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Assessment of Technical and Financial Feasibility of the Gadachaur Lift Irrigation System, Bajura Nepal

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ABSTRACT

Implementation of a cost-effective and technically feasible irrigation project in the hilly topography contains many challenges in operation and management. This study examined the technical and economic feasibility of the lift irrigation system along with diversification of irrigated agriculture in one of the mid-hill districts of Nepal. To achieve the overall aim, a case study was conducted in Gadachaur, Bajura District of Nepal in 2022-2023. The approach consisted of collecting data and information from desk study of Google Earth maps, field visits, surveys, focus group discussions and subsequent interpretation. The study found that the selected system is both technically and economically feasible. The cropping intensity in the chosen area was 105%. The economic analysis indicated that the internal rate of return was 19.7%, and the B/C ratio at a 10% discount was 1.9, while at a 12% discount rate, the B/C was 1.63. After establishing the technical feasibility of the irrigation system, the following recommendations were made; the economic size of the pumping main should be 80 mm, the total dynamic head should be 160 m, the total volume of water to be pumped per day should be 141 m^3, and the HP of the pump required should be 15 KW.

INTRODUCTION

Irrigation is the strategy of artificial water supply to maximize crop production and improve resilience against climate change which is generally achieved by applying an appropriate volume of water at the right time and delivered by the right application method (Das *et al*., 2018, Gao *et al.*, 2023; Koo-Oshima 2023). The spatial and temporal variability in rainfall and on-farm water shortage calls for the development of irrigation to feed the increasing population of the world (Allamine *et al.*, 2023; Dantas *et al.*, 2023). Water use within crop production system accounts for almost 70 to 80% of global water withdrawals and efficient irrigation is critical for managing scarce water resources (Dhungel *et al.*, 2023; ICID 2023). However, the irrigation services provided throughout the world have not achieved the targeted objective of agricultural productivity despite huge investments in irrigation projects has been made (Chand *et al.*, 2023). The economic return per unit of water from the agricultural sector is less compared to service and manufacturing industries indicating the judicial and economic use of water from the planning to implementation stage (Corcoles *et al.*, 2012; Chand *et al.*, 2021). The reasons of acquiring less irrigation water productivity could be technical, socio-economic and/or managerial.

The irrigation in Nepal is broadly divided into two

(2) geographical regions: a) irrigation in plains/ flat regions, and b) hill irrigation (Pradhan and Belbase, 2018). The hill irrigation system taps water from small streams/ rivers and consists of narrow, deep, and long canals with steep slopes or lift irrigation projects (Gautam *et al.*, 2016; Dhakal *et al.*, 2018). The lift irrigation system in the mid hills of Nepal has been identified as one of the high-priority projects for social and economic transformation (ADB, 2016). The design constraints in hill irrigation systems are different from those in the plains. Typically, a sufficient hydraulic head is available in hill irrigation, and losses through structures can be tolerated (Gautam, 2012). Steeper gradients in the canal are possible, allowing for a smaller cross-section. This research was concerned with the economic and technical aspects of lift irrigation in the hilly topography of Nepal. A case study of the Gadachaur Lift Irrigation System, Bajura Nepal was undertaken in 2022-23. The overall objective of the research was to complete a pre-feasibility level study of a mid-hill pumping lift system and to evaluate the technical, economic, and financial pre-feasibility of energy and technology options for year-round irrigation coverage. The specific objectives were to: a) carry out an agricultural survey to assess the existing cropping intensity, b) compute the crop water requirement and compare it with the design discharge, and c) evaluate the economic parameters (Internal rate of return and B/C ratio) and perform a sensitivity analysis of the project.

It is important to conduct a pre-feasibility study of a lift irrigation project in a hilly region to minimize the constraints and make it cost-effective among farming communities. Huge energy costs, more frequent breakage and wear and tear of electro-mechanical components, and the unwillingness of the farmers to share the operation and management costs have been the key constraints to dependable irrigation services in the earlier developed lift irrigation schemes in Nepal (ADB, 2016).

