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# Assessing the performance of farmer managed irrigation systems in Dhading district of Nepal

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## Abstract

This study aims to conduct a performance assessment of two farmer-managed irrigation systems in Dhading District, viz. Bishaltar Irrigation Project (BIP) and Parewatar Majhitar Irrigation Project (PMIP). Performance of the physical infrastructures, water use, institutional and organizational activities were assessed along with agricultural production and serviceability. A mixed methods research design, combining ethnographic work and quantitative surveys for data collection and analysis was employed. Data collection method included system walkthrough, household questionnaire survey, focus group discussion and key informant interview. Both the systems were able to serve the farmers with moderately adequate, reliable, equitable and timely irrigation water supply except for the situations of water scarcity during spring. Water User Associations in both systems were effective in decision-making and conflict resolution but were passive in generating operation and maintenance fund. A huge gap was observed in capacity-building activities in both projects. Cropping intensity had been increased by about 70% in both the projects resulting significant increase in the average level of crop yield. However, the agricultural input facilities, extension services and market facilities are not sufficient for the farmers. Finally, the study provides general recommendations associated with policy adoption to increase resource mobilization and switch to commercial farming.

**Keywords** Performance assessment, Irrigation, Farmer's perception, FMIS, Institutional, Focus group discussion

## 1 Introduction

Agriculture, which contributes about 24.1% to Nepal's Gross Domestic Products [1], has been key to the development of the national economy of Nepal. Only about 24% of the total land of Nepal is suitable for arable agriculture because of its rugged terrain. Potential irrigable area has been estimated at about 2,537,000 ha [2]. Currently, irrigation facilities serve about 1,555,508 ha., which is about 61% of irrigable land [3]. Most of the irrigation development in Nepal is led by farmers and Farmer Managed Irrigation Systems (FMIS). About 50% of irrigated area from surface water irrigation system is under these FMISs [2].



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Agricultural productivity per unit of water could be increased by providing quality service of water (the right amount at the right time) to beneficiaries/farmers through an efficient irrigation management system. The performance of any irrigation system, either FMIS or Agency Managed Irrigation System (AMIS), depends on the operation and management of multidimensional activities of four systems: physical, institutional, social and financial system. FMIS has a simple and farmer-friendly physical system, self-cared rules and regulations, collective decision-making, equitable distribution of water, efficient resource mobilization and a transparent financial system. Conditions for sustainable or viable FMIS are discussed in detail in many literatures [4, 5].

Several previous researches in Nepal [6, 7, 8, 9, 10] revealed that the performance of FMISs are found to be more effective than that of AMISs. However, it is not always the case that FMIS ought to succeed over AMIS. As FMISs have simple and rudimentary intake with temporary structures, they are more vulnerable to being damaged during floods and landslides. Moreover, poor institutional set-up, non-uniformity in the allocation and distribution of water, lack of participatory irrigation management and lack of awareness to collect Irrigation Service Fee (ISF) are the main factors that cause FMIS to fail.

An enabling environment has been established by the Government of Nepal for irrigation development and management through the enactment of Irrigation Regulation (1989), Irrigation Master Plan (1990), Water Resources Strategy (2002), National Water Plan (2005), Irrigation Policy (2013) and recently approved Irrigation Master Plan (2024) and National Irrigation Policy (2024). Following plans and policies, the Government of Nepal introduced intervention programs to rehabilitate the FMIS. It has been remarked that continuous assessment of the performance of existing irrigation schemes is more preferable to the development of new ones [11]. Government of Nepal utilized the internal budget and fund from different donor agencies [Asian Development Bank, World Bank, Kuwait Fund for Arab Economic Development (KFAED) etc.] in the form of soft loans to rehabilitate the FMIS. Medium Irrigation Project (MIP) funded by Government of Nepal, Irrigation and Water Resources Management Project (IWRMP) funded by the World Bank and Community Managed Irrigated Agriculture Sector Project (CMI-ASP) funded by Asian Development Bank were the major rehabilitation projects initially implemented by the Department of Water Resources and Irrigation (the then Department of Irrigation), Government of Nepal. After federalism, the rehabilitation of FMIS is also carried out by irrigation division offices of Provincial Governments. Recently approved IMP (2024) and Irrigation Policy (2024) focused on rehabilitation and modernization of the FMIS. A huge investment has been put into the rehabilitation of FMIS to improve agricultural productivity by empowering WUA, expanding irrigation facilities, and strengthening the enabling environment [2, 12, 13, 14]. But the problem is the performance of rehabilitated FMIS has also run into difficulties because of the failure of irrigation agencies in recognizing the institutional aspect of irrigation systems and focusing only on improving physical capital [15, 16].

Thus, it is of the utmost importance to assess the performance of such rehabilitated irrigation systems whether such systems have failed or succeeded after the interventions. Performance evaluation of irrigation schemes helps in the identification of the problems of the scheme, which will ultimately help the system managers to develop new strategies and ways of solving the problems to ensure higher performance in the future.

Moreover, lessons derived from performance assessment of irrigation systems can be useful in other similar systems. In this backdrop, this paper presents a first-hand ethnographic observation in assessing the performance of two rehabilitated FMIS projects in Dhading district to identify how systems are performing in response to the rehabilitation intervention.

In brief, both the rehabilitated systems were able to serve the farmers with moderately adequate, reliable, equitable, and timely irrigation water supply except for the situations of water scarcity during spring and for the farmers of tail reach. Water User Associations (WUA) were effective in decision-making and conflict resolution but were passive in generating operation and maintenance fund. Cropping intensity in both systems increased by about 70% after rehabilitation, which revealed an increase in agricultural productivity and serviceability. However, a huge gap was observed in capacity-building activities in both projects.

## 2 Materials and methods

### 2.1 Study area

The study area lies in Dhading district in the Bagmati Province of Nepal (see Fig. 1). Dhading is a mid-hill district extended to the Himalayan zone, popular for commercial agriculture. It is one of the largest vegetable-producing districts in the country.

About 48,136 ha. of land is suitable for farming in Dhading district out of which 35,150 ha. is irrigable. Bishaltar Irrigation Project (BIP) and Parewatar Majhitar Irrigation Project (PMIP) are the selected FMIS projects for this study as both the projects were rehabilitated few years ago. BIP was rehabilitated from the Kuwait fund, Irrigation Sector Improvement Project in 2021 and PMIP was rehabilitated from Government Fund, Medium Irrigation Project in 2018. Salient features of the study projects are presented in Table 1.

At both the systems, WUA committee meetings used to decide the mechanism of distribution of water and the decision was communicated through the phone, social media and formal notices. Water distribution among farmers was being carried out on the basis of land area and on a rotation basis during the peak season of water need. Water flow

