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Impact of Modernization of Rani Jamara Kulariya Irrigation System in Kailali District

Er. Nirbhaya Risal[1, *], Dr. Khet Raj Dahal[2], Dr. Ramesh Parajuli[3]

[1] Contractor's Representative of RJKIP, Lot 3, nirbhayarisal@gmail.com
[2]Professor and Campus Chief of Lumbini International Academy of Science and Technology, Lalitpur, dahal.khetraj@gmail.com
[3]Assistant Campus Chief of Nepal Law Campus, drrameshparajuli101@gmail.com

Abstract

The modernization of the Rani Jamara Kulariya Irrigation System (RJKIS) in Tikapur, Kailali district, Nepal, has significantly impacted agricultural productivity, water management, and socio-economic conditions in the command area. The study examines the impacts of the modernization of the irrigation system after the completion of the first phase of modernization and the ongoing second phase of modernization which is close to the completion phase. A questionnaire, interviews, and field observation were used to collect data about the pre-modernization position and the recent status of the system. The study reveals an increase in cropping intensity from 193% to 253%, a shift toward diversified crops, and an increase in the annual crop value of NPR 5,660.27 million. Institutional strengthening of the Water User Association (WUA) improved governance and dispute management in the farmer community with affirmative ratings of modernization showing better operational efficiency. Labour shifts created employment opportunities, contributing NPR of 1.47 billion annually. The financial assessment indicates a pay-back period of 8 years, with an Economic Rate of Return (ERR) of 12.96% and a Benefit Cost (B/C) Ratio of 4.63 illustrating the system's economic sustainability and financial viability. For sustaining the system, farmer training, policy revision, agro-industry promotion, and community participation enhancement are the primary recommendations.

Keywords: RJKIS, Irrigation Modernization, Cropping Intensity, Water User Association, Socio-Economic Impact, Payback Period, Economic Rate of Return

1. Introduction

Appraising the performance of irrigation systems helps for impartial evaluation of the actual and potential performance of different types of irrigation systems and their management practices suitable for local circumstances. This information is capable of choosing the best system for local limitations. Furthermore, understanding how evenly a system applies water can impact crop yield and irrigation efficiency, providing further reasons to conduct system evaluations (Griffiths & Lecler,2006).

The Farmer Managed Irrigation System (FMIS) with a small capacity is encountering various obstacles such as state rivalry among the farmers for irrigation water demand, climatic inconsistency, and changes in the socioeconomic transformation in the society. In the present-day institutions that are responsible for irrigation management, have been established for managing and developing the strategic plan for changing circumstances. However, the immediate changes have deteriorated the institutional adaptive capacity (Thapa, Wester, & Vardya, 2016).

FMISs are innovative irrigation systems that are conceived, designed, constructed, operated, and maintained using the local, traditional knowledge of the farmers. Their unwavering dedication to these irrigation systems has made a remarkable impact on the nation's agricultural output. Unlike agricultural production relying solely on unpredictable natural rainfall, FMIS consistently yields superior results (Pradhan, 2018).

2. Literature Review

2.1. Introduction

*Corresponding Author

Water resource development for irrigation purposes, specifically through the FMIS, aims to boost cereal grain production, achieve self-sufficiency in agricultural products, and mitigate social and economic challenges such as poverty and unemployment (European Commission, 2023).

FMIS has effectively regulated water resources for irrigation in Nepal for decades. However, in recent years, the country's agricultural sector has faced multiple challenges affecting society and irrigation farming. This study explores key institutional changes within irrigation systems, the factors driving these transformations, and how rules, norms, and organizational procedures have evolved (Parajuli, Eakin, Netra, & John, 2018).

FMISs are found in diverse environments and employ a wide range of technologies to exploit different types of water sources for the production of varieties of crops. However, all these irrigation systems require certain essential tasks to be accomplished if the system needs to function productively. One set of management activities focuses directly on the water. Water must be acquired, allocated, and distributed, and if there is excess it must be drained. A second set of management activities deals with the physical structure to control the water. These structures must be operated and maintained. A final set of activities focuses on the organization that manages the water and structure, including decision-making, resource mobilization, communication, and conflict management (Martin & Yoder,1987).

The growing availability of non-farm income and remittances has been a key driver of institutional changes, particularly influencing the adaptation of position and monitoring rules. This shift has been characterized by a transition from in-kind labor contributions to monetary compensation, reflecting broader socio-economic transformations within the irrigation systems (Parajuli , et al., n.d.).

The economic feasibility of irrigation modernization projects is often assessed through the Economic Internal Rate of Return (EIRR) and other financial indicators. A study by the ADB on the Madhya Pradesh Irrigation Efficiency Project in India reported an EIRR of 15.7%, exceeding the required threshold of 9.0%. The study emphasized that over 95% of the total economic benefits were attributed to increased agricultural production, demonstrating the significant impact of irrigation modernization on enhancing crop yields and farm incomes. These findings reinforce the economic rationale for investing in irrigation upgrades, as they contribute to higher productivity, improved water-use efficiency, and long-term sustainability in agriculture (ADB, 2020).