MATERIALS AND METHODS

Study Area

The Gadachaur Lift Irrigation Project (29°27'33.30"N, 81°43'6.32"E, 1750 m) is located in the Badimalika Municipality-7, Bajura District of Nepal (Figure 1) with a net command area of 26 ha, and a gross command area of 31 ha. The main source of water for the project is the Gadachaur River which is located 150m below the proposed reservoir. The predominant climate is semi-arid with summer rains and an average annual precipitation of 179 mm. The study area including the location of intake, source, and general pipeline distribution is illustrated in the Figure 2.

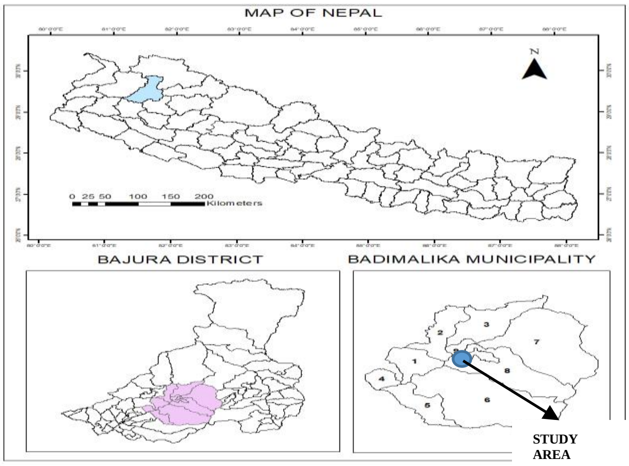

Figure 1: Location of the Study Area

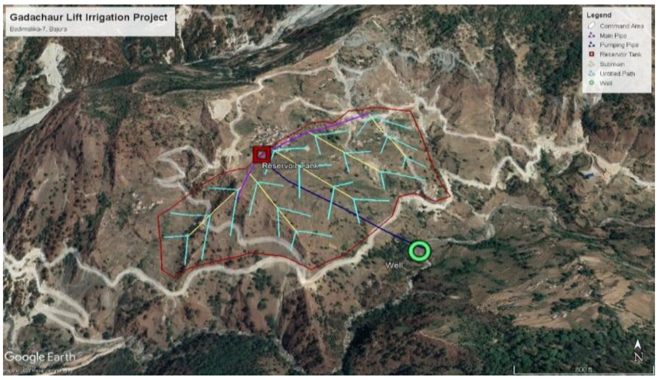

Figure 2: Command Area of the Project (Map retrieved from Google Earth on May 5, 2022)

Methodology

The summary of the methodology applied in this study is presented in Figure 3 as described by Dahal *et al.* (2022).

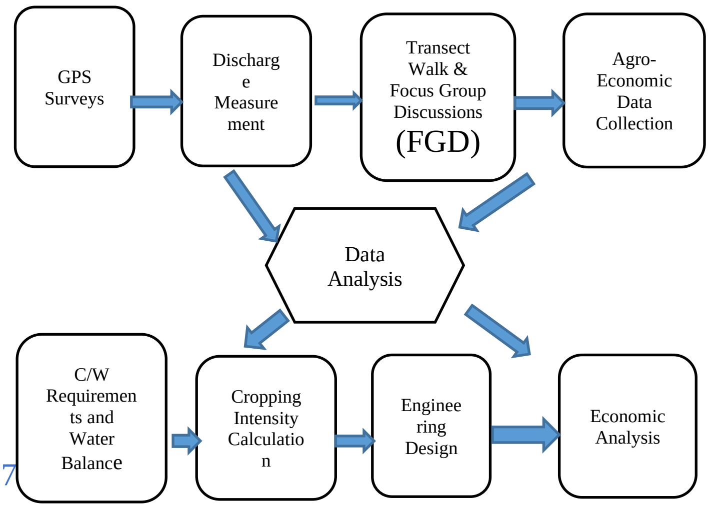

Figure 3: Summary flow chart of the methodology
Source: Adapted from Dahal et al. (2022)

GPS Surveys

In this study, the GPS satellite surveying method was applied to know the altitude and location of the source and command area. The position of the source and reservoir, as well as the layout system, were marked with GPS. The results of surveying were directly digitalized, captured, stored, and processed in numeric forms. Furthermore, the results of the digital data were directly imported into CAD and GIS software following Choi *et al.* (2000).