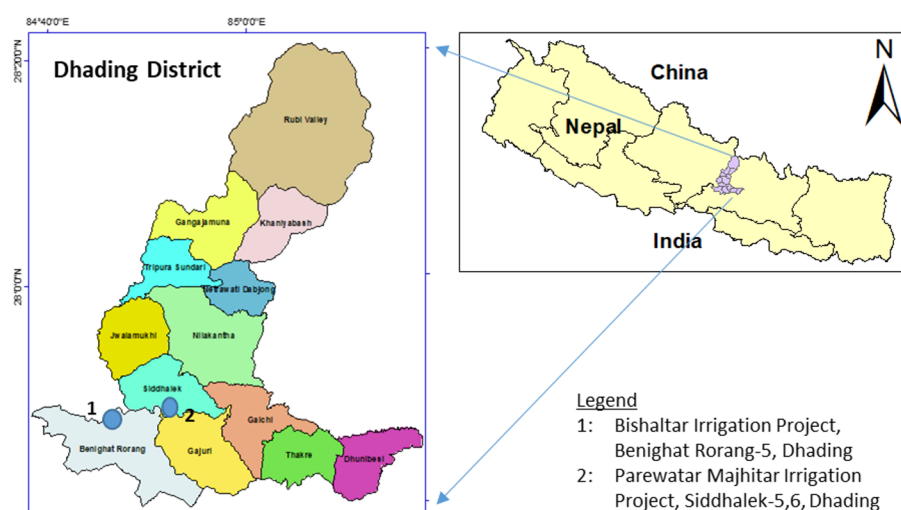


**Fig. 1** Location map of the study area

**Table 1** Salient features of the projects

| Details                      | Bishaltar Irrigation Project (BIP) | Parewatar Majhitar Irrigation Project (PMIP) |
|------------------------------|------------------------------------|----------------------------------------------|
| Project Classification       | Hills/ Rehab                       | Hills/ Rehab                                 |
| Location                     | Benighat Rorang- 5                 | Siddhalek-5,6                                |
| No. of Households            | 78                                 | 485                                          |
| Population                   | 472                                | 3395                                         |
| Nearest Market               | Benighat (2 km)                    | Malekhu (2 km)                               |
| Main Canal Length            | 7200 m                             | 15,040 m                                     |
| Gross Command Area           | 60 ha                              | 300 ha                                       |
| Net Command Area             | 50 ha                              | 252 ha                                       |
| No of blocks in command area | 8                                  | 7                                            |
| Irrigation Rotation          | 72 h                               | 84 h                                         |
| Irrigation frequency         | One block at a time (9 h)          | One block at a time (12 h)                   |
| Name of Source               | Charaundi Khola                    | Thopal Khola                                 |
| Type of Source               | Perennial River                    | Perennial River                              |
| Catchment Area               | 20 km <sup>2</sup>                 | 230 km <sup>2</sup>                          |
| Design Discharge             | 140 lps                            | 500 lps                                      |
| Water Right Issues           | None                               | None                                         |
| WUA Registration             | 1996                               | 1993                                         |

was continuous in the main canal and rotation was done through the branch canals. The possible source of income for WUA are membership fee, ISF, penalties and other charges received from members, donations received from different organization/ persons and loans received by WUA from various financial resources. WUA did not have any provisions for collections of ISF and did not have a systematic practice of keeping the record of income and expenditure. Thus, the irrigation systems were not able to generate resources to meet the O&M requirement. However, the WUA's of both systems were practicing the system of auditing WUA account and presenting the annual account of income and expenditure in general assembly and formal meetings.

## 2.2 Methods

### 2.2.1 Research design

Irrigation performance is defined as knowing the extent to which an irrigation scheme achieves established objectives [17]. A wide range of indicators had been offered in different literatures [18, 19, 20, 21] to characterize physical, institutional, social and financial aspects of irrigation performance because none of the indicators are individually conclusive. Particularly, in FMIS, irrigation performance is correlated with the performance of WUAs since they are the major stakeholder having self-decisive power. This study mainly employed farmer's perception analysis by applying a mixed-methods research design, combining ethnographic work and quantitative surveys for data collection and analysis [22]. The quantitative data consists of a closed-ended structured questionnaire to rate the responses of the respondents about the improvement of the institutional capability of WUA, water allocation, distribution, operation and maintenance, resource mobilization, conflict management, communication, training, decision-making aspects of the project, crop yield, cropping intensity and agricultural return of the irrigation system. The qualitative data consists of the open-ended questionnaire to extract the opinions and experiences of the respondents regarding the institutional

**Table 2** Sample size

| Parameters             | BIP    | PMIP   |
|------------------------|--------|--------|
| Population, N          | 78     | 485    |
| Sample Size, n         | 43.04  | 80.17  |
| Adopted Sample Size, n | 44     | 81     |
| % of Population        | 56.41% | 16.70% |

**Table 3** Questionnaire survey population

| Parameters   | BIP | PMIP |
|--------------|-----|------|
| Head reach   | 5   | 8    |
| Middle reach | 20  | 35   |
| Tail reach   | 19  | 38   |
| Total        | 44  | 81   |

capacity building of WUA, sustainability of the project, conflict management. Both qualitative and quantitative data were collected and used in the study including a field observation, questionnaire survey, key informant interviews (KII) and focus group discussion (FGD). The stakeholders of the project are beneficiary farmers, WUA members, Water Resources and Irrigation Development Division (WRIDD) Dhading, Agriculture Knowledge Centre Dhading, Local government and local people. Both qualitative and quantitative tools cover the questionnaire to find out the problems and conditions of the operational and system management of both irrigation projects.

### 2.2.2 Sample size

The sample size was determined based on statistical power calculations to ensure that the sample was large enough to provide meaningful results. Sample size was calculated based on the following formula [23]

$$n = \frac{\frac{z^2 pq}{e^2}}{1 + \left( \frac{z^2 pq}{e^2 N} \right)}$$

. Where, n= Sample size, z= 1.96 for 95% confidence level.  $p=0.5\%$  of picking choice expressed decimal,  $q=0.5$ , e= Margin of error, using 10% error margin. The estimated sample size is shown in Table 2.

### 2.2.3 Data collection and analysis

Primary data were collected through system walkthrough, KII, FGD and household questionnaire survey. A closed-ended semi-structured questionnaire survey was conducted at 44 households at BIP and 81 households at PMIP. Households were stratified according to arbitrarily partitioned head, middle and tail reach of the canal system and then the samples were selected randomly from each stratum (see Table 3 for stratified sample). Most of the respondents were heads of respective houses. KIIs were conducted with sub-engineer, engineer and division chief of WRIDD and WUA personnel to get an understanding about historical background, project management and sustainability, farmers' participation, project performance, O&M and conflict management. FGD was carried out with different groups consisting of local farmers, WUA members and WRIDD personnel to identify the overall situation of physical infrastructure, water management and maintenance in the irrigation system, agricultural system, productivity,

financial status of the farmers etc. on the basis of checklist. The main purpose of FGD was to triangulate all the information collected from the household questionnaire survey on different aspects of the performance of the irrigation systems. 15 respondents joined FGD in each project.

A questionnaire structured around themes operationalized by items on Likert scales was provided to the farmers of head to tail end region to collect data on the dependent variables (see Table 4). These different variables were intended to assess the dimensions of performance of major physical infrastructures, performance of WUA in water use activities, O&M mechanism and organizational activities and performance on agricultural productivity and agricultural returns of the project. The responses to the questionnaire were first summarized in Microsoft Excel and the scale sum and mean were calculated for the Likert scale questions for quantitative data analysis to calculate separate composite scores [24].

### 3 Results and discussions

#### 3.1 Performance of major physical infrastructure

The quality of rehabilitation work was observed by the system walk through of irrigation systems. The farmer's perception of the quality of rehabilitation construction works was shown in Fig. 2. The result reflected that a reasonable quality of work was ensured. However, the farmers of both systems were of the view that more improvement works are yet to be done.

The condition of the physical infrastructure of both irrigation systems was assessed by taking a composite score for response over 8 indicators, as shown in Table 5. The overall condition of headworks was found to be poor at BIP and fair at PMIP. The condition of the main canal in head and mid reach of BIP was found fair enough, while PMIP had better conditions. The condition of the main canal in tail-reach was found to be poor in both BIP (− 0.5) and PMIP (− 0.94). The condition of canal lining and cross drainage structure were found to be good enough in PMIP as compared to BIP. Branch canal condition is poor in both the systems. The overall response score indicates that the rehabilitation works are still needed (Fig. 3).