Modernization of the existing irrigation systems refers to a more complicated process involving considerable changes to the governing rules for water resource management. This can encompass modifications not only to the physical infrastructure but also to its management practices. It is the process of a combination of rehabilitation and process improvement under the technology available in the country for the sustainability of the Irrigation System (FAO, 2006). Modernization is not merely the introduction of a modern physical structure in a system, it is the process of technical and managerial progression of the irrigation system along with institutional reforms of the Water User Association (WUA) and farmers' community. Depending on the local circumstances, modern water management in any irrigation system can be interpreted by a range, such as the application of water through pipes rather than open channels, with the control of computerized soil-water sensors and different monitoring systems such as satellite images, remote control with real-time data, and so on.

2.2. Need for Modernization

Modernization is crucial for socio-economic progress, especially in developing countries. (Sapkota, 2023) discusses Nepal's pursuit of modernization to overcome infrastructural limitations, cultural barriers, political instability, and environmental sustainability challenges. Addressing these issues is vital for sustainable development and the well-being of the population of the country.

Modernization investments in irrigation systems, including infrastructure and technology upgrades, are widely promoted to enhance water-use efficiency, address water scarcity, and improve agricultural productivity in the face of climate change (Simón et al., 2022). However, these improvements often lead to increased rather than reduced water consumption, a phenomenon known as the efficiency paradox or rebound effect. Understanding this paradox is complex, as multiple institutional, physical, and informational factors influence farmers' water-use decisions, especially in collectively managed irrigation systems governed by

WUA. A study analyzing 37 cases of modernization investments identified 12 key action situations and 192 interlinkages affecting water-saving outcomes. While some studies report a direct link between modernization and water conservation, many highlight challenges related to collective decision-making, water application, and infrastructure maintenance. (Hoffmann & Tomas, 2023).

The study on modernizing irrigation systems and on-farm water management in eight subprojects across four climate-vulnerable provinces in Vietnam: Binh Phuoc, Gia Lai, Kon Tum, and Quang Nga. The Climate Adaptation through Irrigation Modernization Project aims to enhance agricultural resilience by integrating crop diversification with climate-smart irrigation practices to improve water-use efficiency and crop productivity. By addressing dwindling water resources, the project seeks to mitigate the effects of climate change, ensuring sustainable water availability for agriculture and enhancing farmer livelihoods (ADB, 2022).

The project appraisal report suggests that the cropping intensity increased to 255 % in the irrigation facilities after the modernization, which was limited to 157% in the pre-modernization period. The ENPV (Economic Net Present Value) of benefits to the project investments is estimated at NPR 22.4 billion, with ERR at 25.1% (WB, 2018).

User participation was a key element, with farmers contributing 7 to 15 percent of the civil works. The involvement of users in the design and construction phases led to improved system performance, enhancing agricultural productivity (Singh, 2010).

2.3. Role and Responsibility of WUC in Irrigation Management.

WUAs are one of the vital organizations that lead toward the success of Participatory Irrigation Management (PIM). PIM is the model that emphasizes the active involvement of farmers in the operation, maintenance, and management of irrigation systems. WUA is the bridging institution between the farmers and the irrigation agencies, ensuring fair water distribution, and addressing and managing conflicts among the farmer's community and between farmers and agencies. Their primary responsibility is extended to managing the infrastructure at secondary and tertiary levels, ensuring its sustainability, and encouraging collective action. While WUAs have the potential to enhance irrigation system performance, the effectiveness of various models has produced mixed results. Therefore, refining these associations is important for better interaction of the social, political, and cultural contexts of any region (Lacirignola, n.d.).

2.4. Irrigation Water as Common Pool Resources

The harmonized, coordinated development and management of water, land, and related resources available at any spatial to maximize the results in the economic and social welfare of the community without threatening the sustainability of vital ecosystem is the concept of Integrated Water Resource Management (IWRM) (TAC, 2000).

Climatic events such as floods and droughts create fluctuations in the accessibility of surface water or surface runoff. Surface water significantly impacts water quality and quantity due to hydrological settings, boundary conditions, and aquifer properties. To address these challenges, a holistic approach and integrated use of surface and groundwater resources are essential for effective water management. The Mahanadi Reservoir Project, a multipurpose initiative, integrates canal release, groundwater pumping, and crop water allocation based on crop requirements, resulting in maximum relative crop yields throughout the year, balancing soil moisture, and facilitating groundwater flow. (Chowhary, et al., 2012).

Irrigation water is a common pool resource (CPR), characterized by subtractability (one user's consumption reduces availability for others) and difficulty in exclusion (restricting access is challenging). In the absence of effective management, these factors often result in overuse, inefficiency, and conflicts.

3. Methodology

Field observation, in-depth interviews, focus group discussions, and questionnaires are the methodological tools used in this study. The study was conducted in 2024.

3.1. Study Area:

Location and Geographic aspect

RJKIS is located in Kailali district, Sudurpaschim Province. In the geographic coordinate system, its area lies between 280 27’ East to 280 40’ 48” East and 800 53’ 45.6” North to 810 4’ 44.4” North. Eight VDCs namely: Baliya, Dhansingpur, Durgauli, Janakinagar, Munuwa, Narayanpur, Pathariya, Pratappur, and one Municipality Tikapur fall under the project area in the previous administrative division of Nepal where the command area lies in the Janaki Rural Municipality, Lamki Chuwa Municipality, and Tikapur Municipality after the federal division of Nepal. The elevation of the command area varies between 200 m to 100 msl with an average falling gradient of 1 in 700 towards the south.

