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Sustainability Challenges of Multiple-Use Water Systems in Khatyad Rural Municipality, Nepal

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Abstract: This study investigates the sustainability challenges of Multiple-Use Water Systems (MUS) in rural hilly areas, focusing on identifying key problems, their causes, effects, and potential solutions to enhance long-term system viability. A mixed-methods approach was employed, including field observations, interviews, focus group discussions, and a questionnaire survey of 157 purposively selected respondents. Data were analyzed using the Relative Importance Index (RII) based on a 5-point Likert Scale to prioritize issues and solutions. Major sustainability challenges include poor fund management, limited technical knowledge, inadequate maintenance, lack of insurance practices, and weak monitoring. Root causes were identified as irregular Water User Group (WUG) meetings, inconsistent tariff collection, insufficient training, and lack of technical support. The study highlights the need for capacity-building, regular maintenance, formal scheme registration, and stronger government coordination to improve MUS sustainability. This study provides a systematic assessment of MUS sustainability issues using participatory methods and quantitative prioritization, offering new insights into the socio-technical barriers affecting community-managed water systems in hilly regions. To ensure MUS sustainability, policymakers and practitioners should focus on institutional strengthening, financial management training, and improved technical support for WUGs. Regular monitoring, insurance mechanisms, and government collaboration are also critical for long-term success. The research contributes to the discourse on sustainable rural water management by empirically identifying key challenges and actionable solutions for MUS, demonstrating their potential to enhance food security and reduce poverty in vulnerable communities if properly managed.

Keywords: Multiple-Use Water Systems, Rural Water Systems, Water Tariff

A. Introduction

Nepal is said as the world's second most "water-rich" country (after Brazil), but this is due to the fact that the weak nature of its water systems management combined with the great seasonal variance in water supply in Nepal. Poor management of riverine forests and riverbanks, as well as unregulated riverbed mining, have resulted in increased sedimentation, increased dead storage in the dam and its blockage, and in extreme cases, the displacement of path of rivers. Endangered and uncommon species contribute to the great fertility of Nepal's rivers and other wetlands, but they are rarely studied and understood, and they are expected to face significant threats as a result of those issues (Taylor et al., 2014). Although, In the World Economic Forum's Risk 2014, "Water supply crisis" was ranked third among the world's top risks facing (Behind budgetary crises and fundamentally high unemployment) for the next 20 years (Hunt & Rogers, 2014). Nepal has around 42,000 water supply pipe system schemes in total and around 12,00,000 tube well installed in the community. Most of the pipe water supply systems are designed for a life of up to 20-25 years. Currently, the expected service level has not been achieved through the constructed water supply scheme. 28.13% of the scheme are fully functional and 38.07% of the schemes are partially functional and in need of rehabilitation. Around 29.18 are not functional and require major rehabilitation and maintenance and 7.93% of the scheme need to be reconstruct. Inadequate budget, lack of regular maintenance, less technical manpower, and water depletion in the source are the major causes (DWSSM, 2018).

Multiple-use water systems (MUS) is a system for planning and designing water services for new and rehabilitated scheme. They are influenced by feedback from people's various water uses, reuses, and demands in their preferred community locations. Although MUS has been implemented in several locations in Nepal to address water security, the motivators for MUS adoption have not previously been identified in Nepal (N. Raut et al., 2021). Water is traditionally used in the life of a person and communities in Nepal. Hence there are certain common cultural rules, laws, and practices in connection to water usage and its resource management in every civilization. In the past, water supplies were more abundant than the demand. Each ethnic group has to be its own safe water supply system. They use to utilize water following their cultural norms. Water supplies are increasingly decreasing as the population grows. To deal with the deficiency of water, various laws, and regulations were developed as well as adjustments to the way water is used. There are now too many residents in a community using a single water supply due to excessive population density and water source depletion. To utilize the water source, some communities split the existing supply among themselves, while others make a turn and order the usage of the water from the source. Conflicts between ethnic groups are out of control across the nation from east to west, due to rising water demand and declining water sources (Adhikari, 2017). Even though it is clear how important sustainable water resource management is for development, very few people are known about large-scale water resource management and the status of freshwater biodiversity in the hills and mountains, particularly in the context of climate change. Other ministries oversee other aspects of water utilization as well. There isn't much coordination in practice across the ministries or even between different ministry divisions, and there isn't much joint planning (Taylor et al., 2014).

A multiple-use water system (MUS) is a combined water service that has been effective in providing smallholder farmers in Nepal's mountainous regions with both drinking water and water for irrigation. Water is shared by distribution lines, home tap stands, and irrigation off-take lines after being gravity collected from an upstream source and stored in a reservoir tank. The use of micro-irrigation technologies (MIT), such as drip and micro sprinkler irrigation systems, is also expected to support the system. MUS is a community-managed system that primarily serves marginal households and smallholder landowners in rural hilly areas. It can assist to reduce poverty and improve food security for disadvantaged communities when effectively applied. Water for drinking and residential purposes must be made available to the community first; and any extra water is utilized for irrigation in the agriculture field (ICIMOD, 2013).

MUS's construction costs are almost 50% lower than those of a comparable single-use drinking water system since the community provides labor, local technicians, and locally accessible materials. By supplying water to the community for both needs through a single system, MUS lowers the cost of maintaining separate systems for irrigation and drinking water. As a result, MUS dramatically lowers the price of developing, distributing, and managing water resources (Niraula, 2016). In many rural areas of Nepal, there is limited access to reliable water facilities. One of the reasons is that one-third to fifty percent of all drinking water infrastructure distribution systems fail soon after installation (K. Raut, 2014). The main challenge to the MUS's resilience and sustainability is the security of the water resource, with most systems seeing a decline in water flow. Many villages in Nepal's western highlands have experienced that the quantity of water sources has been decreasing in past years, either as a result of climate change or other reasons such as land use change and road construction (Clement et al., 2015).

The multiple-use water system (MUS) has been installed by the NGO/INGO and development agencies in the present day. Community managed infrastructure of the MUS could not be observed as sustainable. As there are many advantages of the MUS but the interventions for sustainability if not considered may become a waste of the financial resource. As the community perceives water as a free natural resource and an aspect of the free use of the supply system. It is observed that government resource is allocated for the reconstruction and maintenance of the same scheme before the design period of the water scheme. This research is about studying the problem and issues associated with the MUS and its feature with the relevancy of the current practice and to dig out its overall effectiveness. The general objective of this study is to identify the issues related to the effectiveness of multiple-use water systems in the high hill region of Karnali province of Nepal.