It was reported that a permanent diversion structure, intake and desilting basin was not constructed at BIP due to limitation in cost per hectare and farmers' priority in improving the main canal system. The major problem of the rehabilitation project in BIP was the piecemeal construction as per the availability of fund. Rehabilitation regarding construction of infrastructures was well implemented in PMIP as compared to BIP.

A study of the performance of 19 irrigation systems in Nepal based on three time periods data divulged that the lack of sufficient investment in physical infrastructure led to low performance of irrigation systems [25]. It was recommended to couple the investment with a conducive environment where irrigators can design and change their own rules through collective action [26].

#### 3.2 Performance of WUA in water use, O&M and organizational activities

##### 3.2.1 Institutional performance

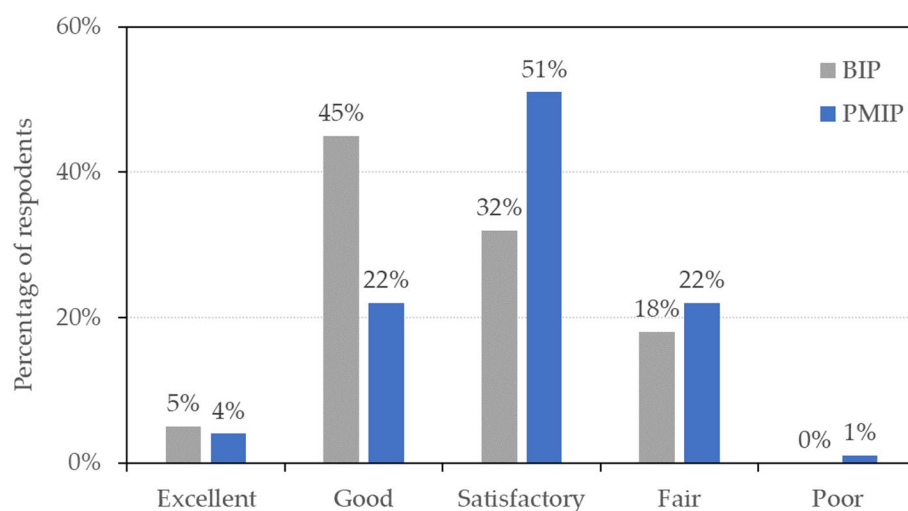
The institutional performance indicators were studied through the household survey on various activities such as the conduction of meetings, general assembly and effectiveness of WUA. The finding of the responses obtained from the respondents is presented

**Table 4** Questionnaire structured around themes operationalized by items on likert scale

| Dimension                              | Variable                                                                                                    | Likert Scale                                                                     |
|----------------------------------------|-------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Condition of irrigation infrastructure | Headworks, Main canal in head reach, mid reach and tail reach, Cross drainage works, culverts, branch canal | 3 (Very good), 1 (Good), 0 (No idea), – 1 (Need re-pair), – 3 (Not functional)   |
| Institutional Performance              | WUA meeting                                                                                                 | 3 (Scheduled), 1 (Few missing), 0 (No idea), – 1 (Ad hoc), – 3 (No meeting)      |
|                                        | Conduction of General Assembly                                                                              | 3 (Scheduled), 1 (Few missing), 0 (No idea), – 3 (No meeting)                    |
|                                        | Participation in General Assembly                                                                           | 1 (Yes), – 1 (No)                                                                |
|                                        | Enforcement of by-laws of WUA                                                                               | 3 (Full), 1 (Partial), 0 (No idea), – 3 (No enforcement)                         |
|                                        | Technical/Financial Capacity of WUA                                                                         | 4 (Excellent), 3 (Good), 2 (Satisfactory), 1 (Fair), 0 (Poor)                    |
| Water use activities                   | Water Adequacy                                                                                              | 3 (Excess), 2 (Adequate), 0 (Inadequate)                                         |
|                                        | Ease of irrigation water supply during cropping season                                                      | 4 (Easy), 3 (Time consuming), 2 (Hard), 1 (Influential), 0 (Impossible)          |
|                                        | Reliability of water distribution                                                                           | 4 (Always), 3 (Almost), 2 (Fairly), 1 (Occasional), 0 (Not reliable)             |
|                                        | Timeliness of water delivery                                                                                | 4 (Excellent), 3 (Good), 2 (Satisfactory), 1 (Fair), 0 (Poor)                    |
|                                        | Communication of water delivery schedule by WUA                                                             | 4 (Excellent), 3 (Good), 2 (Satisfactory), 1 (Fair), 0 (Poor)                    |
| O&M mechanism                          | Equitable availability of water                                                                             | 1 (Yes), – 1 (No)                                                                |
|                                        | Improvement in Capacity of O&M                                                                              | 2 (Increased), 1 (Constant), 0 (No idea), – 1 (Decreased)                        |
|                                        | Evaluation of the O&M of the scheme                                                                         | 2 (Very Good), 1 (Good), 0 (Fair), – 1 (Poor)                                    |
|                                        | Satisfaction with the mobilization of WUA in O&M                                                            | 2 (High), 1 (Average), 0 (Moderate), – 1 (None)                                  |
| Organizational Management Activities   | Decision making and Communication                                                                           | 4 (Excellent), 3 (Good), 2 (Satisfactory), 1 (Fair), 0 (Poor)                    |
|                                        | Adequacy of Fund collected for sustainable O & M                                                            | 3 (More than needed), 1 (Adequate), 0 (No idea), – 1 (Inadequate), – 3 (Minimal) |
|                                        | Sufficiency of annual maintenance expenditure to sustain the system                                         | 1 (Yes), – 1 (No)                                                                |
|                                        | Farmers' Perception towards resource mobilization                                                           | 1 (Should be increased), 0 (Adequate), – 1 (Reducing trend)                      |
|                                        | Farmers' attitude towards ISF collection and penalties                                                      | 1 (Positive), 0 (No idea), – 1 (Negative)                                        |
|                                        | Level and effectiveness of resource mobilization after rehabilitation                                       | 1 (Yes), 0 (No idea), – 1 (No)                                                   |
|                                        | Conflict in irrigation water                                                                                | 3 (Decreased), 1 (No change), 0 (No idea), – 3 (Increased)                       |
|                                        | Conflict management improved or not                                                                         | 1 (Yes), 0 (No idea), – 1 (No)                                                   |
|                                        | Effectiveness of training provided                                                                          | 3 (Excellent), 1 (Good), 0 (No idea), – 1 (Poor), – 3 (Very Poor)                |

**Table 4** (continued)

| Dimension                                  | Variable                                  | Likert Scale                                                                    |
|--------------------------------------------|-------------------------------------------|---------------------------------------------------------------------------------|
| Agricultural Production and Serviceability | Increment in crop yield                   | 3 (Adequate), 2 (Fair), 1 (Balance), 0 (No idea), – 2 (Poor)                    |
|                                            | Change in cropping intensity              | 3 (Totally changed), 2 (Moderately changed), 1 (No change), 0 (No idea)         |
|                                            | Change in cropping pattern                | 3 (Excellent), 1 (Good), 0 (No idea), – 1 (Poor), – 3 (Very Poor)               |
|                                            | People involved in agriculture            | 3 (Highly increased), 2 (Increased), 1 (Constant), 0 (No idea), – 2 (Decreased) |
|                                            | Agricultural extension services           | 3 (Very good), 2 (Good), 1 (Limited), 0 (No idea), – 2 (Not available)          |
|                                            | Agricultural credit services availability | 1 (Yes), – 1 (No)                                                               |
|                                            | Marketing Facilities                      | 3 (Excellent), 1 (Good), 0 (No idea), – 1 (Poor), – 3 (Very Poor)               |
|                                            | Accessibility of transportation           | 2 (Accessible all time), 1 (Only in dry season), 0 (Inaccessible at all)        |
|                                            | General health condition of people        | 3 (Highly improved), 2 (Fairly improved), 0 (No idea), – 1 (No change)          |
|                                            | Livelihood Enhancement of local people    | 3 (Highly increased), 2 (Fairly increased), 0 (No idea), – 1 (No change)        |