Geological aspect

The RJKIS lies in the Terai Zone of western Nepal. The Terai zone is the Nepalese portion of the Gangetic plain that extends from the Indian Shield in the south to the Sub-Himalayan zone to the north. The plain is below 200 m above mean sea level and has thick alluvial sediments. A literature review of the project showed that the soil has 77 % sand, 17.3% silt, and 3.2 % clay and belongs to the loamy sand type.

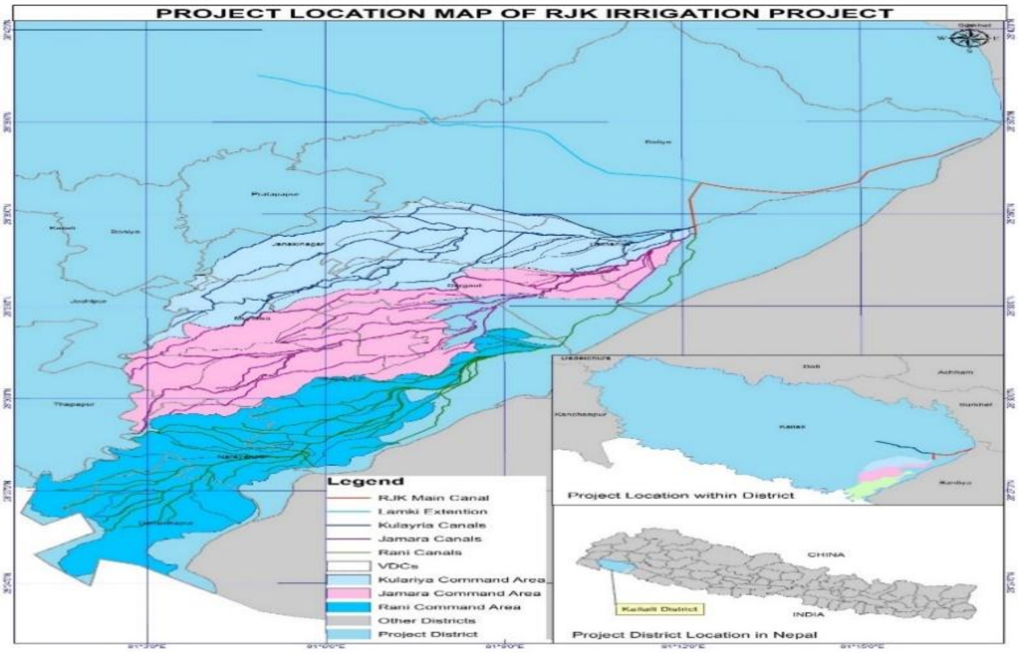

Figure 1. Project Location Map of RJKIP (Source: RJKIP)

Climate and hydrology

The climate in the project area is tropical. The mean annual maximum and mean annual minimum temperatures of the command area are 30.76 °C to 17.4 °C. The project area receives an average annual rainfall of about 1693 mm. Rainfall is concentrated mainly in four months from June to September. In comparison with the eastern part of the country, the monsoon is delayed by nearly one month in the project area as the monsoon enters from the eastern part of the country after the formation of low pressure at the Bay of Bengal.

3.2. Data

The primary data was collected from the interview and field study in the command area from the 7th of January to the 3rd of December to analyze the impact of modernization on RJKIS. The data are deemed to be as complete, accurate, and consistent as possible. Diagrams such as pie charts, bar graphs, and built-in formulas in MS Excel are used for data analysis and presentation. The MS-Excel has such features, a built-in formula that directly calculates the economic parameters ERR.

The sample size of 160 respondents representing the population of 160,000 in the command area and different stakeholders involved in modernization have participated in the questionnaire survey with a permissible error of 7 % based on the formula,

$$\boldsymbol{n} = \frac{\boldsymbol{N}}{\boldsymbol{1+Ne^2}} \qquad \text{(Equation 1)}$$

Where, n= number of samples, N = number of population, and e is the permissible error.

Clear, neutral and clear questionnaires in both English and the Nepalese language were provided to random general farmers with a verbal explanation of each question to encourage honest answers. Likewise, cross-checking with the published norms and data of similar irrigation systems was conducted to minimize the bias of the sample. The questionnaire survey was used to collect the data related to changes in the cropping pattern and intensity, labour shift, and performance of WUA. The in-depth interview was conducted for the collection of data such as the cost of modernization, guiding act and policy of the government for modernization, technical parameters of modernization, involvement of local farmers as construction workforce, and the number of labour donation participants. The field observation was used to collect data on the physical engineering structure and its functional value in the command area, the formation and governance of WUA, and the study of the land use map of the system. In addition, a focus group discussion was conducted to collect data about the historical performance and traditional handover to the next generation, construction material used in pre-modernization, and management of labour donation tradition known as “Desawar” in the Farmer’s community. The study is limited to the primary data acquired during the study period, and only the short-term post-modernization impacts are discussed as the first phase of modernization was completed just before 2 years of the study period, and the second phase is nearly to be completed in this fiscal year.

4. Result and Discussion

4.1. Information about crops per year before and after modernization

Out of 160 respondents to the questionnaire survey, 10 % of the total respondents used to have 1 crop per year, 87% had 2 crops per year and the remaining 3% had 3 crops per year before modernization. The changes after modernization are that 6% have 1 crop/per year, 35% have 2 crops and 59% have 3 crops per year. The cropping intensity before modernization was 193% improved to 253% after modernization. The percentage of respondents having their crop pattern before and after modernization is shown in Figure 2.