Water Resource, Single-use and multiple-use system

Water services are planned, designed, and provided using the Multiple-Use Water Services (MUS) participative method, which starts with the many households and productive demands of water users who draw water from various sources. The MUS strategy includes governance as well as the construction of new infrastructure and its repair (Basnet et al., 2011). Water service is the provision of water of a certain quality, quantity, and dependability at a particular location. While phrases like "water supply scheme" or "irrigation scheme" imply some sort of infrastructure, the definition places more emphasis on outputs-what people get than on that. In this study, the architecture for assessing costs, benefits, and market prospects is provided by water service tiers. Different water service levels enable various household and productive activity levels. Single-use techniques entail planning, funding, and managing water supplies for a single intended application, such as home or agricultural irrigation. In practice, water is frequently used for a variety of reasons, which may have an impact on sustainability and human health. The norm for providing water services is single-use methods. Multiple-use techniques involve the design, financing, and administration of integrated water services for a variety of home and productive purposes depending on consumer demand. The two categories of multiple-use services in our typology domestic plus and irrigation plus, reflect the prevalence of sector-based services and variations in service delivery strategies. Water services for households as well as productive purposes are provided via domestic plus methods. Water services are provided for home and non-irrigation-producing activities as part of irrigation plus techniques (Renwick et al., 2007).

The idea of MUS has drawn more attention in international water and development fora and has shown promise for improving the social and gender equality and productivity of water systems created for single use, such as irrigation or water delivery. The International Development Enterprises and a few other development agencies have been exploring and executing several MUS models in Nepal. Although these systems have been shown to have short-term positive effects on gender issues, promoting gender equality, nutrition, and health, their long-term viability and resilience have not yet been examined. The vast majority of systems continue to provide water for various purposes and still have operational official institutions. Such links between social capital, basic features of water resources, and also the features of infrastructure, such as the geographical nature of the system and technical capability to deliver water equally, were highlighted as the internal determinants influencing sustainability (Clement et al., 2015).

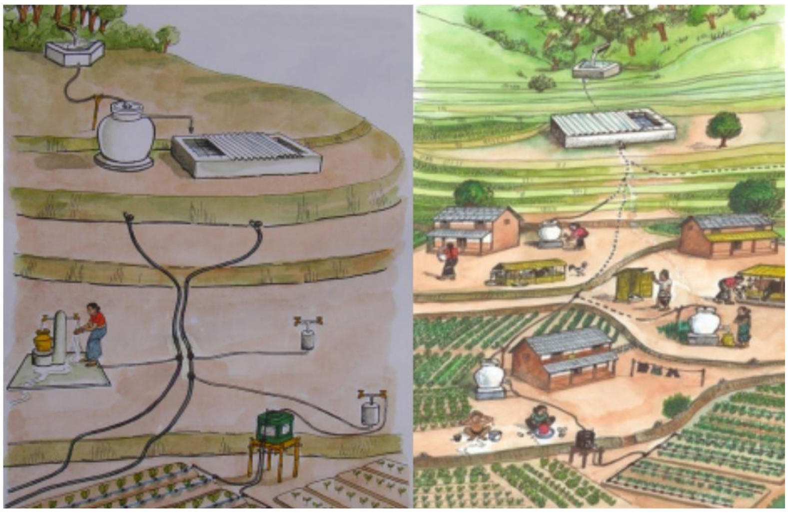

Fig. 1. Pictorial Approach of MUS (ICIMOD, 2013)

Multiple-Use Water Systems (MUS) are water systems constructed in such a manner that a single water system may serve multiple uses, including household, productive, and other water demands such as renewable energy. As a result, it takes into account the water requirements of each of those components. MUS, by definition, might provide a variety of rural community requirements such as clean drinking water, irrigation, rural electrification, improved water mill services, and assistance for various domestic water-based industries such as horticulture, fisheries, animal/poultry farming, and so on (RVWRMP, 2022).

The extent of water-related productive activities in rural Nepali families supported by single-use vs. multiple-use water systems (SUS/MUS) is examined, as well as the elements that allow for highly productive activity in households. Regardless of what the rural water systems were intended to support, it was discovered that the great majority of families engaged in small-scale productive activities, and more than half of them generated revenue from activities related to water. The primary occupation of households with high levels of productive activity is farming. These households also use productive technologies, are driven to engage in productive activity, have received training in water-related productive activity, and have received external support for their productive activity (Gc et al., 2020).

The majority of farmers in Nepal's western middle hills are smallholders who frequently employ family members and adhere to conventional agricultural and water management techniques. In the past, they have relied on rural water systems to supply both their home requirements and a variety of other demands (drinking, cleaning, washing, and sanitation). There is rising interest in using similar systems for other types of small-scale agriculture, such as raising cattle and growing vegetables. These activities appear to be a significant source of revenue for rural households. However, little is understood about the prerequisites for enhancing these activities and improving lives. This study analyzes the prerequisites for rural water systems to become functional and technically sound and provides suggestions for action (Gc et al., 2020).

History of MUS

In the Zaio region, irrigation canal water is used for a variety of purposes that improve health, lower costs of living, or even generate extra cash for rural communities. Water from irrigation canals can be stored in Jboub, traditional water storage structure in North African region, and used for longer periods both inside and beyond the irrigated area, even when there is no flow. For example, the increased potential for livestock and small-scale productive activities, which are derived from the many uses of (stored) canal water (Biologist, 2003).

Water is scarce in the Kingdom of Saudi Arabia, both in terms of supply and quality. This prompted the Kingdom to make significant expenditures on water desalination, an unconventional method that has so far been very expensive to improve water supply. Therefore, water users must use it as efficiently as possible by preventing waste and allocating it to the most lucrative pursuits (Al-Harkan et al., 2009). Users would be encouraged to save water and manage their usage if prices were reasonable. The value of irrigation water would also assist authorities in reallocating water across competing areas and even rival sectors in the most effective manner (Al-Harkan et al., 2009).

Rural residents' water requirements are comprehensive and take into consideration small-scale economic activities, personal cleanliness, drinking water, and food preparation. To ensure food security, generate income, and lessen the vulnerability of the poor, these actions are all crucial. Like in many other nations, water supply projects in Colombia that adhere to national norms and regulations tend to be scattered and frequently overlook creative solutions. Innovative methods that take into account all essential water-related activities connected to livelihoods can significantly improve household economics in underdeveloped places. Diverse kinds of uses and users are taken into account when building rural water delivery systems, and household users engaged in small-scale productive activities are rarely acknowledged. Rural water demands have traditionally been viewed primarily as household requirements, excluding the quantity of water needed for minor crops and livestock (Domínguez et al., 2008).

