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Performance Assessment with Comparative Indicators in Irrigation Schemes: A Case Study of Bramhadev and Sheshnarayan Dakshinkali ISP

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Abstract
The performance of the Brahmadev Irrigation sub project (BISP), Kanchanpur and Sheshnarayan Dakshinkali Irrigation sub project (SDISP), Kathmandu district were assessed using selected comparative indicators grouped into agricultural, economic and water-use performance category. Based on the purpose of study the framework adopted was nested framework which incorporate interdependency of various fields like irrigation, agriculture, economy, social, environmental. The tools and techniques used to carry out the study was direct measurement of indicators. The evaluation involved various activities such as field observation, interviews with beneficiary farmers/WUA, and field measurements. The results of the evaluation indicate that the performance of the SDISP is better than BISP particularly in terms of land and water productivity but in terms of economy, BISP has shown better results. The analysis of water-use performance revealed that the relative water and relative irrigation supply values at BISP and SDISP were calculated as 13.09,110.5 and 1.29, 6.18 respectively, indicating that there is genuine amount of water supplied but water distribution was not adequately aligned with the water requirements of the crops. The economic performance indicators revealed a significant issue concerning the collection of water fees within the scheme at BISP whereas at SDISP there seems complete dependency of system on external help for any kind of maintenance work. Although gross return on investment at BISP showed system has good return on investment than at SDISP, there were challenges in both systems for effectively collecting fees for water usage highlighting the need for awareness to farmers on their physical and financial participation on system management for sustainable and efficient irrigation system.

Keywords
Irrigation, Across system, Performance, Comparative Indicator

1. Introduction

As the global population continues to grow at a significant rate, there is an increasing need to optimize land and water resource utilization more effectively and efficiently [1]. However, irrigation projects in developing countries often fall short of their potential, leading to widespread dissatisfaction due to suboptimal agricultural yields and irrigation efficiencies [2]. Assessing the performance of irrigated agriculture is a complex task, given the multitude of variables at play, such as infrastructure design, management practices, climatic conditions, input availability and pricing, and socioeconomic factors [3].

The development of irrigation performance evaluation concepts was represented and different frameworks were discussed. In order to assess and evaluate irrigation performance, several methods were developed and used. The main methods used to evaluate irrigation system performance are the Fuzzy set theory, direct measurements for indicators, Analysis Hierarchy Process (AHP), and Remote Sensing (RS) [4]. Previous efforts in irrigation performance assessment have primarily focused on internal processes within irrigation systems. Internal process indicators often relate to management targets such as water timing, duration, and flow rate, irrigated area, and cropping patterns. However, these internal indicators are not easily comparable across systems due to variations in irrigation processes and the data-intensive nature of the indicators. Furthermore, assumptions about the relationship between internal processes and outputs may not always hold true. While numerous indicators have been proposed to measure irrigation system performance, there have been limited examples of cross-system comparisons or comprehensive analyses [5]. The International Water Management Institute (IWMI) published and reviewed a set of 9 indicators of irrigation performance. The indicators have been widely field-tested and slightly amended, resulting in this present list. The intent of presenting this set of indicators is to allow for cross-system performance [6].

2. Study Area

In order to illustrate the potential use of irrigation performance indicators in evaluating efficiency of irrigation systems, two schemes respectively in terai (Brahmadev ISP, Kanchanpur) and hilly (Sheshnarayan Dakshinkali ISP, Kathmandu) terrain were considered.

The BISP is small irrigation project and SDISP is medium irrigation project as per classification based on size of command area in respective terrain [7]. The criteria for consideration of the two irrigation projects were based on the geographical location, size of system, availability of data and