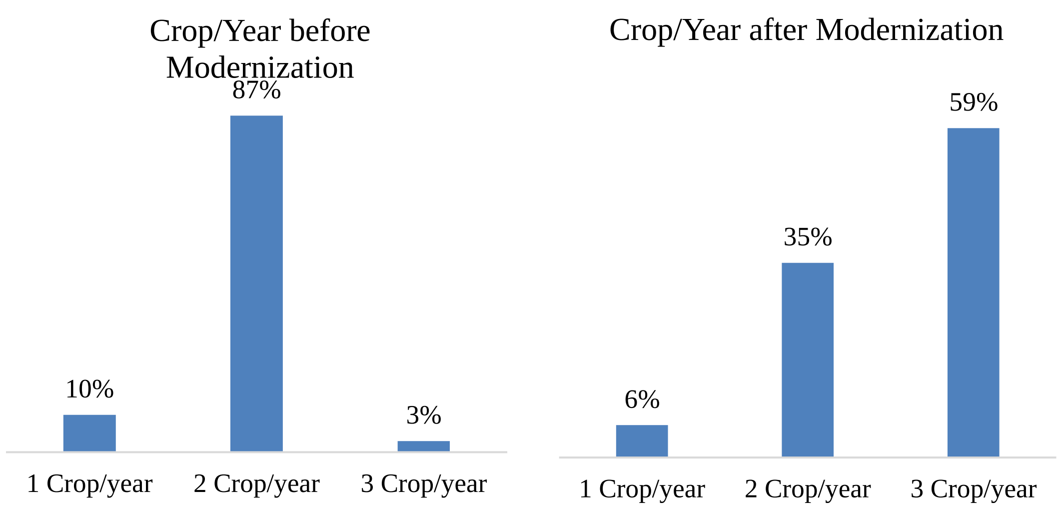

Figure 2. Crop per year before and after modernization (Source: Field Visit Data 2024)

Figure 3 shows the present value of crops in the command area before modernization was NRs 1,365.63 million, which sharply increased to NRs 7,025 million after modernization, indicating a 414% rise in crop value in comparison to the pre-modernization period. This modernization significantly impacted the increase in cropping intensity in the command area, supported by research data showing an upsurge from 1 crop/year to 3 crop/year of crop cultivation.

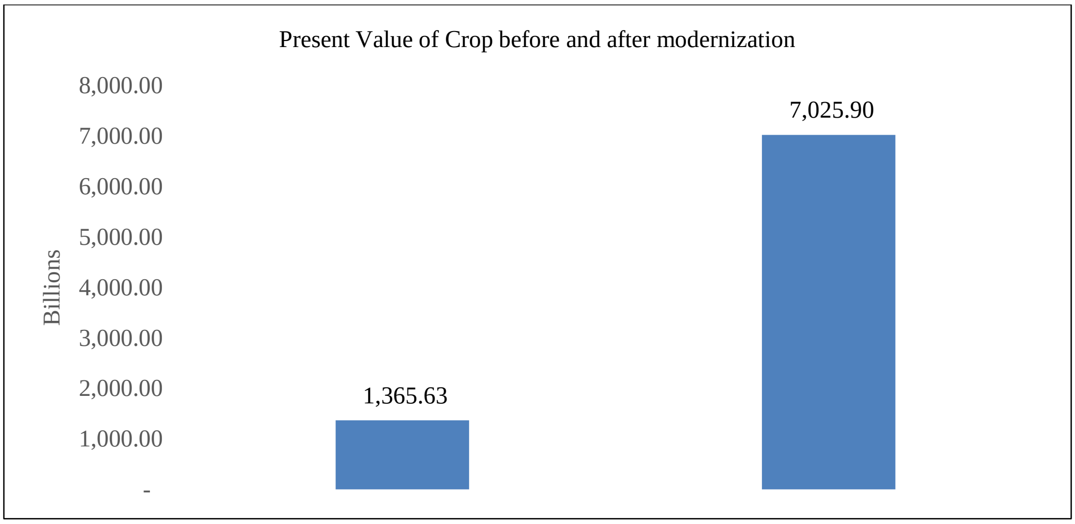

Figure 3. Present value of crops before and after modernization (Source: Field Visit Data 2024)

4.2. New Job Opportunity after the Modernization

Out of 160 respondents, after modernization, 23.3% of the respondents encountered new annual job opportunities, 49.5% of the respondents encountered new semi-annual job opportunities and 27.2% of the respondents did not encounter any new job opportunities. Figure 4 represents respondents' experience in finding new job opportunities and the present job value after modernization. The cumulative present value of the new job opportunity after the modernization is NRs 1.47 billion each year.