These uses are crucial to ensuring people's livelihoods, nevertheless. Although regulations call for surveys to determine local circumstances and the potential for raising water allotments, it is customary for designers to stick with the "number" specified in the regulations. By advising more water for those living in densely crowded areas and less water for those living in smaller communities, it also encourages inequality. The promotion of surface water and groundwater as the only sources of water due to the legislation's approach to supplying drinking water to achieve a health impact. The idea that there is a surplus of water in the country has made the problem. Policies and legislation have pushed for the use of alternate sources, but there hasn't been much of a shift in the rules that enable the activity itself. The water quality requirements for rural water delivery systems need to be more adaptable and based on the various uses of water. To make the most use of available resources in the community, it may occasionally be more effective to encourage water purification at the home level (Domínguez et al., 2008).

The de facto usage of rural water supply infrastructure for productive uses is a recently recognized practice in Honduras. Although this de facto usage of rural water supply systems may pose threats to service sustainability, the instances also demonstrated that a variety of very inexpensive solutions might assist in limiting water consumption. The efficient utilization of rural water delivery systems is shared by all systems and consumers. However, the scope varies depending on the user category. Day laborers and subsistence farmers on one end of the range utilize a little water for tiny livestock or irrigating a kitchen garden. These provide additional food for household consumption as well as some additional revenue on occasion. They only use water delivery systems for these purposes. Because of the quantities they demand, especially during peak hours, their water usage may have a detrimental impact on sustainability, since it may lead to disputes over water resources with neighboring populations or inequitable water allocation within a system. However, it is only one of many elements influencing sustainability, and in most case studies, it is not the most significant (Smits et al., 2010).

GWI has discovered flaws in the single use planning and design approach to water service delivery. Community members eventually changed systems planned for single use, either home or irrigation, into de facto multiple-use systems. This means that rural people require water for a variety of purposes. This necessitates the provision of water for both home and productive needs. As a result, the GWI used the multiple water use system concept in developing water systems for three towns. Before the introduction of the facilities, only 43.3% of people that they traveled fewer than 500 meters (the maximum distance to go to obtain water) to access water. Households in Venn had to trek nearly 2 kilometers to get water from the Black Volta. Following the installation of the new facilities, 70% of people traveled fewer than 500 meters to receive water. The facilities have also decreased the time required to fetch water. To maintain the flow of benefits from the facility, communities are actively involved in its maintenance through contribution and management activities (Gwi-Ghana, 2012).

Since 2003, IDE and Winrock, in collaboration with other non-governmental organizations (NGOs) such as SAPPROS Nepal, Agricultural Enterprise Centre, and Centre for Environmental and Development (CEAPRED), have invented and field-tested these 'hybrid' systems. From 2004 to 2008, IWMI and others recorded and contributed to a national learning alliance for scaling up, particularly as part of the eight-country (Basnet et al., 2011).

Water Service Status of Nepal

The government of Nepal has aimed a goal to make accessible to all Nepalis by 2019 with a basic drinking water system. Nepal government has divided the water service into three levels. Basic level of water service, intermediate level of water service, and high level of water service. Clean drinkable water consisting of the quantity of 45lpcd in the normal area or 20lpcd in a dry area, where people depend on rainwater harvesting, with fetching time less than 30 minutes from the reliable water source is declared the basic service. Clean drinkable water lies under the Nepal government standard consisting of the quantity of 100lpcd availability very near to the house with reliable water source is said as intermediate service. Similarly; the same water as intermediate delivery through the pipe system near the home following the Nepal government quality standard- 2062 is stated as high-level water service. 87.88% of the household has access to the basic level of water service till 2018 which was 83.59% in 2014. Water service coverage in Sagarmatha provenience, Madhesh provenience, Karnali provenience, and Sudur Paschim provenience is below the average service of Nepal. Bagmati, Gandaki, and Lumbini provenience has more than average drinking water service. Gandaki provenience has the highest service coverage which is 89.89% and Karnali provenience has lesser service coverage, which is only 84.18%. Among those service coverage, 51.69% of the household has drinking water facility through a pipeline system (DWSSM,2018).

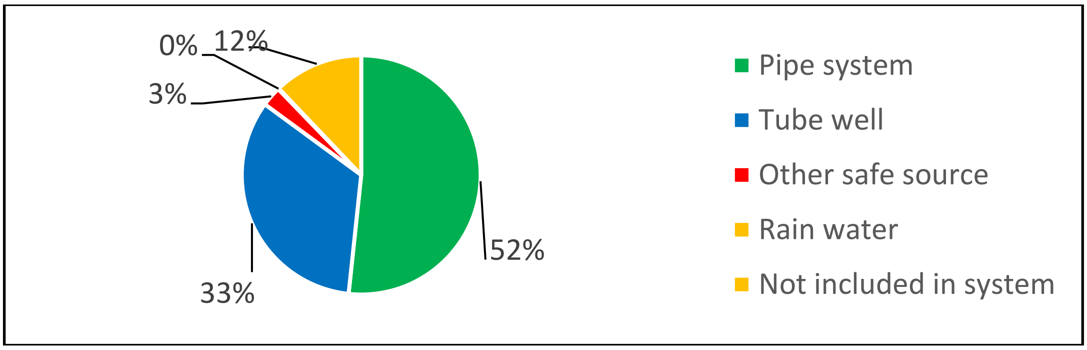

Fig. 2. Overall Water Service Status of Nepal (DWSSM, 2018)

Table 1. Water Service Status in Karnali Provenience of Nepal (DWSSM, 2018).

SN	Water supply system	Numbers of Household	Percentage of Household
1	Pipe system	255061	80.90
2	Tube well	2041	0.65
3	Other safe source	7899	2.51
4	Rain water	412	0.13
5	Not included in system	49866	15.82
	Total	**315279**	**100**

MUS Impact Scenario

The enhancement of human health and rural livelihoods are some of the good benefits of the many uses of irrigation water. The linkages between irrigation and drinking water supplies, the amounts of water used, hygiene practices, and disease transmission pathways are all, nevertheless, poorly known. There is a need for further field research, particularly in sub-Saharan Africa, to determine the ideal institutional and technological settings in which irrigation water might offer potential for health improvement. Combining home and agricultural water systems would target more advantages with the same investment as a result of the recent increasing efforts in the water industry to achieve the millennium development objectives (Boelee et al., 2007).

