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Performance Evaluation of the Manu Barrage Irrigation Project

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Abstract
The Manu River Project is in the southern part of the North-Eastern Region of Bangladesh and covers the Maulvibazar sadar and Rajnagar upazila of Maulvibazar district. The area is bounded by the Kushyara River in the North; the Manu River on the South and West; the Vatera Hills on the East. The project area covers a gross area of 22,672 hectares with a cultivable area of 19,278 hectares and an irrigable area of 12,146 hectares.The main objective of the study was to evaluate the performance of the Manu Barrage irrigation project. Performance evaluation was carried out using hydraulic, agricultural, and socio-economic indicators. Data were collected from secondary and primary sources through a literature review, field visit, and questionnaire survey. In this study water level, discharge, and velocity near the barrage site were analyzed and evaluation of Irrigation Achievement, Irrigated Area Performance, Incremental Production, Delivery Performance Ratio, Total Financial Viability, Cropping Intensity, Crop water requirement, and Frequency analysis were done. In most cases, the results of this evaluation were satisfactory. In these evaluations, a software named CROPWAT 8.0 was used in addition to the necessary equation. From this study, it can be said that the project has been successful in a broader sense. Steps should be taken to ensure sufficient funds should be made available for the maintenance of all types of work on the project.

Keywords: *Manu River; irrigation; performance evaluation; Frequency Analysis; maintenance.*

1 Introduction

The Manu River Project is a multipurpose (flood control, drainage, and irrigation) project covering a gross area of 22,672 hectares with a cultivable area of 19,278 hectares and an irrigable area of 12,146 hectares. The project area covers low-lying Kawadighi haor and is bounded by the Kushiyara River on the north, the flashy Manu River on the South and west, and by the Vatera hills on the East. Flash floods of the Manu and Dhalai river due to severe rainfall in the Tripura hills of India inundated the area all of a sudden causing damage to the crops and congestion of water in low-lying areas for longer periods of the year was the barrier to production and cause sufferings to the people. Paddy is the main crop and people could harvest the crop rarely and most of the years damaged by the flash flood. There is a report of merely 485 hectares of cultivation with jute and 267 hectares with boro crops. The production rate was very poor and only 0.456 metric tons per hectare. Most of the area was single-cropped. Crop intensity was 126% and gross production was 26000 metric tons per year. People were left undone by nature and so was their dream to survive and uplift living standards.

The project was conceived to address the problem of safeguarding the crops from the flash flood and bringing the inundated area under cultivation through drainage following a feasibility-level study in 1962 and the final report in 1972. The implementation of the project started in 1975-76 and was completed in 1982-83. The main objective of the project was to increase agricultural production through supplementary irrigation along with flood control, drainage, and river training works and thereby create employment opportunities. The project also aimed to raise farmer's income, to active hydrological and ecological balance, and to improve the peoples living standards. The main objective of this study is to evaluate the irrigation performance of the Manu Barrage irrigation project.

2 Methodology

The process of performance evaluation of an irrigation project consists of especially measuring the extent to which goals are being met at the end of a given time and thus requires that all relevant inputs and outputs are quantified or evaluated (Raj et al., 2011). To evaluate and compare the performance of the project different performance indicators are used. Performance evaluation in this study was carried out using Hydraulic, Agricultural, and Socio-economic Indicators.

2.1 Hydraulic Indicators

Hydraulic indicators are concerned with the assessment of the water supply function of the conveyance system. They cover the volumetric component that is primarily concerned with supplies to crop demand (Saleh and Mondal, 2001). The hydraulic indicators used in the performance evaluation are water level, discharge, flow velocity analysis in the Barrage site, and delivery performance ratio.

2.2 Agricultural Indicators

Agricultural indicators measure the contribution of irrigation activity to the economy in relation to the consumption of the increasingly scarce resource, water. These indicators provide the basis for comparison of irrigated agricultural performance. The outputs (measured in terms of such aspects as area irrigated and crop production) of the major inputs (water, land, and finance) in an irrigated agricultural system are directly reflected by these indicators (Molden et al., 1998). The agricultural indicators used in the performance evaluation are irrigated area performance, cropping intensity performance, and production performance.

2.3 Socio-economic Indicators

The socio-economic indicators relate to the long-term impacts of operational and agricultural strategies. These indicators have been divided into three primary categories: those relatingto economic viability, those relating to social viability, and those associated with the sustainability of the physical environment for irrigation (Bos et al., 1993). Their main utility is to address concerns that may have greater value to policymakers than to irrigate system managers.The socio-economic indicators used in the performance evaluation are fee collection performance and total financial viability.

2.4 Data Collection

The data were collected from secondary sources and Primary sources. The data were collected from these two sources through field observation and questionnaire survey.