Discharge Measurement

The float method as described in Micheal (2004) and Ngoma and Wang (2018) was used to measure the river discharge. The coefficient K (generally ranges from 0.7 for rough beds to 0.9 for smooth beds) value was taken as 0.7 following Ngoma and Wang (2018) for mountain streams. The cross-section areas at the start and endpoints of the reach were measured and plotted in the graph using a suitable scale. Discharge was computed by multiplying the average area and the mean velocity.

Measurement of Mean Monthly Flow

The Medium Irrigation Project (MIP) method was used for estimating mean monthly flows at ungauged sites and it is the average outcome for long-term flow (Basnet *et al.*, 2018). According to the PSDP Manual M3 (developed by the Nepal Government, 1990), Nepal is divided into seven (7) hydrological regions (Figure 4) and the study area lies in region one. In the MIP Method, once the low flow discharge measurement data is taken (lowest flow occurs in March/April) and the hydrological zone is identified, long-term average monthly flows can be determined by multiplying the unit hydrograph with the measured catchment area.

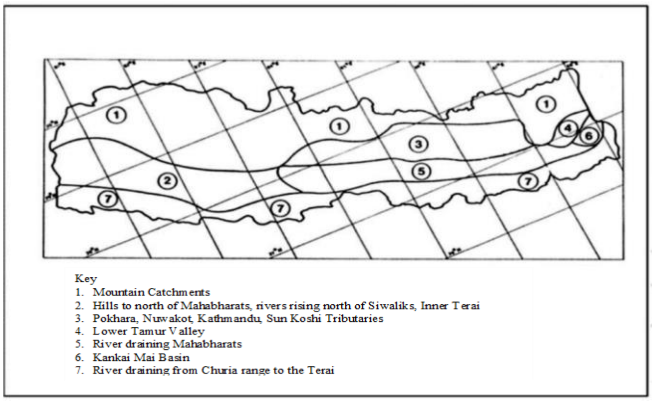

Figure 4: Hydrological Regions of Nepal (Design manual for small-scale irrigation scheme, 2014)

Selection of Design Discharge

The criteria for the selection of design discharge in this study was based on agro-technical considerations including crop water requirement and command area. The monthly water requirement for the chosen case study was calculated based on the major crops cultivated on the site and for the system, design discharge was adopted to fulfill the water requirements.

High Flood Discharge

Initially, the catchment area of the river source was computed to be 50 km^2 with the aid of ArcGIS. As the source river for the proposed project was perennial, the high flood design discharge was computed based on the recommendation of the Ministry of Federal Affairs and Local Development Nepal (2014) using five (5) methods (Equations 1-9) including Modified Dicken's Method, Ryve's Formula, Rational Method, Sharma and Adhikari 2004 Method, and Regional Flood Relationship Method 1990 of Water and Energy Commission Secretariat (WECS), Government of Nepal. In the result and discussion process, the average value of these four (4) methods was taken into consideration. In this study, the high flood discharge with a return period of 50 years was calculated. According to the PDSP manual and design manual for small scale irrigation scheme, the return period is usually taken as 50 years.

Modified Dicken's Method

$Q_t = C_t \times A^{0.75}$ ………………………………… Eq. 1

Where: Q_t= maximum flood discharge in T years, m^3/s, A= Catchment Area, km^2, C_t= Modified Dickens Constant = {2.324log (0.6T) × log($\frac{1185}{P}$)}+4, P= $\frac{a+6}{A+a}$×100, a= Perpetual Snow covered Area, km^2, T= Return Period .

Sharma and Adhikari (2004) Method

The formula for two-year return period

$Q_2 = 2.29 \times A_{3000}^{0.86}$ ………………..…………Eq. 2

Formula For 100 year return period

$Q_{100} = 20.7 \times A_{3000}^{0.72}$ ………………………..Eq. 3

$\ln S = \ln (\frac{Q100}{Q2})/2.326$ …………………... Eq. 4

Where: Q2 = 2 year flood

Q_{100} = 100-year flood

A_{3000} = Catchment area under 3000m or basin area below 3000 m elevation.