**Fig. 2** Farmer's perception of quality of rehabilitation works carried out by WRIDD**Table 5** Composite score for response over the physical status of the irrigation infrastructures

| S.N. | Infrastructure           | BIP    |        |        |        | PMIP   |        |        |        |
|------|--------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
|      |                          | Head   | Mid    | Tail   | Avg.   | Head   | Mid    | Tail   | Avg.   |
| 1    | Headworks                | 0.60   | 0.00   | – 0.84 | – 0.30 | 0.25   | 0.03   | 0.05   | 0.06   |
| 2    | Main Canal in head reach | 0.40   | 0.30   | 0.05   | 0.20   | 0.50   | 0.60   | 1.00   | 0.78   |
| 3    | Main Canal in mid-reach  | 0.00   | 0.05   | 0.16   | 0.09   | 0.50   | 0.14   | 1.00   | 0.58   |
| 4    | Main Canal in tail reach | – 1.40 | 0.00   | – 0.74 | – 0.50 | – 0.75 | – 1.03 | – 0.89 | – 0.94 |
| 5    | Main Canal Lining        | 0.60   | 0.50   | – 0.37 | 0.14   | 1.00   | 0.77   | 0.95   | 0.88   |
| 6    | Cross Drainage Works     | – 0.20 | – 0.05 | – 0.17 | – 0.12 | 0.50   | 0.54   | 0.84   | 0.68   |
| 7    | Culverts                 | – 0.60 | 0.00   | – 0.67 | – 0.36 | 0.75   | 0.54   | 0.87   | 0.72   |
| 8    | Branch Canal             | – 0.60 | 0.10   | – 0.78 | – 0.35 | – 1.00 | – 0.83 | – 1.00 | – 0.93 |
|      | Overall                  | – 0.15 | 0      | – 0.42 | – 0.15 | 0.22   | 0.10   | 0.35   | 0.23   |

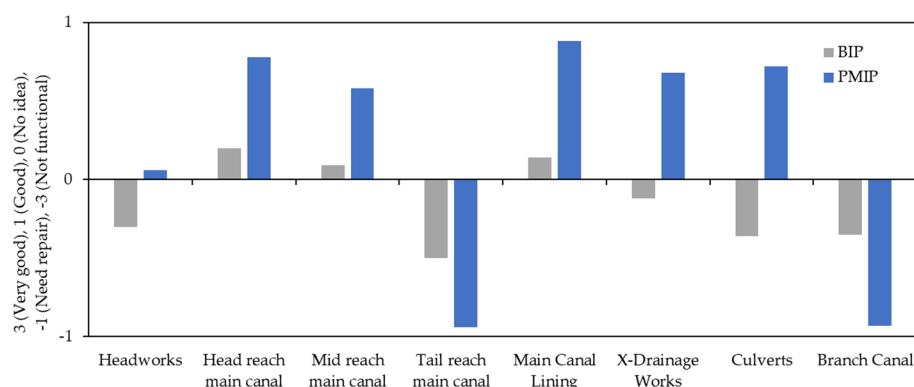


**Fig. 3** Average composite score on condition of irrigation infrastructure on a 5-point Likert scale

**Table 6** Composite score for response over wua's institutional performance

| S.N. | Description                                | BIP  |      |      |      | PMIP |      |      |      |
|------|--------------------------------------------|------|------|------|------|------|------|------|------|
|      |                                            | Head | Mid  | Tail | Avg. | Head | Mid  | Tail | Avg. |
| 1    | WUA Meetings                               | 2.20 | 2.40 | 1.72 | 2.09 | 2.50 | 2.20 | 2.42 | 2.33 |
| 2    | Conduction of General Assembly             | 3.00 | 2.90 | 1.50 | 2.41 | 3.00 | 2.31 | 2.95 | 2.68 |
| 3    | Participation in General Assembly Meeting  | 1.00 | 0.80 | 0.78 | 0.81 | 1.00 | 1.00 | 0.95 | 0.98 |
| 4    | Enforcement of by- laws                    | 2.20 | 1.90 | 1.33 | 1.70 | 1.25 | 1.03 | 1.05 | 1.06 |
| 5    | Effectiveness of Technical capacity of WUA | 2.40 | 2.50 | 1.72 | 2.16 | 2.63 | 2.34 | 2.18 | 2.30 |
| 6    | Effectiveness of Financial capacity of WUA | 2.20 | 2.35 | 1.78 | 2.09 | 2.50 | 2.11 | 2.13 | 2.16 |

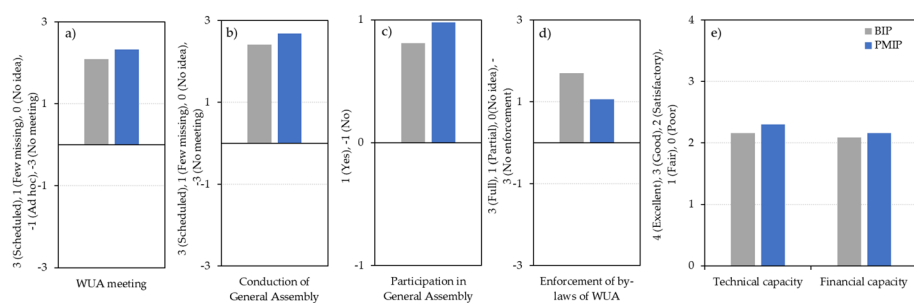


**Fig. 4** Average composite score for response over WUA's institutional performance

in Table 6. It was found that the WUA meetings and general assembly meetings were held regularly and as scheduled, with few missing in both systems. It could be concluded that most of the farmers had participated in general assembly meeting, as the composite response level was found to be 0.81 for BIP and 0.98 for PMIP. Enforcement of bylaws was partial in both projects, as the composite response level found was 1.70 for BIP and 1.06 for PMIP. The effectiveness of technical and financial capacity of WUA was found to be satisfactory, as the average responses level were found to be above 2 in both the systems (see Table 6; Fig. 4e). Thus, the overall status of WUA performance was found at the desired level and effective for organizational sustainability, as the composite response level of all activities was found to be satisfactory.

### 3.2.2 Performance on water use activities

In both the systems, it was revealed that the systems did not have major problem of water acquisition and water right to use the source of water. Allocation of water for