2.4.1 Primary Source

Primary data include target irrigation, target crop yield, target production, irrigation fees, operation and maintenance allocation and requirements, etc. A questionnaire was prepared, and the survey was conducted to collect data directly from the beneficiaries. Bangladesh Water Development Board, Moulvibazar involved in the conversation about the socio-economic aspects of the project and helped in giving information about crop patterns, crop production, cropping intensity, etc.

2.4.2 Secondary Source

Secondary data include temperature, relative humidity, wind speed, sunshine hours, rainfall, discharge, crop area, cropping pattern, crop yield, crop production, etc. These data were collected from Bangladesh Water Development Board (BWDB), Moulvibazar, Bangladesh Meteorological Department (BMD), and Water Resources Planning Organization (WARPO).

2.5 Data Analysis

The collected data were analyzed to determine the different indicators used in performance evaluation.

2.5.1 Analysis of Water level, Discharge and Velocity

For the analysis of Water level, Discharge and Velocity these data are collected from the BWDB, Moulvibazar. Then required table are inserted to show highest and lowest value of these data and make compare among them.

2.5.2 Computation of Delivery Performance Ratio (DPR)

Delivery Performance ratio (DPR) is the ratio of the actual discharge to the target discharge. For the computation of delivery performance ratio actual and target discharge are required. These data were collected from the BWDB, Moulvibazar and field visit. Then using the actual discharge to targeted discharge ratio delivery performance ratio was obtained.

2.5.3 Computation of Irrigated Area Performance

The irrigated area performance is the ratio of the actual irrigated area to the target irrigated area for different cropping years. For the computation of irrigated area performance actual and target irrigated area for different cropping year are required. These data were collected from the BWDB, Moulvibazar and field visit. Then using the actual irrigated area to targeted irrigated area ratio irrigated area performance was obtained.

2.5.4 Computation of Cropping Intensity Performance

Cropping Intensity data were directly collected from the BWDB, Moulvibazar and field visit.

2.5.5 Computation of Production Performance

Production performance is the ratio of the actual production to the target production for different cropping years. For the computation of production performance actual and target production for different cropping year are required. These data were collected from the BWDB, Moulvibazar and field visit. Then using the total production to targer production ratio the production performance was obtained.

2.5.6 Computation of Total Financial Viability

Total financial viability is the ratio of actual operation and maintenance allocation to target operation and maintenance requirements (Garg, 2020). For the computation of total financial viability actual operation and maintenance allocation and target operation and maintenance requirements are required. All this data was collected from the BWDB, Moulvibazar, and field visits. Then using the actual operation and maintenance allocation to the total operation and maintenance requirement ratio Total Financial Viability was obtained.

2.5.7 Computation of Evapotranspiration

For the calculation of Crop Evapotranspiration (ET_c) the maximum and minimum temperature, relative

2.5.8 Computation of Evapotranspiration

For the calculation of Crop Evapotranspiration (ET_c) the maximum and minimum temperature, relative humidity, wind speed, sunshine hours are required. This data is collected from Bangladesh Meteorological Department (BMD). Then Potential Evapotranspiration (ET_o) is computed from CROPWAT 8.0. Then Crop Evapotranspiration (ET_c) is obtained by multiplying Potential Evapotranspiration (ET_o) with crop coefficient (K_c). The value of K_c is different for different crops (Trivedi et al., 2018). The range of monthly values of K_c for Rice is (0.85 -1.30). The average value of K_c for rice is taken as 1.20.

2.5.9 Frequency Analysis

Frequency analysis is done by Gumbel's Graphical Method. First, the highest values are taken. Then these values are sorted in descending order (Bhagat, 2017). Then return period (T) is calculated from the following equation.

Return period, $T = (N+1)/m$
Where, N = total number of observations and m = order number

After calculating the return period, a Discharge vs. Return period graph is plotted in the semi-log paper. From this graph, for return periods 10, 20, 30, 50, and 100 years, the corresponding discharge is determined. From this analysis, the return period for a given design discharge of Barrage can also be determined.

3 Result and Discussion

3.1 Water Level, Discharge, and Velocity Analysis Near Barrage Site

The highest and lowest water level, velocity, and discharge data near the barrage site from 2009 to 2018 were collected and the result is presented in Table 1. Here all the elevations are measured in m (PWD).

Table 1. Analysis of Water Level, Discharge, and Velocity near the barrage site.