$Q50 = e^{(LnQ_2 + Ln S \times 2.054)}$ ……………………Eq. 5
Q50 is the peak discharge for the return period of 50 years

Regional Flood Relationship (WECS, 1990) Method

Formula for two year return period
$Q_2=1.8767\times A^{0.8783}$ ……………………… Eq. 6
Formula For 100 year return period
$Q_{100}=14.630A^{0.7342}$ ………………….. Eq. 7
$Q50 = e^{(LnQ_2 + Ln S \times 2.054)}$ …………………. Eq. 8

Rational Method

$Q=0.278C\times i\times A$ ……………...…………Eq. 9
Where: Q= peak discharge in m^3/s, C= runoff coefficient (roughly defines as the ratio of runoff to rainfall), I= rainfall intensity in mm/h, and A= Catchment Area, km^2

Transect Walk and Focus Group Discussions

A joint transect walk with the study team and key informants was carried out and a site investigation was done to identify the problems of river stability at the intake site to identify high-risk zones for laying the pipe network and to select a reservoir location. A focus group discussion (FGD) with local growers was conducted applying Participatory Rural Appraisal (PRA)/Rapid Rural Appraisal (RRA) tools to obtain information about socio-economic and water-related parameters (availability, requirements, allocation, and distribution). The questionnaire was prepared following Mishra (2022) and household surveys on 300 houses were done in March 2022 using key informants to identify the basic agro-economic condition of the site which included average landholding size, cropping system, and irrigation facilities to find out the cropping intensity in the project area.

Crop Water Requirements and Water Balance

The crop water requirements (CWR) of various crops grown in the command area of the selected case study were calculated based on evapotranspiration, crop coefficients, and effective rainfall of the area. CropWat 8.0 FAO software was used to calculate CWR. The mean monthly flow was calculated using the MIP method, and a water balance table was prepared. From the water balance table, it was checked whether the mean monthly flows were sufficient to irrigate the crops in the command area throughout the year.

Cropping Intensity Calculation

Cropping intensity in this study was calculated following Saud (2021). Cropping intensity refers to the raising of several crops from the same field during one agricultural year; and gives an index of the extent of multiple cropping taking place on a farm. Higher cropping intensity shows intensive use of land for agricultural purposes.

Economic Analysis

Economic analysis in this study was undertaken with two major assumptions: a) the project life is 25 years, and b) the maintenance cost is taken to be 1% (based on design manual) of the total investment cost and it will occur from the 2nd year. The cost considered both investment costs and operation and maintenance costs. The investment cost included all expenditures incurred during the construction period (i.e. construction costs, capital goods costs, labor costs, and terminal costs). The operation and maintenance cost included all costs apart from the investment incurred, in the maintenance throughout the project life (i.e. intermediate material cost, transportation cost, labor cost, etc.) The two tools, namely internal rate of return (IRR) and benefit-cost ratio (B/C) were applied and sensitivity analysis was carried out.

Internal Rate of Return

Internal rate of return (IRR) is the rate of discount at which the cost and benefit streams over the life of the project are equalized (Ruegg and Marshall, 2013; Matos *et al.*, 2015). It is the maximum interest rate that a project could pay for the resources used if the project is to recover its investment and operating costs. It is that discount rate that will make the net present worth of the incremental net benefit stream equal to zero. IRR in this study was calculated using Equation 10, following Matos *et al.* (2015):

$$\sum_{t=1}^{N}\frac{(B_t - C_t)}{(1+r)^t} = 0$$

……………………………… Eq. 10

Where: B_t - Benefit in each year, C_t - Cost in each year, r -internal rate of return (IRR), t-1, 2, 3…..N, years, and N - Life of the project

Benefit-cost Ratio (B/C Ratio)

The benefit-cost (BC) ratio is an indicator showing the relationship between the relative costs and benefits of a proposed project, expressed in monetary or qualitative terms (Pasqual *et al.*, 2013). If a project has a BCR greater than 1.0, the project is expected to deliver a positive net present value to a firm and its investors. BCR in this study was calculated using Equation 11, following Hayes (2022) and Matos *et al.* (2015):

$$\frac{B}{C}=\sum_{t=1}^{N}\frac{\frac{B_t}{(1+i)^t}}{\frac{C_t}{(1+i)^t}} \quad \text{………………………… Eq. 11}$$

Where: B_t - Benefit in each year, C_t - Cost in each year, I-Discount rate, T -1, 2, 3…..N, years, N - Life of the project.