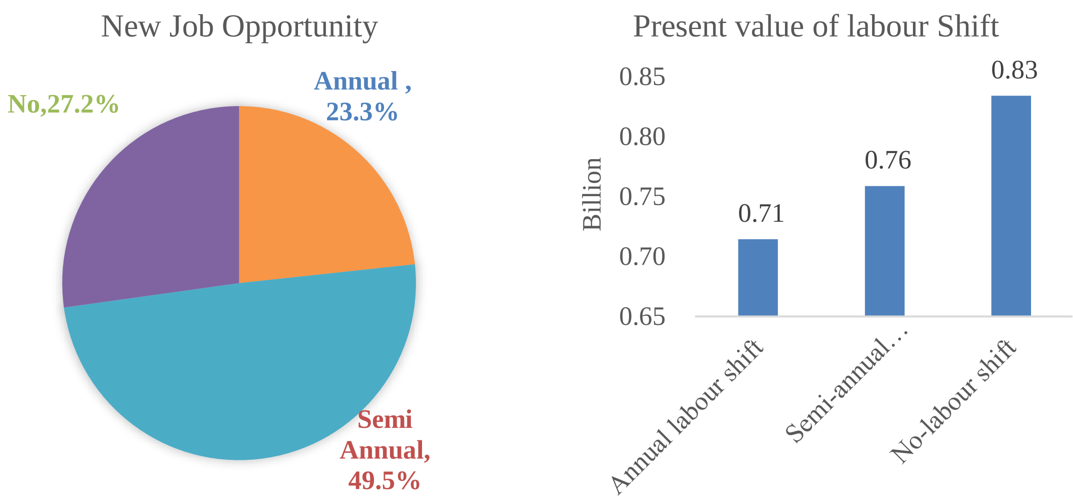

Figure 4. New Job Opportunity (Source: Field Visit Data 2024)

4.3. Strength of WUA before and after Modernization

Sample of 160 respondents, 42.6% rated the performance of WUA to be extremely poor, 24.3% rated it poor, 21.4% rated it neutral, 10.7% rated it good and 1% rated it excellent before modernization. Conversely, the change in a scenario in the performance of WUA after modernization with respondents rating 1.9% extremely poor, 1.1% poor, 39.8% neutral, 36.9% good, and 10.7% rated excellent. The changes in the by-laws, superseding traditional governance with the acts and irrigation rules of irrigation are the major lacking in the adoption of the new governance. Figure 5 illustrates the strength of WUA before and after modernization.

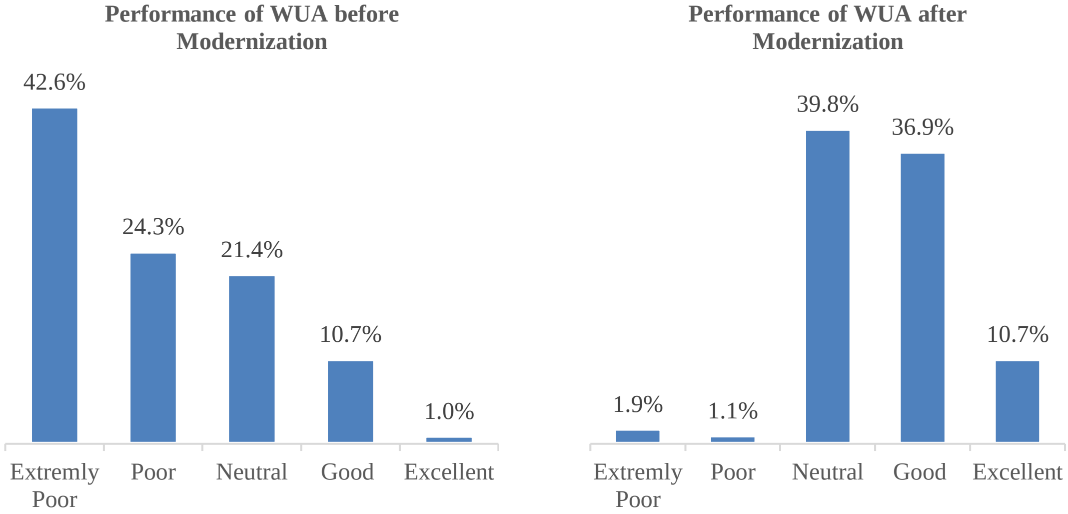

Figure 5. Strength of Water User Association before and after modernization (Source: Field Visit Data 2024)

4.4. Duty in Command Area before and after modernization

The duty of the command area is reduced to 2 liters per second per hectare from 6 liters per second per hectare. The construction of hydraulic structures, canal lining, and regulated flow has provided reliable round-year irrigation is the primary reason for the sharp decrease in duty in the command area.