	Highest Value			Lowest Value		
Year	Water Level (m)	Discharge (m^3/s)	Velocity (m/s)	Water level (m)	Discharge (m^3/s)	Velocity (m/s)
2009	18.89	760.392	1.748	12.66	4.946	0.234
2010	17.89	618.360	1.759	12.53	5.873	0.291
2011	16.52	317.310	1.192	12.78	9.543	0.319
2012	18.41	872.944	2.062	12.87	8.179	0.308
2013	16.33	491.425	2.359	12.95	12.178	0.355
2014	18.34	487.675	2.466	12.96	8.637	0.397
2015	17.77	165.483	1.194	12.85	9.515	0.426
2016	16.29	345.911	1.396	12.83	5.211	0.232
2017	15.39	180.096	0.850	12.98	10.083	0.384
2018	16.31	288.692	1.104	13.33	6.155	0.244

From Table 1, it is seen that the maximum and minimum values of water levels are 18.885m (occurred in 2009) and 12.53 m (occurred in 2010) respectively. Similarly, the maximum value of Discharge (872.944 m^3/s) occurred in 2012 and the minimum value of Discharge (4.946 m^3/s) occurred in 2009. Furthermore, from the velocity analysis, the highest and lowest Velocity was found to be 2.466 m/s (occurred in 2014) and 0.232 m/s (occurred in 2016) respectively.

3.2 Evaluation of Irrigation Achievement, Irrigated Area Performance, and Production

Target Irrigated Area, Actual Irrigated Area, Pre-project production, and Post-project Production data near the barrage site from 2009 to 2018 were collected and the result is presented in Table 2.

Table 2. Analysis of Irrigation Achievement, Irrigated Area Performance, and Production

Year	**Target Irrigated Area (ha)**	**Actual Irrigated Area(ha)**	**Irrigated Area Performance (%)**	**Pre-project production (Metric Ton)**	**Post-project productin (Metric Ton)**	**Increasing Rate**
2008-09	12146	8385	69.03	26,000	38571	1.484
2009-10		8492	69.92		38214	1.470
2010-11		8626	71.02		41405	1.593
2011-12		8622	70.99		40955	1.575
2012-13		8524	70.18		40063	1.541
2013-14		8717	71.77		40550	1.560
2014-15		8830	72.7		42472	1.634
2015-16		8872	73.04		42576	1.638
2016-17		10400	85.62		46800	1.800
2017-18		10450	86.04		52215	2.008

From Table 2, it is seen that actual irrigated area and irrigated area performance have increased over time. Moreover, the maximum value of the actual Irrigated Area (10450 ha) occurred in 2017-18, whereas the minimum value of the actual irrigated Area (8385ha) occurred in 2008-09. Besides, it has been found from Table 2, the maximum value of Irrigated Area Performance (86.4%) occurred in 2017-18 and the minimum value of Irrigated Area Performance (69.03%) occurred in 2008-09. It can be surmised from this observation that the irrigation performance of the Manu Barrage irrigation project is quite satisfactory. It is also seen from Table 2 that except for 3 years, production is at an increasing rate.

3.3 Evaluation of Delivery Performance Ratio, Total Financial Viability, and Cropping Intensity

For the computation of the delivery performance ratio, actual and target discharge are required. These data were collected from the BWDB, Moulvibazar, and field visits. Then using the following equation delivery performance ratio was obtained.
Delivery Performance Ratio = Actual Discharge / Target Discharge
At Manumukh main canal (section 01), Delivery Performance Ratio=70%
At Manumukh main canal (section 02), Delivery Performance Ratio = 67%
At Manumukh main canal (section 03), Delivery Performance Ratio = 66%
So, it can be said that Delivery Performance Ratio is around 70%

Actual operation and management allocation, total operation, and management requirement data were collected from the BWDB, Moulvibazar, and field visits. Then using the following equation Total Financial Viability was obtained.
Total Financial Viability = Actual O & M Allocation/Total O & M Requirement
In the year 2018, Total Financial Viability = 6000000/20000000 = 30%
In the year 2017, Total Financial Viability = 5000000/15000000 = 33%
Here, it is seen that Financial Viability is very low. Proper operation and management cannot be done because of a shortage of money.

Cropping Intensity data were directly collected from the BWDB, Moulvibazar, and field visit. According to collected data the intensity of the year 2000, 2010, and 2018 are presented below.
Cropping Intensity in 2000 = 126%,
Cropping Intensity in 2010 =150%, and
Cropping Intensity in 2018 =185%
So, it is seen that cropping intensity is increasing day by day.

3.4 Crop Water Requirement

Crop water requirement data for all 12 months in 2018 were collected and the crop water requirement for all 12 months was calculated by using CROPWAT 8.0.
In 2018, the average ET_c or crop water requirement in the irrigation period = 3.736 mm/day = 40.84×10^6 m^3.
Average effective rainfall during irrigation period = 164 mm = 19.92×10^6 m^3
Net irrigation requirement = 20.92×10^6 m^3.
Supply from canal head regulator in irrigation period = 66×10^6 m^3
Here it is seen that the irrigation supply is greater than Net Irrigation Requirement (NIR). So, the irrigation supply is satisfactory.