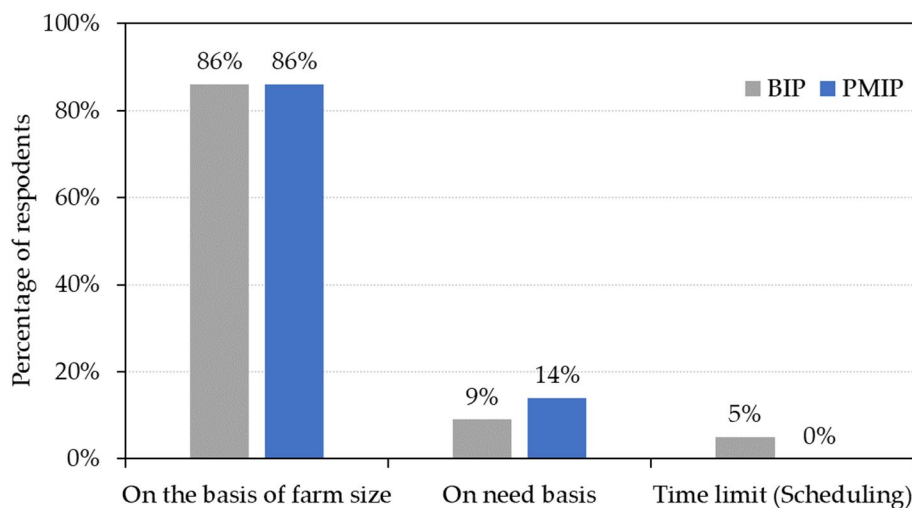


**Fig. 5** Response over basis for water distribution

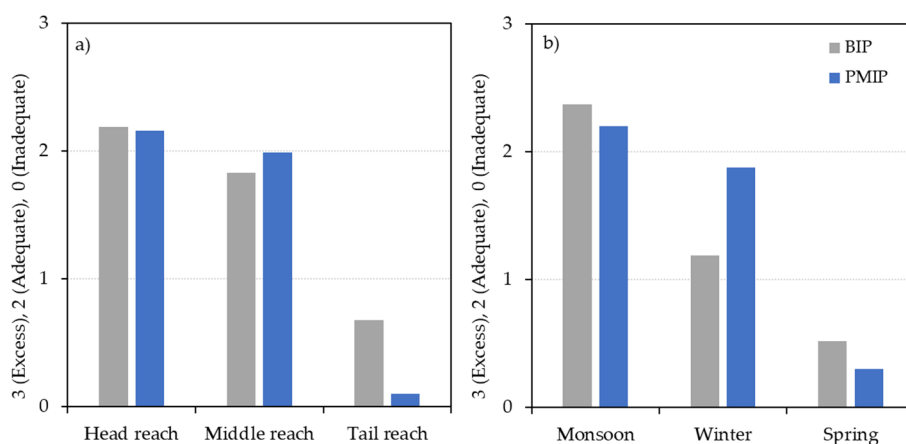


**Fig. 6** Average composite score for water adequacy at (a) different reaches (b) different seasons

system is primarily for irrigation use. In the household survey, 100% of the households said that they had never encountered any water right issues. 86% of respondents from both systems expressed that water was distributed on the basis of farm size (see Fig. 5).

Water adequacy at different locations and at different seasons, ease of irrigation water supply during cropping season, reliability, timeliness and equitable distribution of water delivery and performance of WUA in management of water distribution were analyzed and discussed below.

The water adequacy was found to be more than adequate in head-reach, nearly adequate in mid-reach and inadequate in tail-reach at both systems (see Fig. 6). Likewise, water was abundant in the monsoon, nearly adequate in the winter and inadequate in the spring season. Both the systems badly suffer from inadequate irrigation water supply in tail-reach, mainly due to the poorer condition of the main canal in tail-reach. Other reasons included incomplete lining of the main and branch canal, inadequate canal section of branch canal, lack of functional water course and lack of regular maintenance. There is a potential to improve the performance of the systems by investing the capital in the enhancement of the main canal in tail-reach and the branch canal (Table 7).

**Table 7** Composite score for response over water adequacy

| Table 7 Composite score for response over water adequacy |              |      |      |      |      |      |      |      |      |
|----------------------------------------------------------|--------------|------|------|------|------|------|------|------|------|
| S.N.                                                     | Description  | BIP  |      |      |      | PMIP |      |      |      |
|                                                          |              | Head | Mid  | Tail | Avg. | Head | Mid  | Tail | Avg. |
| Water Adequacy at different locations after improvement  |              |      |      |      |      |      |      |      |      |
| A                                                        | Head reach   | 2.00 | 2.20 | 2.22 | 2.19 | 2.75 | 2.14 | 2.05 | 2.16 |
| B                                                        | Middle reach | 2.33 | 1.70 | 1.89 | 1.83 | 2.13 | 1.94 | 2.00 | 1.99 |
| C                                                        | Tail reach   | 0.67 | 1.00 | 0.33 | 0.68 | 0.25 | 0.17 | 0.00 | 0.10 |
| Water Adequacy at different seasons after improvement    |              |      |      |      |      |      |      |      |      |
| A                                                        | Monsoon      | 2.60 | 2.40 | 2.28 | 2.37 | 3.00 | 2.23 | 2.00 | 2.20 |
| B                                                        | Winter       | 1.50 | 1.30 | 1.00 | 1.19 | 2.00 | 1.89 | 1.84 | 1.88 |
| C                                                        | Spring       | 1.00 | 0.40 | 0.56 | 0.52 | 2.00 | 0.23 | 0.00 | 0.30 |

**Table 8** Composite score for response over water availability

| S.N. | Description                                            | BIP  |      |      |      | PMIP |      |      |      |
|------|--------------------------------------------------------|------|------|------|------|------|------|------|------|
|      |                                                        | Head | Mid  | Tail | Avg  | Head | Mid  | Tail | Avg  |
| 1    | Ease of irrigation water supply during cropping season | 3.00 | 2.79 | 3.17 | 2.98 | 4.00 | 3.32 | 3.00 | 3.24 |
| 2    | Reliability of water distribution                      | 2.60 | 3.00 | 2.67 | 2.81 | 3.63 | 2.80 | 1.87 | 2.44 |
| 3    | Timeliness of water delivery                           | 2.20 | 2.37 | 1.76 | 2.10 | 2.75 | 2.09 | 2.11 | 2.16 |
| 4    | Equitable availability of water                        | 0.60 | 0.58 | 0.00 | 0.33 | 0.75 | 0.54 | 0.63 | 0.60 |
| 5    | Communication of water delivery schedule by WUA        | 2.20 | 2.64 | 1.82 | 2.19 | 2.38 | 2.14 | 2.08 | 2.14 |

Farmers of the middle and tail-end of both systems informed that it was not hard but time-consuming to get water during the cropping season since they had access to acquire water only after completion of sowing by head-reach farmers. Water distribution was found almost reliable in both systems since the average composite response level was estimated at 2.81 and 2.44 for BIP and PMIP, respectively (see Table 8; Fig. 7). In both the systems, water distribution was found satisfactory in the command area since the average composite response level was found at 2.10 and 2.16 for BIP and PMIP respectively. This implies that the conveyance capacity of the canal was increased, which was also confirmed during FGD with farmers. It was found that the communication of water delivery schedule by WUA was satisfactory in both the systems. Moreover, water distribution was found fairly equitable along the head and middle reaches in both systems. Some tail-end farmers in both system reported that water distribution was dominated by the farmers of the head-end so that water became inadequate at the tail-end of the system. The inadequate and unpredictable water supply to the tail region of Nepal's irrigation systems is very common and usually discourages tailenders from pursuing collective actions [10]. Special focus shall be entailed on maintaining water adequacy at the tail-end to enhance the functional level of irrigation systems [10].

Furthermore, farmers' perception about satisfaction over water distribution and availability revealed that 64% of the respondents were found fully satisfied, 34% were found fairly satisfied and 2% were found non-satisfied in BIP. In PMIP, 87% of the respondents were found fully satisfied and 13% were found fairly satisfied.

### 3.2.3 Performance in organizational management activities

**3.2.3.1 Performance in operation and maintenance** The operation and maintenance of irrigation structures is an important aspect of irrigation system management. Operation and maintenance of irrigation system was evaluated in terms of capacity improvement, status of O&M and satisfaction with the mobilization of WUA in O & M (see Fig. 8). It was found that the capacity of O&M quality level was improved in both the systems, as the average composite response level was found at 1.93 and 1.91 for BIP and PMIP respectively. Evaluation of the status of O&M of the scheme revealed that both schemes were found between good and fair. Survey of farmer's satisfaction with the mobilization of WUA in O & M revealed that farmers of both systems are fairly satisfied since the average composite response level was found at 0.59 and 0.63 for BIP and PMIP, respectively.