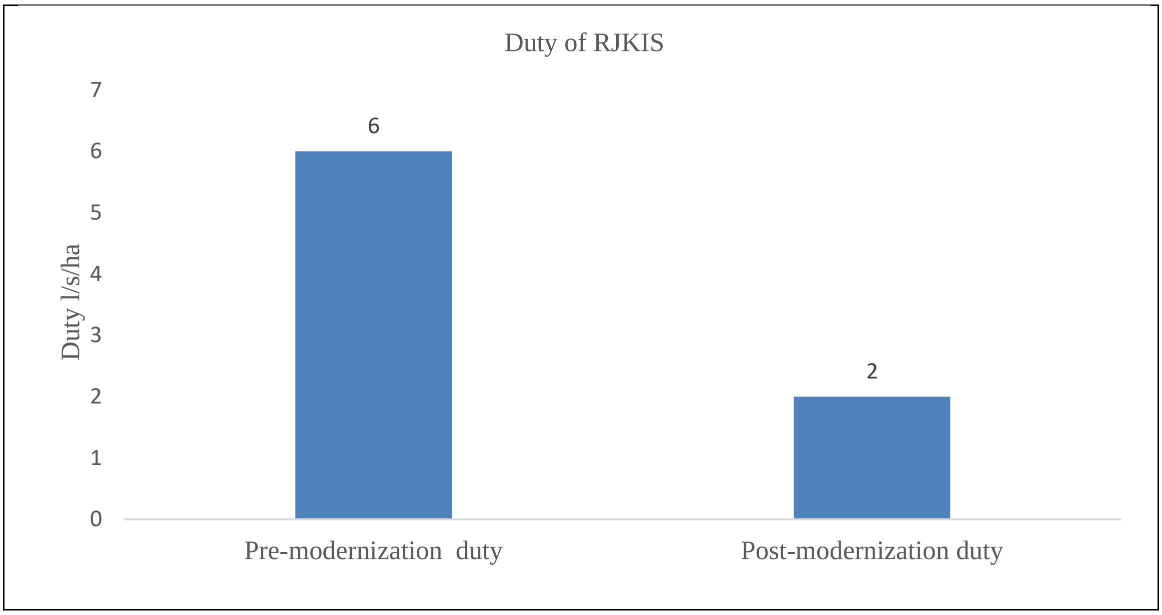

Figure 6. Comparison of Pre and Post modernization Duty of irrigation (Source: Field Visit Data 2024)

4.5. Revenue generation from Hydropower at Feeder Canal

After, the modernization the off-taking discharge of RJKIS is limited to 28.6 cumecs from 57.2 cumecs. The optimization of duty after modernization enhances the irrigation system of the existing Pathariya Irrigation System (PIS) through the diversion of water at the Headworks of the system. In addition, optimization results in the development of a new irrigation system of 6000 ha in the vicinity of RJKIS known as Lamki Extension. These two systems are planned to be in operation nearly after 10 years of research period.

The advantage of hydraulic drop at Chainage 10+050 m directs the installation of a small hydropower plant with an install capacity of 4.71 MW. The present cost of a powerhouse, electromechanical, and hydromechanical is about NRs 300 million. The hydropower produces a firm energy of 4.71 MW as the discharge in the feeder canal remains constant without major fluctuations as compared to seasonal changes in the discharge of the River in the Run of River (RoR) hydroelectric project.

Considering, the firm energy of RoR and tariff of the energy for ROR as NRs 8.4 for dry season from Poush to Chaitra and NRs 4.8 for wet season from Baishak to Mangsir and the outage rate of 5%, the total revenue is NRs 0.24 billion per year.

Conversely, considering, the firm energy of the storage hydropower project and tariff of the energy for storage project as NRs 8.4 for the dry season from Poush to Chaitra and NRs 7.1 for the wet season from Baishak to Mangsir, the outage rate of 5%, the total revenue is NRs 0.31 billion per year. Figure 4 is the comparative value of revenue of hydropower considering ROR and Storage Hydroelectric Project.

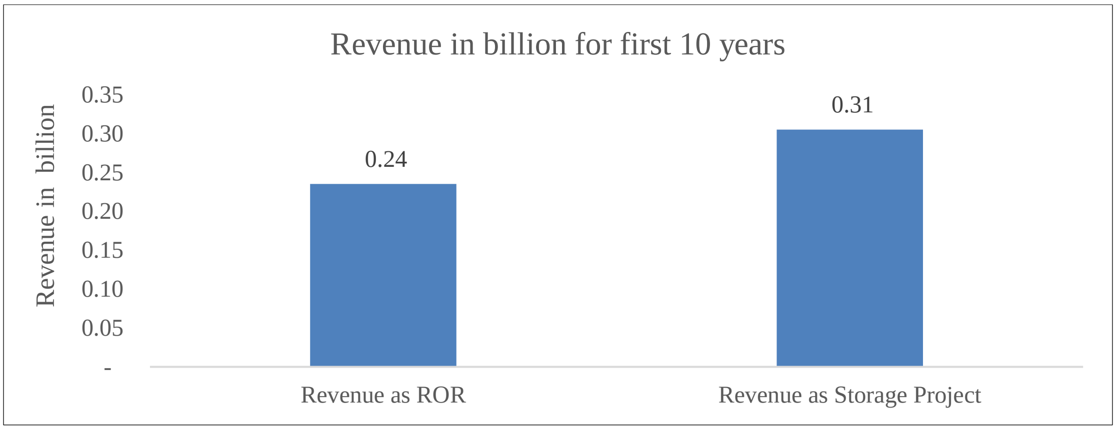

Figure 7. Comparison of RoR and Storage Hydropower (Source: Field Visit Data 2024)

4.6. Present value of project Cash Flow, ERR, Payback, and Conventional Benefit Cost Ratio

The Present value of investment in the modernization including the hydropower plant is NRs 20 billion, with the projected present value of revenue from the system being NRs 2.74 for the first ten years and 2.31 from the next 10 years to 50 years. The ERR of the modernization is 12.96 %, with a payback period of 8 years and a conventional B/C ratio of 4.72.

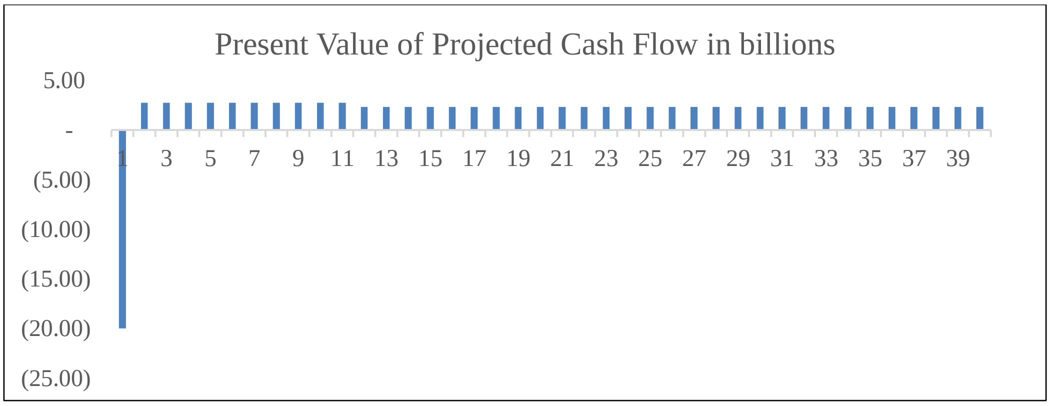

Figure 8. Present value of project cash flow (Source: Field Visit Data 2024)