3.5 Frequency Analysis

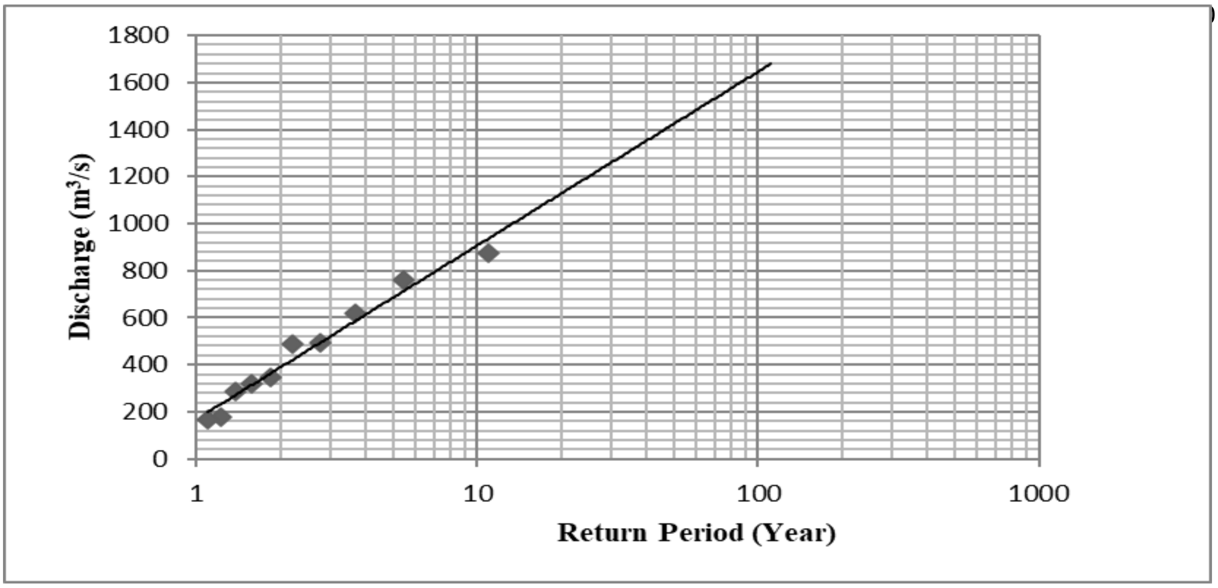

Figure 1. Discharge, Q (m^3/s) Vs. Return Period, T (Years) plot

From Figure 1, it is evident that for return periods 10, 20, 30, 50, and 100 years the corresponding discharge is 900 m3/s, 1120 m3/s, 1240 m3/s, 1420 m3/s, and 1640 m3/s. From this analysis, it is also determined that the design discharge (1275 m3/s) of Barrage has a return period of 32 years.

4 Conclusion

This study found that actual irrigated area and irrigated area performance have increased over time. Besides, the irrigation supply is greater than Net Irrigation Requirement (NIR). So, the irrigation supply is satisfactory. This finding implies that the irrigation performance of the Manu Barrage irrigation project is quite satisfactory. It is also evident that cropping intensity has also significantly increased. A vast land in this region was suffering from flash floods and congestion of water. The project is very effective in protecting the crops from flash floods and bringing the inundated area under cultivation. However, the operation and maintenance allocations are very meager which needs to be taken care of. Overall, the Manu River Project has turned the food deficit area into a food surplus area.

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References

Bhagat, N. (2017). Flood frequency analysis using Gumbel's distribution method: a case study of Lower Mahi Basin, India. Journal of Water Resources and Ocean Science, 6(4), 51-54.

Bos, M. G., Murray-Rust, D. H., Merrey, D. J., Johnson, H. G., & Snellen, W. B. (1993). Methodologies for assessing performance of irrigation and drainage management. Irrigation and drainage systems, 7, 231-261.

Garg, S. K. (2020). Irrigation Engineering and Hydraulic Structures: Water Resources Engineering (Vol. II). Khanna Publisher.

Molden, D. J., Sakthivadivel, R., Perry, C. J., & De Fraiture, C. (1998). Indicators for comparing performance of irrigated agricultural systems (Vol. 20). Iwmi.

Raj, P. N., Azeez, P. A., & Hussain, A. S. (2011). Performance evaluation of an irrigation project with reference to its irrigation objectives. African Journal of Agricultural Research, 6(11), 2472-2478.

Saleh, A. F. M., & Mondal, M. S. (2001). Performance evaluation of rubber dam projects of Bangladesh in irrigation development. Irrigation and Drainage: The journal of the International Commission on Irrigation and Drainage, 50(3), 237-248.

Trivedi, A., Pyasi, S. K., & Galkate, R. V. (2018). Estimation of Evapotranspiration using CROPWAT 8.0 Model for Shipra River Basin in Madhya Pradesh, India. International Journal of Current Microbiology and Applied Sciences, 7(5), 1248-1259.