition in canals and vegetation overgrowth is essential for ensuring the effective functioning of the irrigation infrastructure. Active participation from local communities in maintaining the canals can lead to improved system performance.

Furthermore, the collaboration between the Nepal Livestock and Khetar Irrigation Management Organization (NLKIMO) and Water Users Associations (WUA) should focus on decreasing the maintenance cost to revenue ratio. This can be achieved by reducing maintenance expenses while simultaneously increasing gross revenue collection, thereby enhancing the financial sustainability of the irrigation system.

For future studies, it is crucial to consider the sustainability of the irrigation system from an environmental perspective. Incorporating environmental performance indicators into the assessment framework will provide a more holistic understanding of the system's impact on local ecosystems and resource conservation. This approach will not only ensure the long-term viability of the irrigation infrastructure but also promote sustainable agricultural practices that align with environmental conservation goals.

The baseline data established through this study serves as a valuable resource for stakeholders involved in the management and improvement of the Khageri Irrigation System. By addressing the identified challenges and implementing the recommended strategies, it is possible to enhance the efficiency, financial viability, and productivity of the irrigation system, ultimately contributing to the sustainable development of agriculture in the region.

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