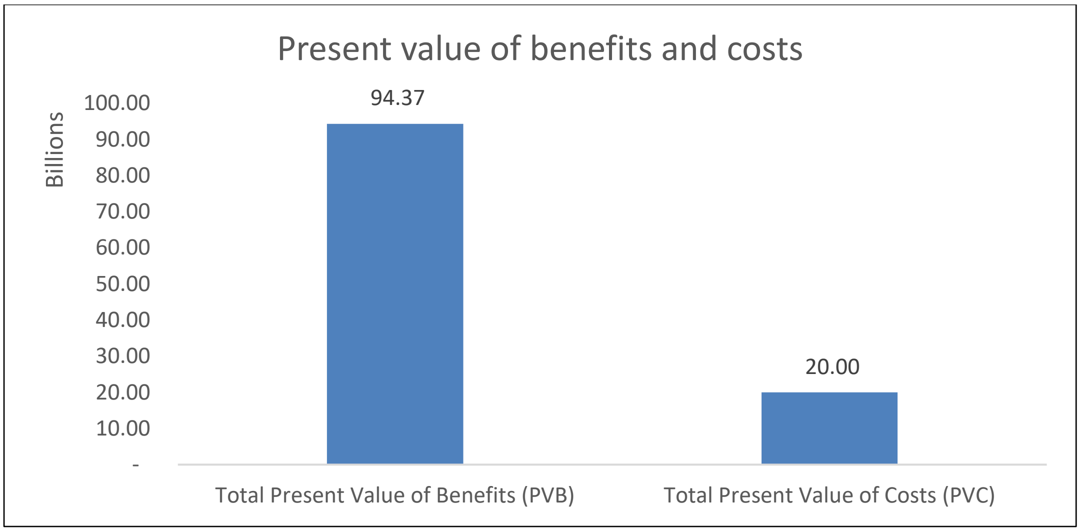

Figure 9. Present value of benefit and cost (Source: Field Visit Data 2024)

5. Discussion

i) Findings from Focus Group Discussion

The irrigation system has been in operation for more than 150 years, about 4 generations have been witnessed of this system who are actively involved in the establishment, operation, maintenance, and handover to the succession generation.

The irrigation system before the modernization was labor-intensive traditional system known as "Desawar" and used natural resources at the local level such as wood, vegetation, and big boulders. The discharge in the Main Canal, Secondary Canal, and Sub-Secondary Canal remained fluctuated due to the lack of permanent and gauged structures. Households of the farmer community used to participate in the Desawar of the Secondary System in the Karnali River. The mighty challenge Desawar consists of the risk of wildlife, lack of drinkable water, accommodation under the free sky, and mainly the risk of life-threatening construction of a temporary diversion weir in the perennial Karnali river.

After, the completion of phase 1 of the project, this might Desawar for the diversion of water in Secondary Canal has been history. The reflection of Desawar can be seen in the Sub-Secondary Canal in the form of Canal cleaning and maintenance only.

The farming practices have slightly changed, with the introduction of the cultivation of vegetables and unseasonal agricultural products. The primary cultivation in the whole command area remains the paddy or rice during the monsoon period. Likewise, the cultivation of maize after the harvest of the mustard is another parameter of change after the implementation of modernization.

In the present context, the new challenges have evolved after the modernization with the expectation of the farmer's community such as the need for fertilizer, agriculture tools, storage, and market of the products. To address these, new problems requires more skills, technique, awareness, and infrastructure.

ii) Findings from In-depth Interview

Head Regulator and Cross Regulator (HRCR), Long Crested Weir (LCW), and Proportional Distributor (PD) are the main water regulation structures in the system, LCW and PD are self-operating structures based on the difference in water head and discharge in the parent canal whereas HRCR is the flexible structure in which discharge in parent and off taking Canal can be adjusted through opening the vertical steel gates.

Aqueduct has a significant role in increasing water efficiency, as they convey the water through a drain or another canal system. Before modernization, the wooden aqueduct had major water loss through it, which was eliminated after the permanent Reinforced Cement Concrete (RCC) aqueduct. Syphon is another structure that has a vital role in drainage management, syphon has solved the circumstance of complex hydraulic formation during the mixing of Canal water and drain water during the monsoon period.

Equitable water from each Secondary Canal is distributed round the year as per the requirement of the crops. The net profit from the agricultural product is about 15% of the gross production concerning the present market value.