Sensitivity Analysis

Sensitivity analyses assess 'how changing inputs to a model or an analysis can affect the results. A sensitivity analysis is needed to see how the output of any decision-making process changes when input varies (Hall *et al.*, 2009; Kamiński *et al.*, 2018). It provides an idea of how much model output values change by changing model input values (Cacuci *et al.*, 2005). In contrast, sensitivity analyses also help to understand the uncertainty of a model or a system and to assess the riskiness of a plan. In this research, a sensitivity analysis was performed to understand the economic viability of the chosen irrigation project at several selected input scenarios. This study carried out sensitivity analysis and examined the risks that occur when investment cost increases, incremental benefit suffers a shortfall, and when both investment cost increases and incremental benefit suffers a shortfall.

Data Analysis

The PDSP M3 Manual of Nepal Government and Standard Assumptions of Lift Irrigation System Design in Nepal were used in the data analysis for this study. The three (3) major parts of Excel: worksheets, charts, and standard Excel software files developed for irrigation schemes in Nepal were used for the data calculation. ArcGIS was used for mapping and confirming the GPS Data as recommended by Maguire (2008). The first mode of New LocClim was adopted for meteorological parameters in this study. The new LocClim is a freeware tool to estimate local climatic conditions for any location on earth which uses the FAO agro-climatic database with observations from nearly 30,000 stations worldwide (Grieser *et al.*, 2006). CROPWAT software, a computer program to calculate crop water requirements, was installed and finally, water balance from climatic and crop data was calculated and used in this study. AutoCAD was used for the design of various structures like intake well, pump houses, and electric systems following Patpatiya *et al.* (2019).

RESULTS AND DISCUSSION

Agricultural assessment, hydrological assessment, and economic analysis are the general outcomes of this study. Specifically, the parameters including cropping intensity, crop water requirement and water balance, engineering design, and economic analysis were studied in this research which are going to be discussed in the following sub-sections.

Cropping Intensity

FGD carried out with farmers indicated that they were reluctant to adopt intensive cultivation due to the high risk of crop failure due to water scarcity on the farms. These limitations were found to be the major reasons for the existing traditional and subsistence-based agricultural production system. The existing cropping intensity in the case study area was 105% (Table 1). Based on ADB (2016), the existing cropping intensity below 110% indicates the necessity for irrigation development.

Table 1: Current cropping intensity at the irrigation scheme

Cropping Intensity :				105%					Cropped Area				26.0	ha														
S.N.	Season	Crop	Area		Pou	Mag	Mag	Fag	Fag	Cha	Cha	Bai	Bai	Jes	Jes	Asa	Asa	Sra	Sra	Bha	Bha	Ash	Ash	Kar	Kar	Mar	Mar	Pou
		Pattern	%	(ha)	Jan		Feb		Mar		Apr		May		June		Jul		Aug		Sep		Oct		Nov		Dec	
					1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	Winter																											
	Spring																											
	Summer	Paddy	0	0.00																								
2	Summer																											
	Winter	Wheat	20	5.20																								
	Spring																											
1	Spring	Maize	25	6.50																								
	Summer																											
	Winter																											
2	Summer																											
	Winter	Oilseeds	5	1.30																								
	Spring																											
3	Spring																											
	Summer	Pulse	10	2.60																								
	Winter																											
4	Summer																											
	Winter	Potato	15	3.90																								
	Spring																											
5	Summer																											
	Winter	Vegetables	10	2.60																								
	Spring																											
6	Spring																											
	Summer	Vegetables	20	5.20																								
	Winter																											
		Total Area		27.30	ha																							
	Net Command Area			26.0	ha																							

Table 1 indicates that the farmers in the study area mostly grow maize in the spring season and oilseeds are cultivated in the limited area. The majority of the arable area was under-utilized and remained fallow. The proposed project will allow farmers to increase cropping intensity in the project area by providing an appropriate quantity of water regularly based on crop water requirements. Irrigation facilities will have an impact on increasing the intensity of crops, so the percentage of fallow land will decrease Chand *et al.* 2021).