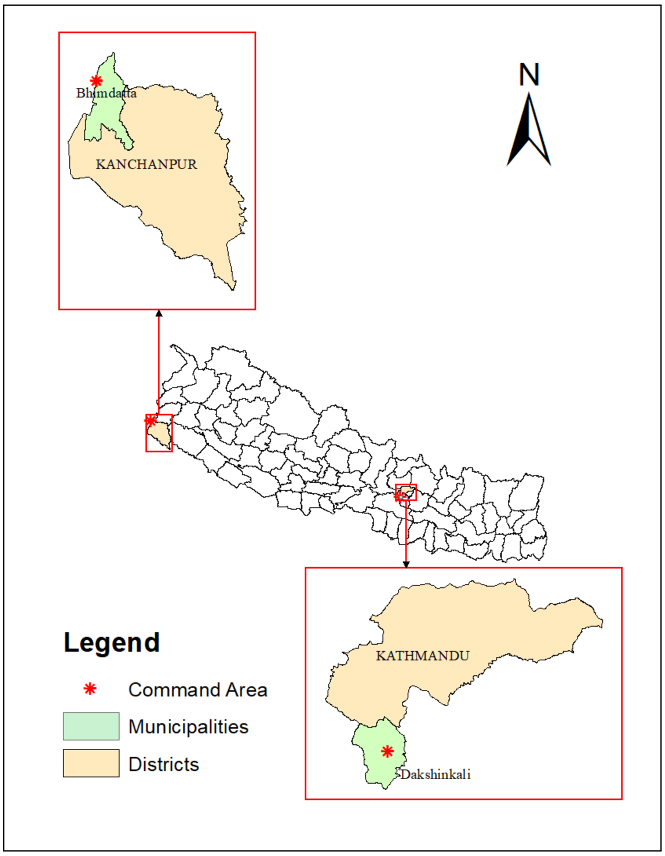

Figure 1: Study area

accessibility.The BISP area is located at Bhimdatta Municipality-9 of Kanchanpur District. The district headquarter is nearly 16 km far from the project site. The location of project is 29.067° latitude and 80.14° longitude with elevation of 312m above MSL. The road head to access project area is about 6km from Mahendra highway. The gross and net command area are about 150ha and 137ha respectively.

The intake of SDISP is located at longitude of 85.260 and latitude 27.610. The sub-project command area lies in Dakshinkali Municipality of Kathmandu district. The elevation of the area is about 1541 m above MSL. The subproject is at a distance of about 14.8 km from Balkhu. The gross and net command area are 34ha and 32ha respectively. The study area is shown in Figure 1.

3. Data and Methodology

The study involved evaluating the hydraulic, agricultural, and financial performance of the irrigation projects to gain firsthand information about how effectively the land and water resources were being utilized for agriculture. This research project utilized a nested system network approach, focusing exclusively on irrigation systems, irrigated agriculture, and agricultural economic systems within its defined scope. The study employed a direct measurement technique for assessing indicators and adhered to IWMI guidelines for evaluating performance indicators. The necessary parameters for calculating these performance indicators were either measured or gathered during the research following the steps shown in Figure 2

3.1 Data Collection

3.1.1 Climate data

The hydro-meteorological data for study projects were collected from DHM for the respective nearby and available stations. Precipitation, wind speed, humidity, temperature, sunshine hours data were collected and arranged in format compatible with CROPWAT.

3.1.2 Soil data

The type of soil in the command area of study projects were found from the NARC soil map with the help of coordinates of command area taken during field visit which was further verified from reports prepared by Agriculture knowledge center. The properties of type of site soil like total available soil moisture, maximum infiltration rate, maximum rooting depth, initial soil moisture depletion, as required for calculation of crop water requirement in CROPWAT modal, were taken from FAO.

3.1.3 Crop data

The data for type of crops, cropping area, their planting and harvesting time, yield, farmgate rate were collected through focus group discussion (WUA members). Crop coefficient value (Kc), root depth, stage, critical depletion, yield response, crop height data of crops were taken from FAO.

3.1.4 Financial data

The cost of irrigation infrastructure construction for both study projects were estimated after estimating quantity and doing rate analysis for F/Y 2078/79. As irrigation infrastructure, only conveyance system was considered as suggested by IWMI guideline. The data of revenue generated from ISF and O/M cost for the fiscal year 078/79 was collected from WUA and Water Resources and Irrigation Development Division of the respective study areas. Exchange rate of dollar to Nepalese rupees for the study year was obtained from NRB official site which was Rs 127.51=1$ [8]. The price of base crop(paddy) at international market was taken that of USA and from commodity market outlook (2 May 2023) published by WB.

3.2 Cropwat model

The data required for running the model were collected and formatted in CROPWAT compatible format. After complete input dataset, the model was run to get crop water requirement of different crops cultivated in study areas.

3.3 Calculations

The data required for running the model were collected and formatted in CROPWAT compatible format. After complete input dataset, the model was run to get crop water requirement of different crops cultivated in study areas.