The UWA shows a satisfactory view of the joint management of the system which has enhanced the irrigation system in terms of water distribution, strengthening or institutional development of UWA, and increase in crop yield.

iii) Findings from Field Observation

Under the observations, the farmers were waiting for the construction in the Sub-Secondary level as the sub-secondary is the root of the irrigation in the real ground. The following observations were made during the field observation,

- Formation of WUA up to the Sub-Secondary level
- Training and skill development have been carried out by the agency for the institutional development and awareness
- The new crops are started for cultivation and cropping intensity is likely to be increased as spring/summer crop was abandoned in the previous days
- The labour shift is found in most of the cases where young youth are abroad for employment as the Desawar is almost reduced to the simple form and young women are engaged in Canal cleaning and maintenance
- The rapid and haphazard construction of the houses is seen in the entire command area. The municipal and government land use policy shall be established and monitored to save the cultivable command area.

The side intake of the system at Chisapani and all embankments for the defense of the irrigation Canal and human habitation during high discharge in a river is affected by the uncontrolled extraction of river bed material. This uncontrolled extraction shall lead to the failure of embankments triggering the devastating events in the system. In addition, the Baridya National Park located in the opposite bank of side intake has strictly prohibited the extraction of river bed materials. The imbalance extraction of the river bed has resulted in the imbalance natural flow in the bifurcation of Karnali River, as the consequences degrading the natural ecosystem of the entire National Park and the downstream of the river as the flow towards the national park during the dry season is minimal.

6. Conclusion

The farmers have positive feedback for the strength of WUA before and after the modernization demonstrating the institutionalization of WUA during the modernization reveals that the modernization is successful in the capacity development of the farmers and WUA.

The present value cost of modernization is NRs 20.0 billion, and the present value of annual crop revenue i.e contribution in Gross Domestic Production (GDP), from a change in the cropping pattern and intensity is NRs 5.6 billion per year, with a net annual profit of NRs 566.03 million per year. The NRs 1.47 billion is the economic benefit from the labour shift from the extreme minimization of the Desawar System. The hydropower generates the revenue of NRs 0.31 for the first 10 years and NRs 0.27 for the remaining active life of 40 years. The results show that the payback period from the study period is about 8 years and ERR is 12.96% considering the economic parameters of revenue generation from hydropower, increase in cropping pattern, and labour shift only. The BC ratio of modernization is 4.72 which shows that modernization is economically viable.

The study would like to suggest that a regular training and skill development programme shall be conducted under the present context of changing technology of farming and irrigation management to increase the cropping pattern and crop yield. Similarly, the Argo-based cottage industries shall be established for the employment generation of those who remain unemployed after modernization.

References

Asian Development Bank (ADB) (2020). *[Title not specified]*. s.l.: s.n.

Asian Development Bank (ADB) (2022). *Climate Adaptation through Irrigation Modernization Project*. Manila: Asian Development Bank. et al.:

Chowdhary, A.K., Chowdhary, K.K. and Shrivastava, R.K. (2012). 'Integrated water management for a multipurpose project', *International Journal of Engineering and Innovative Technology*, 2(1), pp.261–265

European Commission Joint Research Centre (JRC) (2023). *Water Reuse*. Luxembourg: Publications Office of the European Union.

Food and Agriculture Organization (FAO), n.d. *Irrigation water management: irrigation water needs*. Rome: FAO.

Griffiths, B.A.K. and Lecler, N.L. (2000). 'Irrigation system evaluation', *Proceedings of the South African Sugar Technologists' Association*, 75, pp.58–67.

Hoffmann, P. and Villamayor-Tomas, S. (2023). Irrigation modernization and the efficiency paradox: a meta-study through the lens of networks of action situations, *Sustainability Science*, 18(1), pp.181–199. et al.

Hamdy, A. and Lacirignola, C., (1994). Water resources management in the Mediterranean basin, in: *Land and Water Resources Management in the Mediterranean Region*, International Conference, Valencano, Bari, 4–8 September, pp.1–28.

Martin, E.D. and Yoder, R. (1987). Institutions for irrigation management in farmer-managed systems: examples from the hills of Nepal, *Agricultural Administration (Research and Extension) Network Paper 6*. London: Overseas Development Institute.

Parajuli, J., Eakin, H., Chhetri, N and Anderies, J.M., (2018). Institutional change of farmer-managed irrigation systems: experience from Nepal, *International Journal of the Commons*, 12(1), pp.1–25.

Pradhan, P., 2018. Farmer-managed irrigation systems in Nepal: challenges and opportunities.

Sapkota, M., 2023. Issues and challenges of modernization in Nepal: a development perspective, *Nepalese Journal of Development and Rural Studies*, 20(1), pp.28–41.

Shivakoti, G.P., Shukla, A. and Khatri-Chhetri, T.B., (1988). Comparative study of Pithuwa and Chainpur irrigation systems, in: *Irrigation Management in Nepal: Research Papers from a National Seminar*, Bharatpur, Nepal, 4–6 June 1987. Kathmandu: IIMI, pp.60–69.

Singh, A.M. (2010). Modernization of farmer's managed irrigation systems in Nepal, *Hydro Nepal: Journal of Water, Energy and Environment*, 6, pp.55–60.

Global Water Partnership Technical Advisory Committee (TAC) (2000). *Integrated Water Resources Management*. Stockholm: Global Water Partnership.

Thapa, B., Wester, P. and Varady, R., (2016). 'Towards characterizing the adaptive capacity of farmer-managed irrigation systems: learnings from Nepal', *Current Opinion in Environmental Sustainability*, 21, pp.37–44.

World Bank (WB), 2018. *Project Appraisal Document*. s.l.: s.n.

World Bank (WB), 2018. *Project Appraisal Report*. s.l.: s.n.