A finding from Bangladesh (Mondal *et al.*, 2015) indicates that there is always a high scope of increasing cropping intensity up to 200 to 300% from the existing level after incorporating good irrigation service coverage in the command area. In the study of cropping intensity, its determinants, and farmer's income, Saud (2021) found that the extent of irrigation service was statistically relevant to cropping intensity. In the agricultural transformation from subsistence-based to industrial farming, the crop parameters including cropping pattern and intensity have an important role (Challinor *et al.*, 2015; Wu *et al.*, 2018; Saud 2021; Liu *et al.*, 2021). One of the major challenges faced by the agricultural industry is to increase yield per unit of land area which can be fulfilled through the improvement of cropping intensity (Mondal *et al.*, 2015; Bhatt *et al.*, 2016; Negi and Ballav 2018; Waha *et al.*, 2020; Liu *et al.*, 2021).

Discharge

The total discharge of the river (14th March, 2022) was found to be 5 m^3/s (5000 l/s) which is presented in Table 2.

Table 2: Discharge of the river considered in the study

$V_{surface}$ (m/s)	K	V_{mean} (m/s)	The average area of river sections 1 & 2 (m^2)	Total discharge (m^3/s)
0.9	0.7	0.63	7.94	5

Mean Monthly Flow

Following the MIP method, using the ordinate of the non-dimensional hydrograph given in the PDSP manual M3, the mean monthly flows were obtained. Half monthly flow and 80% reliable flow are presented in Table 3. The detailed procedure of the mean monthly flow calculation is presented in the supplementary tables. Table 3 indicates that August had the maximum mean monthly flow (94.69 m^3/s) and there was the lowest flow in April (i.e. 3.78 m^3/s). These flow data were used for water balance.

Table 3: Mean monthly, half monthly, and 80% half monthly flow in the study area

Month	Mean Monthly Flow (m^3/s)	Half Monthly Flow(m^3/s)		80% Reliable Flow (m^3/s)	Half Monthly 80% Flow(m^3/s)	
		1st Half	2nd Half		1st Half	2nd Half
Jan	9.1	9.71	8.48	2.93	3.14	2.71
Feb	6.82	7.34	6.31	2.16	2.33	2
Mar	4.93	5.3	4.56	1.59	1.71	1.48
Apr	3.79	3.3	4.29	1.22	1.12	1.31
May	9.85	7.67	12.03	2.5	2.08	2.92
Jun	22.73	17.64	27.83	4.74	3.75	5.74
Jul	54.93	46.09	63.77	11.37	8.95	13.8
Aug	94.7	93.66	95.75	25.76	25.33	26.2
Sep	62.5	70.55	54.46	14.4	16.54	12.27
Oct	30.31	35.79	24.83	7.96	9.03	6.88
Nov	15.54	17.67	13.4	5.31	5.81	4.82
Dec	11.75	12.54	10.95	3.87	4.17	3.58

Crop Water Requirement and Water Balance

The major crops in the study area including rice, maize, oilseeds, potatoes, vegetables, and pulses were considered for crop water requirement calculations. Water requirement at the farm level means the actual amount of water being used by different crops and the intake water requirement means the actual amount of water fed through the intake structure ie. sump well (Micheal 2004; Arora 2012; Garg 2015). The total adopted water requirement was calculated as 140.4 m^3/day (details are provided in the supplementary table). After the water balance study, it was found that the available water was thus sufficient to irrigate the proposed cropping system in the study area.