If health is openly and effectively addressed, multiple-use water services can be more beneficial to health than separate water sources for home and industrial users. This implies that appropriate water allocation for diverse uses, safe sanitation, and giving supplemental health and hygiene education must all be given the proper consideration in the design process. These components can also be helpful in the gradual transition from single-use systems to water services with multiple-uses. For cleanliness and drinking water, enough high-quality water is required (Boelee, 2008). In terms of effects on household livelihoods, raising livestock and gardening were the most frequent productive uses of water made by all families, with the growing of basic crops largely reliant on seasonal rainfall. Brewing beer, selling food and water, creating bricks, and other water-based activities were also available. The latter was utilized by significantly fewer families, but for those who did, the earnings recorded were comparably substantial. Households in iWASH communities (and particularly MUS interest group members) were more likely to engage and generate revenue from practically all activities involving water (Marks et al., 2016).

Additionally, iWASH families were able to more effectively vary their assortment of productive water-based activities. In iWASH villages, more respondents (67%) stated that women made at least half of their household’s total income, compared to respondents in control areas (51%). Comparing MUS interest group homes to control households, iWASH communities’ MUS interest group members were more likely to report being food secure and consuming a larger variety of food kinds. Comparing MUS interest group participants to control homes, the likelihood that a member of the group had consumed one or more animal products (meat, milk, or eggs) in the past. Children under the age of five, saw fewer cases of diarrheal disease and respiratory illnesses in iWASH communities, while people of all ages suffered fewer injuries from water fetching. Although the difference in injury incidence was statistically significant, further studies and a bigger sample size are required to fully understand the effects of MUS on children’s health (Marks et al., 2016).

In Toridada-Nepal, most families exhibited a need for access to water for both residential and productive purposes, and vegetable consumption and income increased. As with previous MUS initiatives, better water availability and support of kitchen gardens resulted in less time spent fetching water and more time spent growing. inclusion of the community in all phases of implementation, negotiation to resolve caste-related disputes, creation of a workable water user committee for system operation and maintenance, instruction in the use of micro irrigation and vegetable cultivation, and creation of a marketing committee to assist villagers in selling production (Mikhail & Khawas, 2008).

Rural household supply frequently includes livestock drinking facilities. In rural places, it is very common and well welcomed by the communities to add livestock troughs to the water facilities that serve the public. For bathing at rivers or other sources and for grazing on shared property, herds of animals still frequently have to travel considerable distances in many places, especially during the dry season. Small-scale farmers find this time-consuming, and it lowers the production and health of the animals (IRC, 2012). Even in areas with extremely limited access to water, people utilize water for domestic and productive tasks at and around the homestead, even though not all members of a community may be participating. Water availability that households have determines how much of these activities they engage in. The more water is put to productive use after meeting basic domestic requirements, the better the access to bigger volumes of water brought closer to the homestead (Smits et al., 2008).

Normally between 40 to 100 lpcd are required, supplied within a short roundtrip from the homestead, for small-scale productive uses to occur at a substantial level. A water ladder that may be used to prepare for the amount of access necessary to satisfy particular water needs summarizes the empirical relationship between access to water and its usage for various purposes. The explicit allocation of more water is a difficulty that water committees overseeing multiple-use services must address in order to meet the community's diverse demands while ensuring a basic supply for everybody. Evidence of this was discovered, notably in the form of internal rules and regulations. But for communities to create regulations, outside assistance may be necessary. This has to be specifically addressed in support programs for community-managed services. Despite the minimal quantities needed for MUS, growth of MUS in restricted basins might be constrained by availability to water resources. There is potential to improve access to water resources for a variety of applications in open basins. When there is a chance that anything may put other users in a position of local, that risk needs to be handled within the parameters of local water resource management (Smits et al., 2008).

Integration of both watershed and livestock management necessitates even more coordination and communication between sectors, which is already required for the provision of multiple-use water services in general. Failure to take livestock demands into consideration in water systems with numerous users, especially in places with watershed management practices like enclosures, may exacerbate inequality and conflict while boosting competition for limited water and land resources. Much larger advantages for rural development might possibly be attained when livestock demands for water and food are taken into consideration (IRC, 2012).

In many places of the world, there is a shortage of water resources due to rising demands for irrigation, industrial, and environmental applications. Typically, these conflicting needs are taken into account on a macro inter-sectoral scale, and policymakers are mostly interested in how to deal with rivalry between urban, industrial, and agricultural water supply systems. Local water competition, on the other hand, is very significant and affects the availability of water across sectors for different consumers. Some industries that consume water, particularly irrigated agriculture, also supply water for uses other than their main one. Despite the fact that the effectiveness of irrigation systems is mostly measured by how well they can supply water for agricultural output, irrigation systems can supply water for other purposes. Despite the little amounts of water consumed, these activities are highly valuable in terms of household income, nutrition, and health (Meinzen-Dick & Jackson, 1996).

Multiple-use water services are in a good position to incorporate livestock demands into its planning, financing, provision, and administration of sustainable water services for household and productive purposes because they take people's diverse water needs as their starting point. Due to the great demand and rather inexpensive construction costs, cattle troughs are included in the majority of functional multiple-purpose projects. To adapt to changing livestock management methods, people in regions with watershed measures may need to make extra preparations, such as supplying water and space for feed production (IRC, 2012).

Communities have a long history of creating their own diverse water sources in many nations for a variety of reasons. Ancient traditional irrigation canals, healing springs, sacred ponds, and waterspouts are still in use today in Nepal and are an essential component of the country's culture, religion, and overall wellbeing. Some of these older structures are still standing today because of their excellent original quality and the great skill and desire of the users to contribute to their upkeep. The core of WUMPs is the identification of water resources. While some infrastructure was created with many uses in mind from the beginning, gravity flow water systems intended for home use were transformed significantly into multiple-use systems in practice (Rautanen et al., 2014).

Communities and project management both seemed to need to unlearn single-use mentalities. Therefore, encouraging different uses for water and multiple sources of water is all about accepting that this will happen regardless of whether the systems are built for it or not. Many stakeholders must simultaneously maintain vigilance to ensure that essential requirements for the provision of drinking water are not jeopardized. WUMPs methods were completely integrated into local government planning processes at the intermediate level. Even in a highly politicized environment without any elected council members in place, this planning, prioritization, and institution-building process seemed to remain stable. Regardless of the new local government system, the project's capacity development for critical mass is anticipated to have an impact over the long run. The fundamental procedure is now economical because to the modular approach to WUMPs, and as a result, any local government may now prepare WUMPs without external finance. Finally, longer-term transparent planning at least partially prevents ad-hoc elite capture (Rautanen et al., 2014).