In BIP, the maintenance works, regular as well as emergency, were carried out through labor contract and the contract amount was recovered from farmers on the basis of land size. But in PMIP, the maintenance works were carried out through the mobilization of member household farmers. WUA forms ad-hoc O&M subcommittee responsible for coordinating with the farmers for the operation and maintenance of the canal and to ensure participation from each household during the regular maintenance. Absent household farmers during the maintenance had to pay a proportionate amount in cash. Main canals were cleaned of debris and mud and temporary headwork was repaired during the regular maintenance. The canal operator had been appointed for canal operation and simple repair works, while water delivery was done by the farmers themselves to their respective fields. In both the systems, the WUA had not prepared a maintenance plan and had not generated a maintenance fund, due to which there was always some difficulty in conducting emergency maintenance works. The farmers were totally dependent on the external agencies and government funds even for small improvement works and maintenance of the system. Similar results were reported during performance evaluation of FMIS in Nepal [27] and in Punjab [28]. O&M becomes a challenging task due to the low level of ISF and non-collection of ISF [28].

The findings of the responses over resource mobilization obtained from the respondents from head to tail end of the systems are presented in Table 9; Fig. 9. The fund collected for sustainable O & M was not found adequate, as the composite response level was found at -1.74 and 0.65 for BIP and PMIP respectively. It was revealed that the amount of annual expenditure for maintenance of irrigation system was not sufficient to sustain the system over time (see Fig. 9; Table 9). Farmer's perception towards resource mobilization was "should be increased" since the composite response level was found at 0.83 and 0.95 for BIP and PMIP respectively. Farmer's attitude towards ISF collection and penalties was found positive in both systems. The farmers were of the opinion that the effectiveness of resource mobilization had been increased since the composite response level was found at 0.76 and 0.98 for BIP and PMIP respectively.

**3.2.3.2 Decision making and communication** The respondents were asked to rate the performance of WUA over decision-making and communication process. Table 10 showed that the decision-making and communication process of WUA were fairly effective since the composite response level was found above 2 for BIP and PMIP respectively.

**3.2.3.3 Conflict management** The trend of conflict between farmers over irrigation water, issues of conflict, procedure to address conflicts and practices of conflict manage-

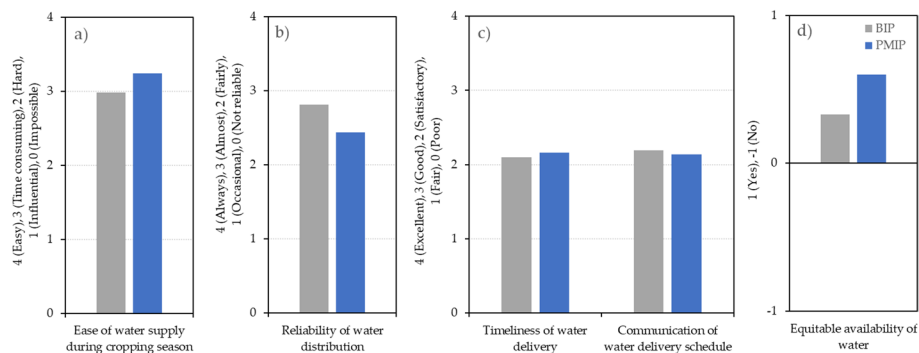


**Fig. 7** Average composite score for response over water availability

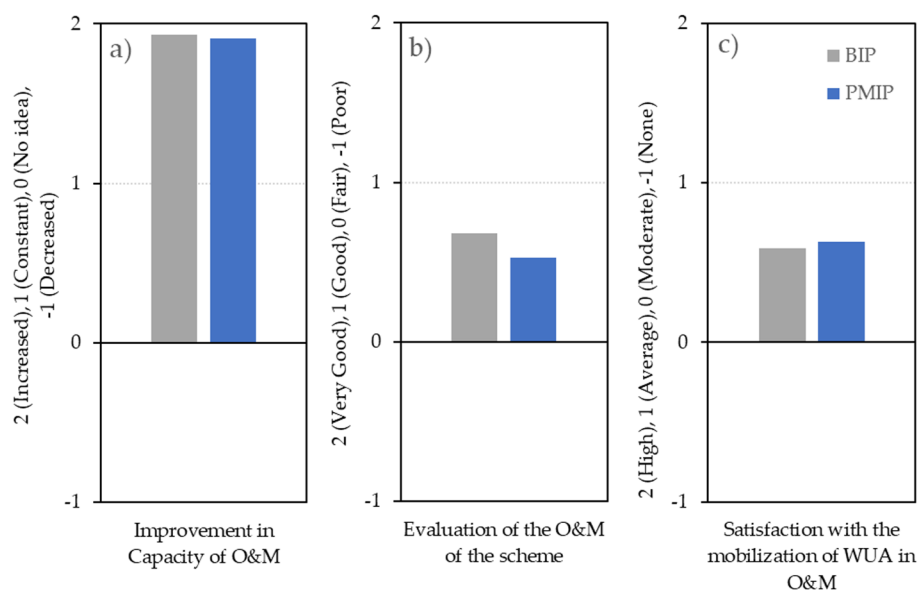


**Fig. 8** Average composite score for response over O&M of the system

**Table 9** Composite score for response over resource mobilization

| S.N. | Description                                                                   | BIP   |      |      |      | PMIP |      |      |      |
|------|-------------------------------------------------------------------------------|-------|------|------|------|------|------|------|------|
|      |                                                                               | Head  | Mid  | Tail | Avg  | Head | Mid  | Tail | Avg  |
| 1    | Adequacy of Fund collected for sustainable O & M                              | -1.40 | -    | -    | -    | 1.00 | 0.31 | 0.89 | 0.65 |
|      |                                                                               |       | 1.40 | 2.22 | 1.74 |      |      |      |      |
| 2    | Sufficiency of annual maintenance expenditure to sustain the system over time | -0.60 | -    | -    | -    | 0.75 | 0.20 | 0.84 | 0.56 |
|      |                                                                               |       | 0.80 | 1.00 | 0.86 |      |      |      |      |
| 3    | Farmers' Perception towards resource mobilization                             | 0.40  | 0.90 | 0.88 | 0.83 | 0.88 | 0.97 | 0.95 | 0.95 |
| 4    | Farmers' attitude towards ISF collection and penalties                        | 1.00  | 1.00 | 1.00 | 1.00 | 1.00 | 0.97 | 1.00 | 0.99 |
| 5    | Level and effectiveness of resource mobilization after rehabilitation         | 0.40  | 1.00 | 0.59 | 0.76 | 1.00 | 0.97 | 0.97 | 0.98 |

ment were discussed below. It was found that 33% of the respondents acknowledged that they had faced some sort of conflict arising from the distribution and allocation of irrigation water in BIP whereas only 5% of the respondents had faced conflict over irrigation water in PMIP. BIP farmers mentioned that water scarcity, water theft and competition among users were the prominent factors that caused water conflict. It was found that