Table 4: Total water requirements in the study area

Peak water requirement (m^3/s)	Duty (m^3/s /ha)	Water requirement (m^3/day/ha)	Total water requirement in the command area (m^3/day)
0.00968	0.00015	5.4	140.4

Note: It is generally considered a duty of 0.00015 m^3/s /ha for lift irrigation schemes in Nepal (ADB 2016).

High Flood Discharge

In this study, four (5) methods were applied to assess the high flood discharge to design the intake structure (engineering design) required for the selected irrigation system (Table 5). The average value of 183.2 m^3/s was found with a return period of 50 years.

Table 5: Summary of high flood discharge calculated from different methods

S/N	Methods	Discharge (m^3/s)	Average Discharge (m^3/s)
1	Modified Dicken's Method	127	
2	Ryves Formula	122	
3	Rational Method	167	
4	Sharma and Adhikari (2004) Method	284	183.2 m^3/s
5	Regional Flood Relationship (WECS, 1990) Method	216	

Main Pipe and Pump Design

The capacity of the reservoir tank proposed is 76.05 m^3 (with dimensions 7.8m × 6.5m × 1.5m). For the main riser, GI pipe (medium class) of 80 mm diameter was used with a length of 700 m as per the design. The command area will have a network of laterals connected to the outlet valves.

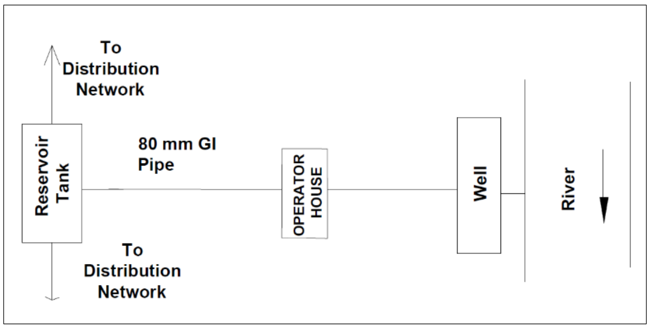

Figure 5. Schematic diagram of the water distribution network of the irrigation scheme

The pipe distribution system consists of the main pipe, sub-main pipe, and laterals that have been chosen to irrigate the maximum possible command area. The total length of the main pipe is 700 m, the sub-main 1500 m, and the laterals 3200 m. The economical size of the pumping main was calculated as 80 mm (nearest GI pipe size). The total volume of water to be pumped per day was calculated as 140.4 m^3 per day.

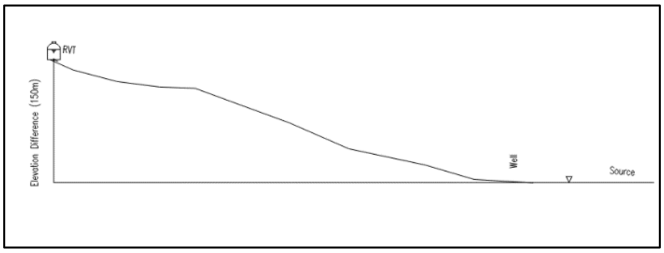

Figure 6: Simple elevation profile of the study components

The total dynamic head was calculated as 160 m. Assuming the efficiency of the pump of 55%, the HP of the pump required was calculated to be 15 kW (supplementary table). Shifting the pumping unit is cumbersome and may result in damage to the units (Shiyekar & Patil, 2017). It is thus conceptualized that the water from the river is pumped using an electric pump to a higher elevation and collected in the reservoir. This reservoir is further connected with the main, sub-mains, and laterals or distributors to convey water to the different parts of the command area.

Economic Analysis

Economic analysis is an important task to investigate the cost-effectiveness of any project including irrigation and viability thereafter. Economic assessment is generally conducted through a cost-benefit analysis of projects (Paudel & Adhikari 2018; Subedi *et al.*, 2020). The economic tools including benefit-cost ratio (BCR), economic internal rate of return (IRR), and payback (PB) period are commonly adopted to assess economic feasibility analysis in engineering projects (Ahammed *et al.*, 2020).