The situation in the working village development committees in 2007/2008, when the WUMPs were completed for the first time, is compared to the situation in 2010/2011, when the WUMPs were reviewed and revised, at the household level. This demonstrates a significant improvement in service standards. There are now 11,359 households at service level 1, up from 2178 before. This indicates that the homes in question now have better access to, availability of, quality, and dependability of water supplies. In contrast to 2007/2008, when only 7615 households had access to water within a 15-minute round-trip commute, this number increased to 20,197 households in 2010/2011. Due to a scarcity of water, several households have developed home gardens, which were not common before (Rautanen et al., 2014).

MUS Adoption

Water shortages for agriculture and consumption can addressed via MUS. Its acceptance is impacted favorably by the availability of water during dry seasons and a water storage system. The fact that the members of the water user group share water is one of the beauty of MUS (N. Raut et al., 2021). Depending on the socioeconomic and agro ecological context, different motivational variables may relatively have importance. However, provincial/national agricultural and policy interventions should emphasize the significance of MUS adoption and its advantages for the economy and food security (N. Raut et al., 2021). Water resources, land use planning, forest health and quality, and biodiversity protection will all be under more stress as a result of climate change, which is a risk multiplier. Water supply is already being significantly impacted by climate change, which is also modifying the monsoon pattern, causing droughts and floods, altering water levels, and changing how freshwater is stored in glaciers. Climate change increases the frequency and intensity of extreme weather occurrences, which increases ambiguity regarding what constitutes a sufficient and suitable natural disaster (Taylor et al., 2014).

B. Methods

The study was carried out using the tools such as field observation, in-depth interview, focus group discussion, and questionnaire survey for the field investigation. Total 157 number of responded from different field of MUS were questioned using a standard set of questionnaires. The answers were collected and analyzed using the relative importance index (RII). The appropriate computer application i.e., MS Excel was used for coding numbers to the respondents' answer for data analysis. The responds of the questionnaire were numerically coded to enter the data systematically and efficiently. In this study the results were presented in the forms of tables, bar chart and pie chart. The study was conducted during the period from August 2024 to February 2024. The study area for this study was Khatyad rural municipality (RM) of Mugu district of Nepal. The Khatyad RM is one of the rural municipalities which is located in the mid-hill region of Karnali province of Nepal. This rural municipality was formed in line with the federal framework and is made up of seven prior VDCs: Hanglu, Kotdanda, Sukadhik, Gamtha, Khamale, Seri, and Shrakot. It covers 281.12 square kilometers. Brahmin, Kshetri, Dalit, Thakuri, and other ethnic groups live in the RM. The RM contains 2821 households and 17116 people.

The targeted number of respondents for the questionnaire were 157. The survey on the study was focused on three primary targeted respondents: i. water user group (WUG), ii. Engineers or Sub-Engineers, and iii. Community members of the study area. For the field observation, single usage and MUS project were taken. In-depth interview was carried out with the Engineer and Sub Engineer who were working in the sector of single and multiple-use system. Focus group discussion was carried out with users of the single and multiple-use system.

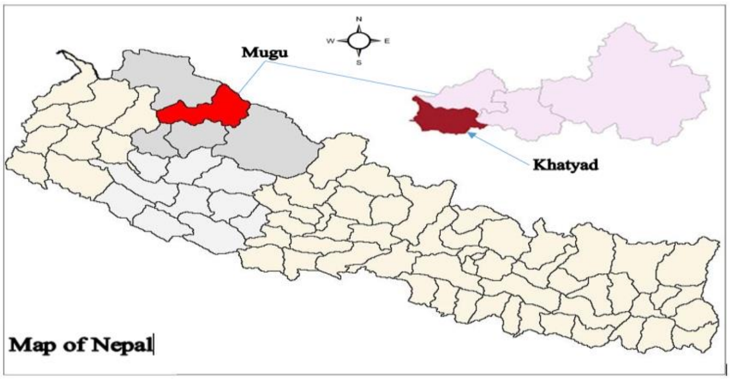

Fig. 3. Map of study area (Source: Arc GIS)

C. Results and Discussion

During field observation, in-depth interview, focus group discussion and questionnaire survey was conducted, problems identified are presented in figure (Fig 4).