1. Output per Cropped Area ($/ha)

$$= \frac{\text{Production}}{\text{Irrigated cropped area}}$$

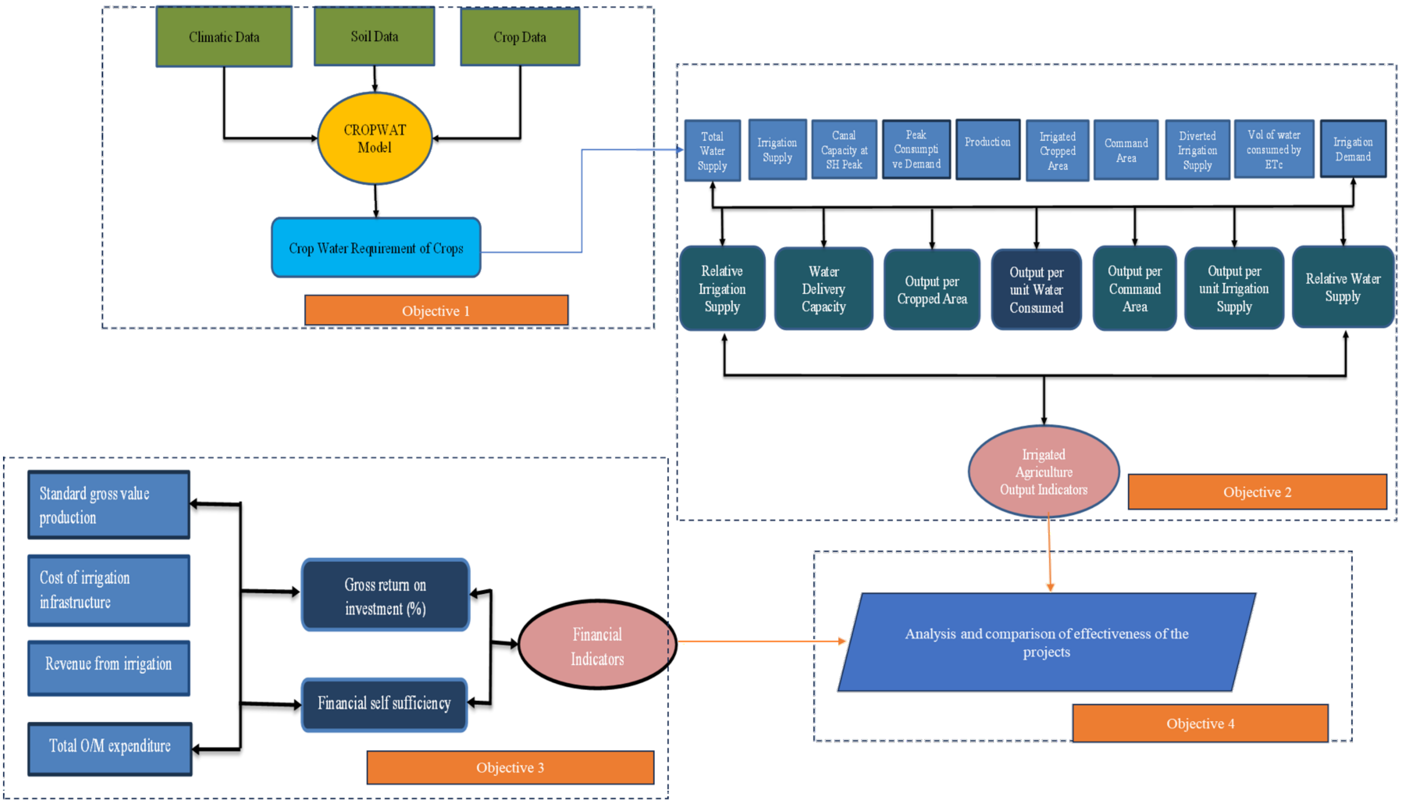

Figure 2: Methodological Framework

2. Output per Command Area ($/ha)

$$= \frac{\text{Production}}{\text{Command area}}$$

3. Output per Irrigation Supply (m^3)

$$= \frac{\text{Production}}{\text{Diverted irrigation supply}}$$

4. Output per Water Consumed(m^3)

$$= \frac{\text{Production}}{\text{Vol of water consumed by Et}}$$

5. Relative Water Supply (Ratio)

$$= \frac{\text{Total water supply}}{\text{Crop demand}}$$

6. Relative Irrigation Supply (Ratio)

$$= \frac{\text{Irrigation supply}}{\text{Irrigation demand}}$$

7. Water Delivery Capacity (Ratio)

$$= \frac{\text{Canal capacity to deliver water at system head}}{\text{Peak consumptive demand}}$$

8. Financial Self-Sufficiency (%)

$$= \frac{\text{Revenue from irrigation}}{\text{Total O/M expenditure}}$$

9. Gross Return on Investment(%)

$$= \frac{\text{SGVP}}{\text{Cost of irrigation infrastructure}}$$

To obtain SGVP, equivalent yield is calculated based on local prices of the crops grown, compared to the local price of the predominant, locally grown, internationally traded base crop. The second step is to value this equivalent production at world prices.

$$\text{SGVP(\$)} = \left(\sum Y_i \times \left(\frac{P_i}{P_b}\right) \times Ai\right) \times (P_{world})$$

where,
SGVP is the standardized gross value of production,
Y_i is the yield of crop i,
P_i is the local price of crop i,
P_{world} is the value of the base crop traded at world prices,
A_i is the area cropped with crop i, and
P_b is the local price of the base crop.