Internal Rate of Return

Internal Rate of Return (IRR) is commonly used to determine the rate of capital growth and, it is a measure of the percentage yield on investment (Matos *et al.*, 2015). The IRR is compared against the investor's minimum acceptable rate of return (MARR), to ascertain the economic attractiveness of the investment. If the IRR exceeds the MARR, the investment is economic. If the IRR equals the MARR, the investment's benefits or savings just equal its costs (Ruegg and Marshall, 2013). According to Matos *et al.* (2015), IRR is the rate of discount that equates the present value of the benefits to the initial investment in a project. Meredith and Mantel (2009) concluded that if the calculated IRR is greater than the adopted discount rate in any study, the selected engineering project can be economically feasible. According to Ahammed *et al*. (2020), if the initial cost of a project recovers quickly, the project is less vulnerable. The economic internal rate of return (IRR) in this study was found to be 19.66% which suggests that the project is economically viable.

Benefit-cost Ratio

Benefit-cost analysis is one of the most widely accepted economic instruments since it is a rational and systematic decision-making support tool (Molinos-Senante *et al.*, 2010). The benefit-cost analysis starts from the premise that a project should only be commissioned if all the benefits exceed the aggregated costs. According to Ahuja (2005) and Ahammed *et al.* (2020), if the calculated BCR of any engineering project is greater than one, the development of such a system can be economically viable. A greater B/C ratio of 1.50 is usually specified for irrigation projects. A project which gives a B/C ratio of greater than 1 is economically viable. A greater B/C ratio of 1.50 is usually specified for irrigation projects. For a private enterprise, the best project is the one that gives the highest B/C ratio because it would give the maximum return on investment.

The benefit-cost ratios (B/C) of the studied project at 10% and 12% discount rates were found to be 1.86 and 1.63, respectively, which are greater than one, and hence the project is implementable from the viewpoint of the economy (supplementary table). For a private enterprise, the best project is the one that gives the highest B/C ratio because it would give the maximum return on investment. In Nepal, most of the water resource projects are executed by the government. The aim of the government is generally to achieve the maximum benefits and not necessarily the highest B/C ratio. However, at the same time, the project should be economically viable & should give some minimum rate of return. In most, water resources development projects, the benefits increase with an increase in the size of the project (Arora 2012). However, the cost also increases. A stage is reached beyond which an increase in size may not give the minimum attractive return. The size of the project is usually fixed at that stage (Michael 2004; Garg 2014).

Sensitivity Analysis

The result of sensitivity analysis in this study considering four (4) different cases is presented in Table 6. The analysis showed that the project is flexible based on the cost and benefits scenarios. It is found to be economically feasible even in different adverse conditions. Three conditions were considered in this study:

a. Investment cost increase: While efforts have been made to accurately estimate the costs of Project investment, it is of course possible that actual costs may be higher than this calculation. A 10% increase in construction costs will cause the EIRR to fall to 17.97%.
b. Incremental benefit shortfall: If incremental benefits were to decrease by 10%, the EIRR could be expected to be only 18.81%.
c. Both investment cost increase and incremental benefit shortfall: In the worst case if both investment cost increases by 10% and incremental benefit also shortfalls by 10%, the EIRR is observed to drop to 15.91% which indicates that the project is still beneficial. Overall, the project is expected to have strong economic returns. Those returns are less sensitive to incremental benefit shortfalls by 10% and cost overruns by 10%.

Table 6: Sensitivity analysis in the study considering four different cases

Case	Description	BCR at 10%	BCR at 12%	EIRR (%)
I	Normal	1.86	1.63	19.66
II	Cost increase by 10%	1.84	1.60	17.97
III	Benefit decrease by 10%	2.02	1.76	18.81
IV	Cost increase by 10% and Benefit decrease by 10%	1.66	1.44	15.91

CONCLUSION

The study concluded that the crop water requirement of the study area meets the design discharge. The diversion discharge meets the crop water requirements; and the cropping intensity of the study area will increase from 105% to 180% after the project. The EIRR in this study was 19.66% and the B/C ratio at a 10% discount was 1.86 while at a 12% discount rate, it was 1.63. The result of the financial, economic, and sensitivity analysis indicated that the project will be stable on both economic and financial grounds and hence is recommended for the implementation.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this research and publication.

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