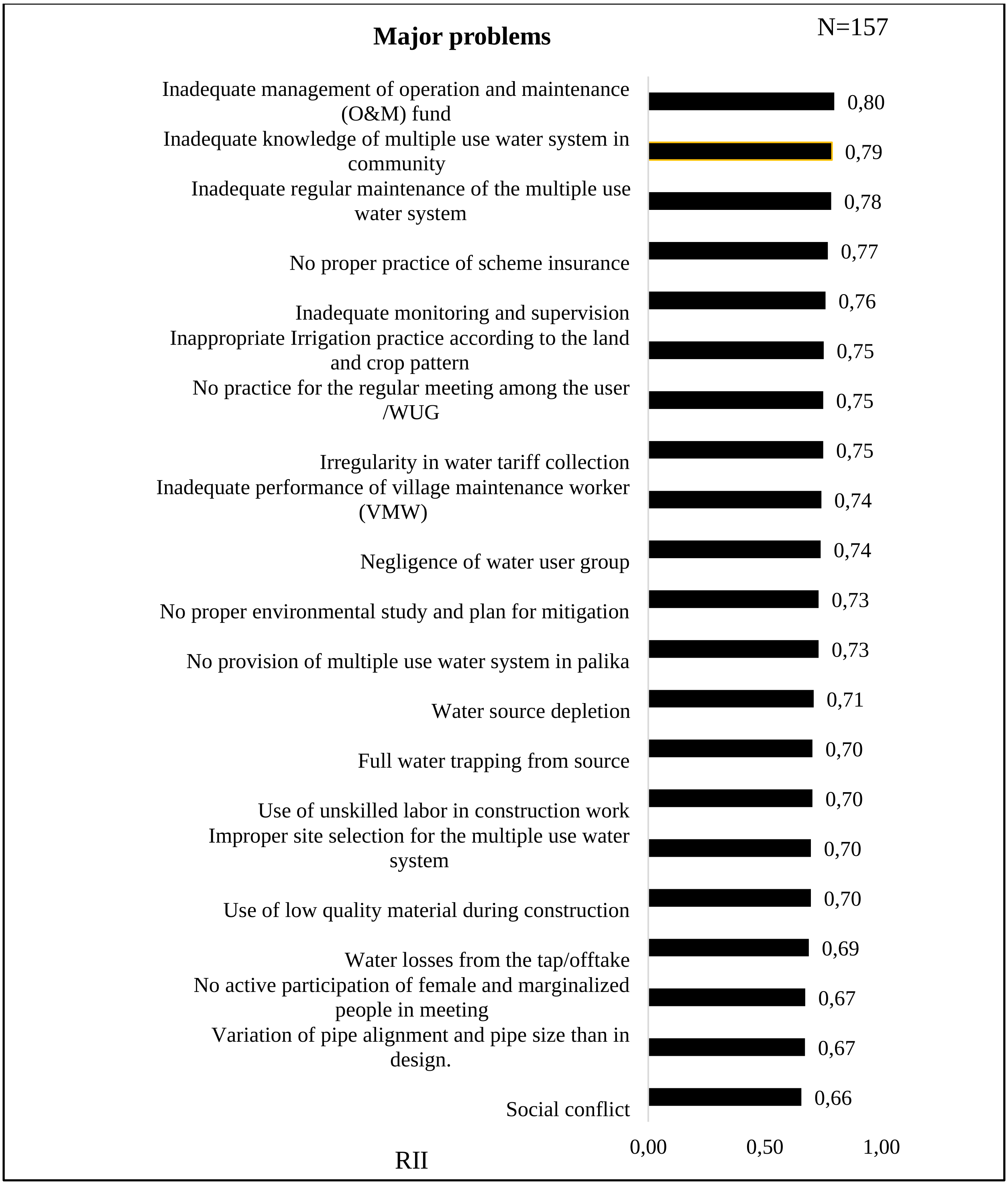

Fig. 4. Major problem with RII value (Questionnaire Survey, 2024)

Causes and effects of the aforesaid problems

Causes of social conflict:
The reason of the major problem "social conflict" linked with MUS was discovered by a questioner survey, in which five alternatives were presented, with inadequate water

distribution receiving the highest RII value of 0.72 and the lowest RII value of 0.67 on unequal labor wages during construction. The RII value presented in the figure below.

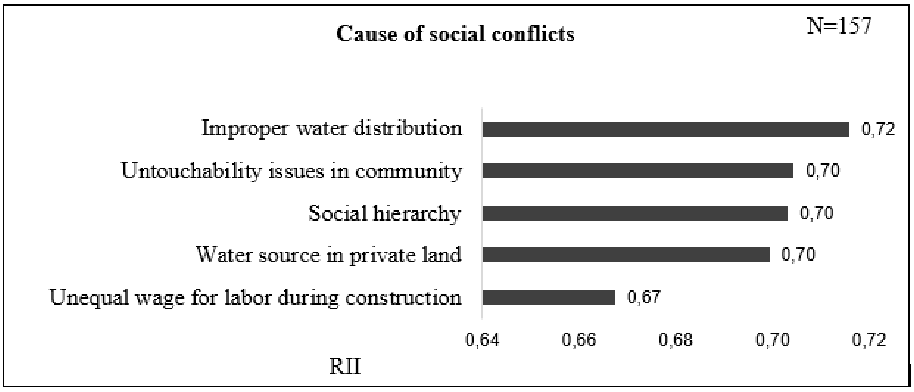

Fig. 5. Causes of social conflict (Questionnaire Survey, 2024)

Effects of social conflict:
Major effect of the social conflict shows by the survey presented in the figure. In which, "no sustainability of the system" has received the RII value of 0.76 and least RII value on "dispute among user". Which shows that unsustainability of the scheme through the social conflict is relatively higher than other effects. All the effects of social conflict are presented in the figure (Fig. 6).

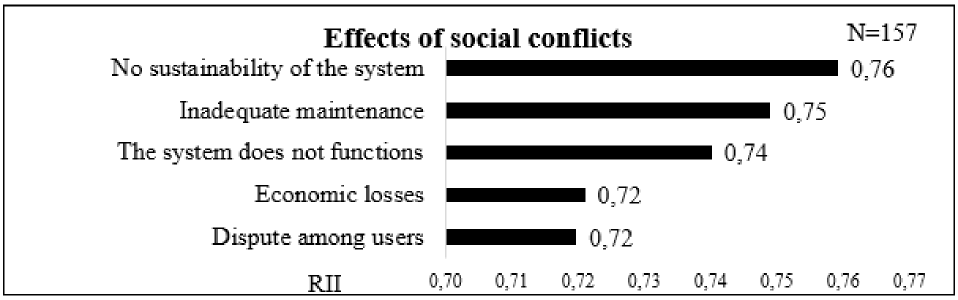

Fig. 6. Effects of social conflict (Questionnaire Survey, 2024)

Causes of use of low-quality material during construction:
The questioner survey shows that corruption interest has receive RII value of 0.76 is which is relatively high and relatively lesser RII of 0.65 in material quality depreciation during transportation were the causes of low-quality material. All the causes are presented in the figure (Fig. 7).

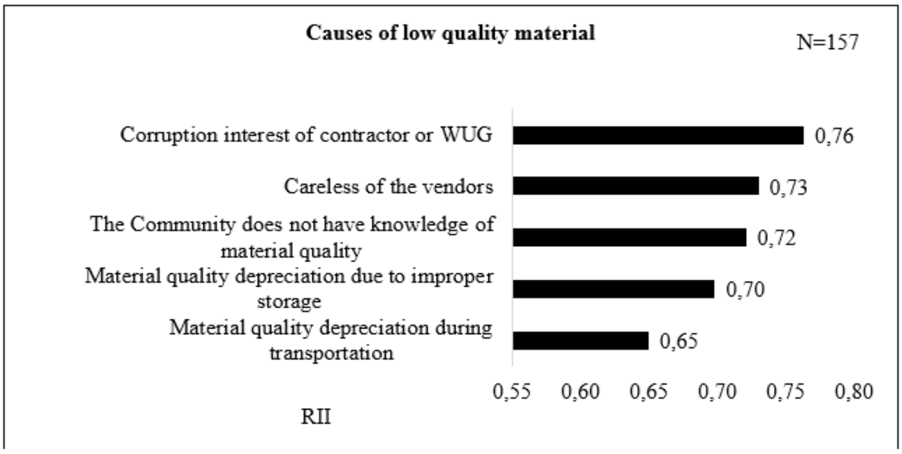

Fig. 7. Causes of Low-Quality Material Use (Questionnaire Survey, 2024)

Effects of use of low-quality material during construction:
Possibility of losses & leakage has relatively higher effects of the low-quality material using during construction and lower effects on tools and fitting damage due to low quality material. The details of the result are presented in the figure (Fig. 8).