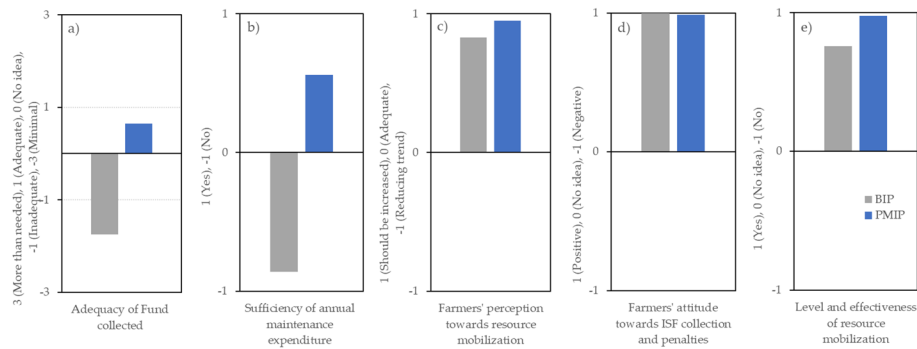


**Fig. 9** Average composite score for response over resource mobilization

**Table 10** Composite score for response over effectiveness of decision making and communication

| S.N. | Description             | BIP  |      |      |      | PMIP |      |      |      |
|------|-------------------------|------|------|------|------|------|------|------|------|
|      |                         | Head | Mid  | Tail | Avg  | Head | Mid  | Tail | Avg  |
| 1    | Decision-making process | 2.17 | 2.20 | 1.94 | 2.09 | 2.38 | 2.03 | 2.13 | 2.11 |
| 2    | Communication process   | 2.20 | 2.40 | 1.94 | 2.19 | 2.50 | 1.97 | 2.11 | 2.09 |
|      | Overall                 | 2.18 | 2.30 | 1.94 | 2.14 | 2.44 | 2.00 | 2.12 | 2.10 |

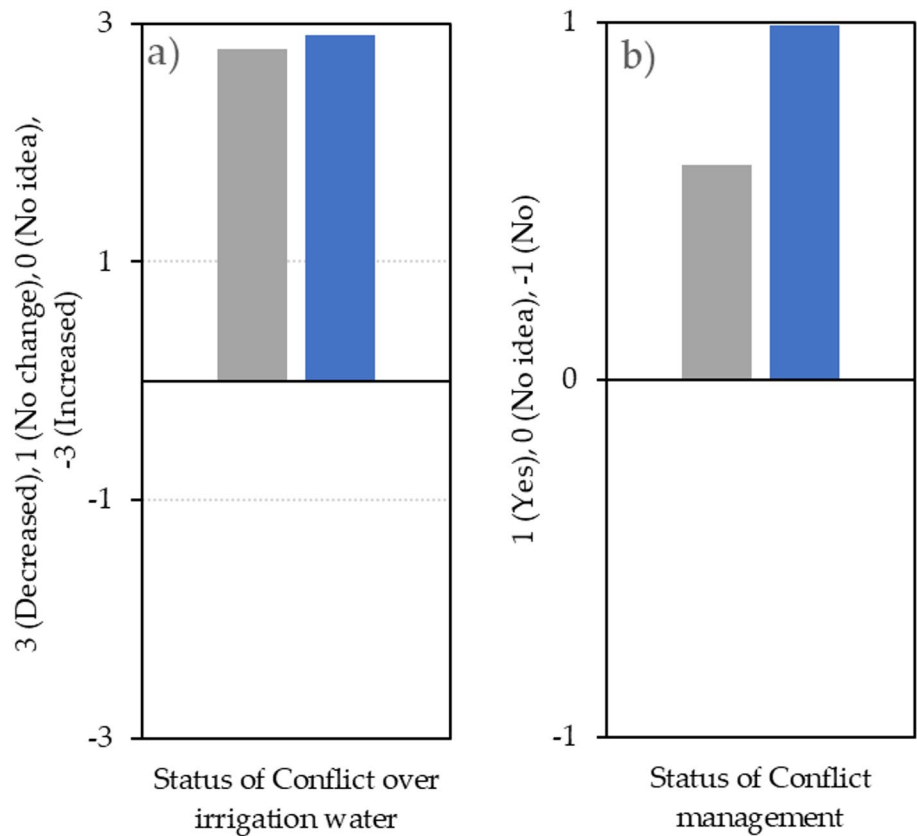
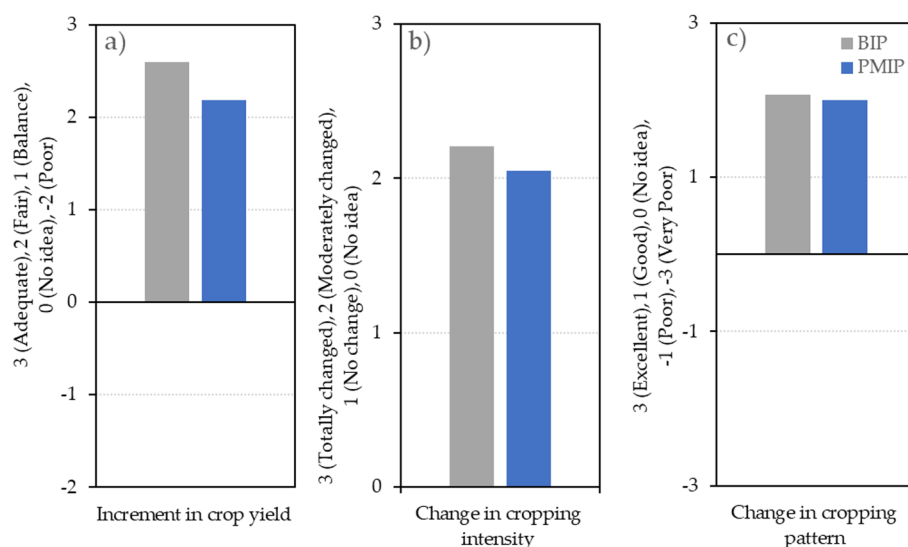


**Fig. 10** Average composite score for response over **a** status of conflict over irrigation water and **b** conflict management

**Table 11** Crop yield (t/ha) before and after project rehabilitation

| S.N. | Crops      | District average | BIP    |       | PMIP   |       |
|------|------------|------------------|--------|-------|--------|-------|
|      |            |                  | Before | After | Before | After |
| 1    | Paddy      | 3.97             | 2.73   | 4.58  | 2.80   | 3.50  |
| 2    | Maize      | 2.50             | 2.00   | 2.40  | 2.00   | 2.40  |
| 3    | Vegetables | 11.85            | 11.00  | 18.00 | 6.00   | 16.00 |

**Fig. 11** Average composite score for response over **a** increment in crop yield, **b** change in cropping intensity and **c** change in cropping pattern

conflict over irrigation water had decreased significantly and conflict management had been improved to a satisfactory level for both systems (see Fig. 10).

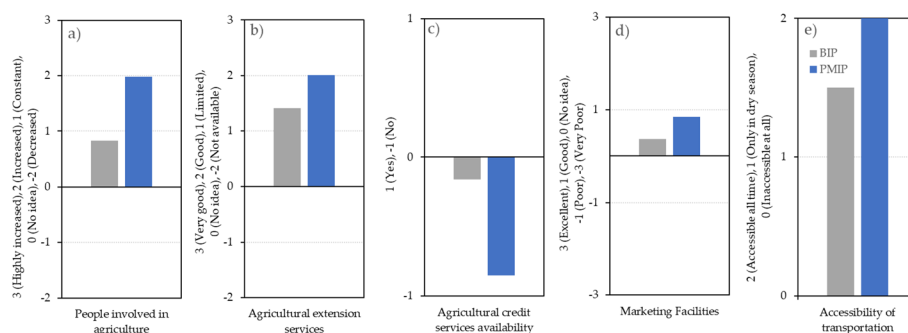
**3.2.3.4 Capacity building** During FGD and KII with WRIDD officials and WUA members, it had been reported that farmers had received some sort of training. The training provided was about the quality of construction, irrigation structure, maintenance of the system, account keeping, institutional development and irrigation water management. The farmers complained that very few numbers of trainings were conducted and only a few farmers benefited from the training. Only 12% of the respondents in BIP and only 7% of the respondents in PMIP stated that they had received some kind of training during the implementation of the project.