4. Result and Discussion

The value of various irrigated agricultural output and financial comparative parameters were obtained following IWMI guideline which are shown in Table 1.

Table 1: Value of Indicators

	Indicators	BISP	SDISP	Units
1.	Output per Cropped Area	652.12	3220.34	\$/ha
2.	Output per Command Area	1304.24	6440.67	\$/ha
3.	Output per Unit Irrigation Supply	0.004	0.18	$\$/m^3$
4.	Output per Unit Water Consumed	0.2	0.77	$\$/m^3$
5.	Relative Water Supply	13.09	1.29	ratio
6.	Relative Irrigation Supply	110.5	6.18	ratio
7.	Water Delivery Capacity	7.52	8.25	ratio
8.	Financial Self-Sufficiency	5.2	0	%
9.	Gross Return on Investment	245.14	165.22	%

The research compared two irrigation projects, BISP and SDISP, based on various performance indicators. Here are the key findings:

1. Output per Cropped Area: BISP had an output of $652.12 per hectare, while SDISP performed significantly better with $3220.34 per hectare, indicating that SDISP made better use of the command area, possibly by cultivating higher-value crops.

2. Output per Command Area: BISP had a lower value of $1304.24 per hectare compared to SDISP's $6440.67 per hectare, suggesting that BISP may have grown lower-income crops and underutilized the command area.

3. Output per Unit Irrigation Supply: BISP achieved $0.004 per cubic meter, whereas SDISP performed much better with $0.18 per cubic meter, indicating that SDISP was more efficient in utilizing irrigation water.

4. Output per Unit Water Consumed: BISP had a lower value of $0.2 per cubic meter compared to SDISP's $0.77 per cubic meter, suggesting that BISP's crops did not yield a satisfactory return in terms of water consumption.

5. Relative Water Supply (RWS): BISP had a high RWS value of 13.09, indicating an excessive supply of water compared to crop demand, possibly due to misconceptions among farmers. SDISP had a lower and more desirable RWS value of 1.29.

6. Relative Irrigation Supply (RIS): BISP had a high RIS value of 110.5, suggesting an overabundance of irrigation supply compared to demand. SDISP's RIS value was much lower at 6.18, indicating better water utilization.

7. Water Delivery Capacity Ratio: The system had a capacity ratio of 5.15, suggesting that it could meet peak crop water demands and had potential for command area expansion and changing cropping patterns.

8. Self-Sufficiency: BISP achieved a self-sufficiency level of 5.2 percent, indicating that its revenue fell significantly short of covering operation and maintenance expenses. SDISP had a self-sufficiency of 0, likely due to the absence of ISF collection.

9. Gross Return on Investment: BISP had a higher gross return on investment at 245.14 percent compared to SDISP's 165.22 percent, indicating better financial performance for BISP in terms of construction costs of conveyance system.

5. Conclusion

This study evaluated the performance of the Brahmadev irrigation project (BISP) and the Sheshnarayan Dakshinkali irrigation system project (SDISP) using comparative indicators. These indicators assessed the utilization of resources like land, water, agricultural and production. The key findings and comparisons between the two projects are as follows:

- SDISP outperformed BISP in terms of output per command/cropped area, attributed to higher crop yields and the cultivation of higher-value crops. Factors affecting yield included seed quality, fertilizer and pesticide availability, awareness of crop water requirements, weather conditions, and managerial aspects.

- SDISP demonstrated higher water productivity, with greater output per unit of water consumed and irrigated, indicating optimal water use and cultivation of high-value crops.

- Both projects satisfied crop water demands through irrigation and rain, with RWS values exceeding 1. BISP had a more generous water supply than SDISP.

- BISP had a significantly higher RIS value due to continuous water diversion, irrespective of crop water requirements. In contrast, SDISP supplies the irrigation water based on crop needs. However, BISP's production per unit of water supplied was lower.

- Both projects had sufficient infrastructure to meet peak water demands, offering room for command area expansion or changes in cropping patterns.

- BISP had a low financial self-sufficiency indicator but a high gross return on investment, possibly due to lower construction costs per unit of command area. SDISP had a financial self-sufficiency indicator of 0, relying entirely on external support for maintenance. To improve financial self-sufficiency, suggested solutions included institutional reforms for water management, accurate fee collection, timely fee payments, and strengthening Water User's Associations. Institutional reforms for efficient water management were deemed essential.

6. Future works

This study provides a starting point for evaluating irrigation systems in Nepal, demonstrating the application of IWMI-developed methods on two selected projects. While the limited sample size prevents an in-depth examination, with a sufficient number of samples, this methodology could potentially enable the establishment of benchmarks and objectives over time.Hence, performance assessment of numerous different irrigation systems with comparative indicators could be done by interested researchers in the future.

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