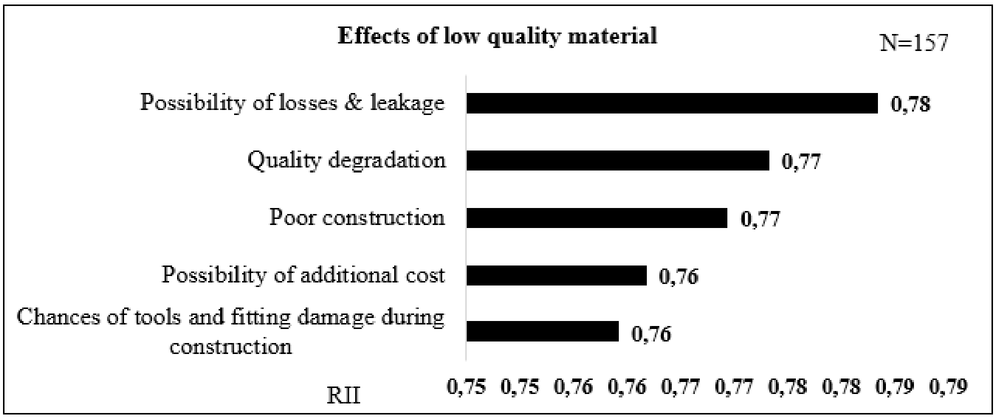

Fig. 8. Effects of low-quality material use (Questionnaire Survey, 2024)

Causes of inadequate monitoring and supervision:
Causes of inadequate monitoring was asked to the responder with five options and found limited number of technical manpower is the relatively major cause which has RII value of 0.76. All the causes with their RII value are presented in the figure (Fig. 9).

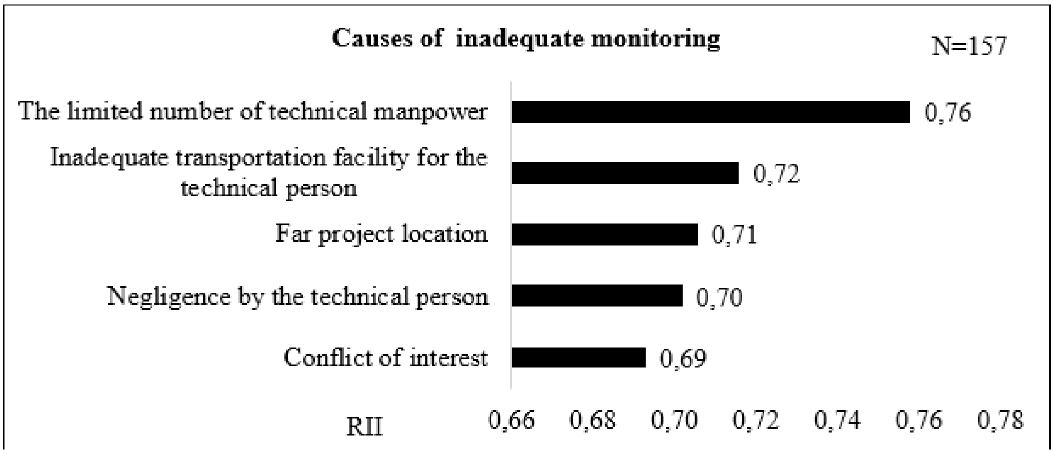

Fig. 9. Causes of inadequate monitoring (Questionnaire Survey, 2024)

Effects of inadequate monitoring and supervision:
Effects of inadequate monitoring was asked to the responder with five options and found improper construction is the relatively higher effects which has RII value of 0.79. All the effects with their RII value is presented in the figure (Fig. 10).

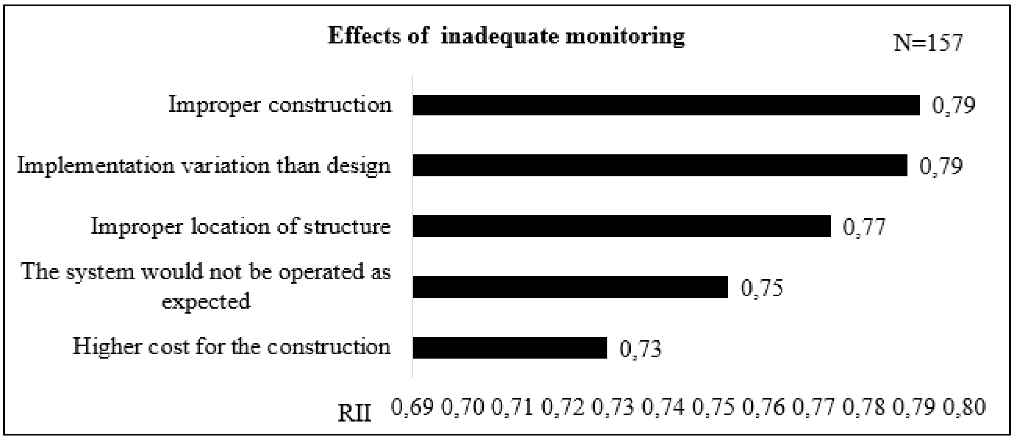

Fig.10. Effects of inadequate monitoring (Questionnaire Survey, 2024)

Causes of unskilled manpower used in construction work

The results shown that the necessary of the mason training in the study area is the relatively important cause of the unskilled manpower use in construction work. Which has the RII value of 0.75. the cause money saving interest has lesser the RII value of 0.68 which is relatively lesser important for the consideration (Fig. 11).