The effectiveness of training provided to beneficiaries was evaluated. It was found that the trainings provided were not effective, as the composite response level was found at 0.67 and 0.09 for BIP and PMIP respectively. Regarding the need for further training; 85% of the respondents in BIP and 99% of the respondents in PMIP stated that the training was needed.

During FGD and household survey, the beneficiaries remarked on the requirement of the trainings on improved agricultural practices, use of inputs for increased production, resource mobilization, commercial farming, off-seasonal vegetable farming, floriculture, fish farming, institutional development, marketing of agricultural products, multiple use of water and livelihood improvement. It implies that WUA members and farmers

**Table 12** Composite score for response over different aspects of serviceability

| S.N. | Description                        | BIP  |      |       |       | PMIP  |       |       |       |
|------|------------------------------------|------|------|-------|-------|-------|-------|-------|-------|
|      |                                    | Head | Mid  | Tail  | Avg   | Head  | Mid   | Tail  | Avg   |
| 1    | People involved in agriculture     | 1.00 | 0.40 | 1.29  | 0.83  | 2.00  | 1.91  | 2.03  | 1.98  |
| 2    | Agricultural extension services    | 0.20 | 1.89 | 1.24  | 1.41  | 2.00  | 2.03  | 2.00  | 2.01  |
| 3    | Agricultural credit serviceability | 0.20 | 0.00 | -0.33 | -0.16 | -0.75 | -0.77 | -0.95 | -0.85 |
| 4    | Marketing Facilities               | 0.40 | 0.21 | 0.53  | 0.37  | 1.00  | 0.71  | 0.95  | 0.85  |
| 5    | Accessibility of transportation    | 1.00 | 1.53 | 1.63  | 1.50  | 2.00  | 2.00  | 2.00  | 2.00  |

**Fig. 12** Average composite score for response over different aspects of serviceability

are keen to learn the necessary skills and knowledge through various training programs, workshops, demonstrations, discussions and exposure visits.

### 3.2.4 Performance on agricultural production and serviceability

**3.2.4.1 Crop yield and cropping intensity** The crop yield before and after rehabilitation at the project site were compared for three crops namely, paddy, maize, and vegetables. Yield data before rehabilitation were taken from the Detailed Design Report (baseline survey) [29, 30] and yield data after rehabilitation were taken from the impact study report [31] and verified from the field survey. The crop yield of the command area in both the projects was recorded higher compared to the district average [32] for paddy and vegetables (see Table 11).

The average composite response level for change in cropping intensity was found at 2.21 and 2.07 for BIP and PMIP, respectively, showing the moderately changed cropping intensity (see Fig. 11b). The cropping intensity, in BIP, has been increased from 180 to 250%, and in PMIP, it has been increased from 178 to 250%. Intended cropping intensity during project appraisal was 225% in BIP [29] and 237% in PMIP [30]. The National Water Plan (NWP) 2005 target for cropping intensity in 2027 is 193% for year-round irrigated area [33]. The Irrigation Master Plan (updated 2024) [2] aims for a cropping intensity of 230% by 2045. The cropping intensity in both systems exceeds national targets. The results implied that both irrigation systems performed well after project rehabilitation. Furthermore, it strengthened the necessity of allocating budget to the rehabilitation of FMIS.

From the KII and FGD, it was found that people used to grow mainly paddy, maize, vegetables, oilseeds and wheat before system rehabilitation. Now, they shifted to growing mainly vegetables, paddy, maize and a few oilseeds. Paddy and wheat are the main crops cultivated in the command area. Paddy is cultivated in monsoon, followed by vegetables and little oilseeds in winter and vegetables and little maize in spring. The average

composite response level for change in cropping pattern was found at 2.05 and 2.00 for BIP and PMIP, respectively (see Fig. 11c).

**3.2.4.2 Serviceability** As shown in Table 12; Fig. 12, the number of people involved in agriculture was decreasing in BIP, whereas it was increasing in PMIP. The average composite response level was found at 0.83 in BIP and 1.98 in PMIP. The reason for decreasing involvement in BIP was the shift of agriculture to foreign employment by the young people. It was found that agricultural extension services were fairly good in BIP and good in PMIP (see Fig. 12).

The agricultural unit in local level (AULL) provides agricultural extension and technical services to the farmers. The Prime Minister Agriculture Modernization Project is also supporting the agriculture in both systems by declaring both systems as vegetable zone. However, farmers complained that AULL was not able to provide the technical services at the proper time. Credit services availability was found poor at both systems, as the average composite response level was found at -0.16 for BIP and -0.85 for PMIP (see Table 12). It was found that marketing facilities were fairly good, as the composite response level was found at 0.37 for BIP and 0.85 for PMIP. Both systems had good accessibility to the nearest market.

**3.2.4.3 Farming practice and livelihood enhancement** From FGD and household survey, it was found that about 85% of the respondents in BIP and 100% of respondents in PMIP were used to selling their agricultural produce in the market. The farmers (58% in BIP and 46% in PMIP) shift from subsistence-based farming to intensive commercial seasonal and off-season vegetable farming. However, the number of farmers engaged in commercial farming was found increased by taking the land on lease compared to the scenario before the project. 79% of the respondents in BIP and 100% of the respondents in PMIP stated that their income had increased after rehabilitation of the systems. It was revealed that the general health condition and livelihood enhancement of local farmers were fairly improved after system rehabilitation since the overall response level was found at 2.11 and 2.00 for BIP and PMIP, respectively.

## 4 Conclusions

Performance assessment of two FMIS in Dhading District of Nepal indicated considerable improvement in the systems' performance level after rehabilitation. Both irrigation systems were able to serve the farmers with an adequate, reliable, equitable, and timely irrigation water supply except for the situations of water scarcity during spring. However, the timeliness of water delivery and water availability at the tail-end were found to be poor which could be addressed by implementing improved infrastructure, improved water management practices and enhancement of farmers' knowledge towards equitable water distribution. It is suggested to explore major factors behind the water inadequacy at the tail end of the irrigation systems.

The effectiveness of WUA in technical and financial capacity in both systems was found satisfactory. Mobilization of WUA in operation and maintenance (O&M) of the system was rated moderately satisfied. It is necessary to enforce rules for the collection of membership fee, ISFs, penalties and other resources to generate maintenance funds to cover scheduled and emergency operation and maintenance activities so that

dependency on government funds for O&M could be reduced. It is recommended to develop an asset management plan, including O&M plan.

This study revealed that agricultural productivity and serviceability have increased in both projects due to proper management of water by WUA after the intervention of rehabilitation. Cropping intensity in both systems increased by about 70% after rehabilitation. Reasonable prices for agricultural products shall be fixed by the government to encourage farmers to grow various crops and switch to commercial farming. Furthermore, it is recommended to develop entrepreneurs at the local level through a series of technical skill development. This study lacks the performance evaluation related to water delivery service due to a deficiency of data pertaining to water balance, which needs to be addressed in the future.

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#### Author contributions

R.T. and M.S. wrote the main manuscript, R.T. performed all field observation, R.T. and M.S. conducted analysis and prepared tables and figures. All authors reviewed the manuscript.

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#### Data availability

The data presented in this study are available on request from the corresponding author.

#### Declarations

##### Ethics approval and consent to participate

This study involved a semi-structured questionnaire-based survey of farmers, Key Informant Interview and Focus Group Discussion. No ethical concerns arose, as the interviews were conducted solely for research purpose. Individual participants provided their verbal/written informed consent for the related survey questions.

##### Consent for publication

All authors agreed to publish this manuscript.

##### Competing interests

The authors declare no competing interests.

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