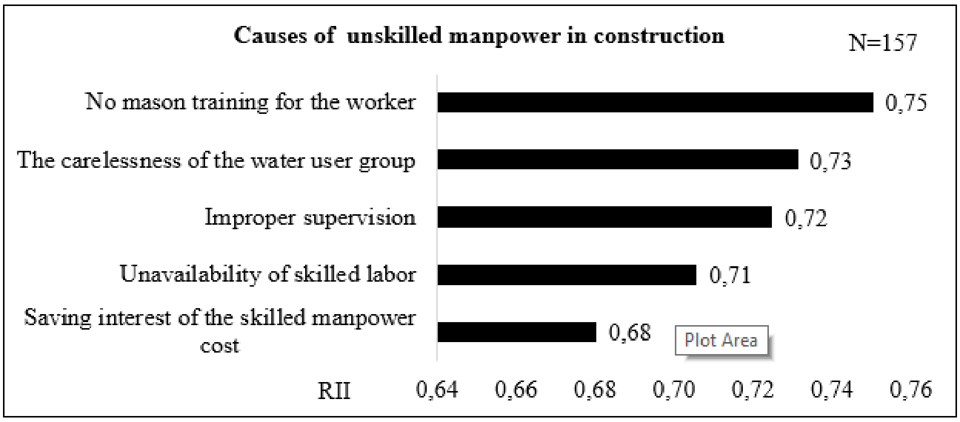

Fig. 11. Causes of unskilled manpower in construction work (Questionnaire Survey, 2024)

Effects of unskilled manpower used in construction work

The results shown that poor construction is the relatively major effects of the unskilled manpower use in construction work. Which has the RII value of 0.79. the possibility of contamination has lesser RII value of 0.74 which is relatively minor effects (Fig. 12).

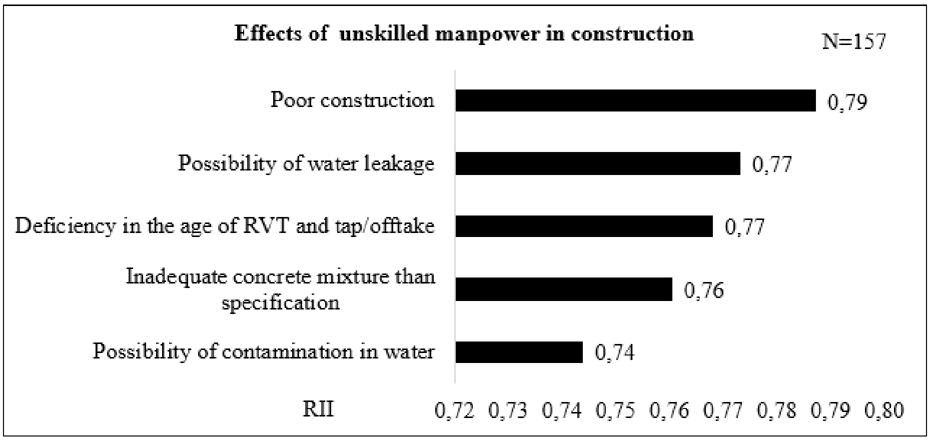

Fig. 12. Effects of unskilled manpower in construction work (Questionnaire Survey, 2024)

Causes of negligence of water user group

During the group formation all household not gathering is the relatively major causes of WUG negligence shown by the result which has RII value of 0.73. Whereas relatively minor cause is could not adopt multiple-use system rather than single-use, which has RII value of 0.67. All the causes are presented in the figure (Fig.13).

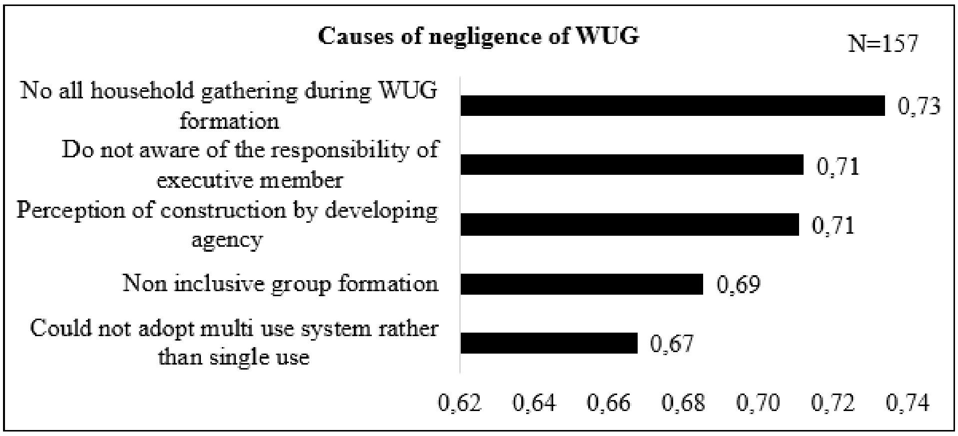

Fig.13. Causes of negligence of WUG (Questionnaire Survey, 2024)

Effects of negligence of water user group

Not establishing O&M fund provision relatively effect more by the negligence of WUG shown by the result which has the RII value of 0.8. Whereas relatively minor impact on shown for possibility of loss and damage of the material with RII value of 0.77 (Fig. 14).

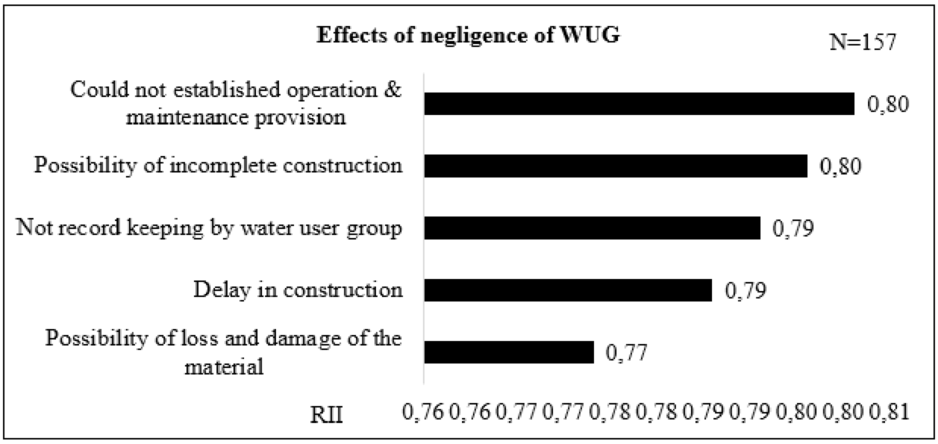

Fig. 14. Effects of negligence of WUG (Questionnaire Survey, 2024)

Causes of inadequate regular maintenance of MUS

Not establishing O&M fund provision is the relatively major causes of inadequate regular maintenance with RII value of 0.73. People perception of functionality always after construction has relatively low RII value of 0.68. All the causes with RII value are shown in the figure (Fig. 15).

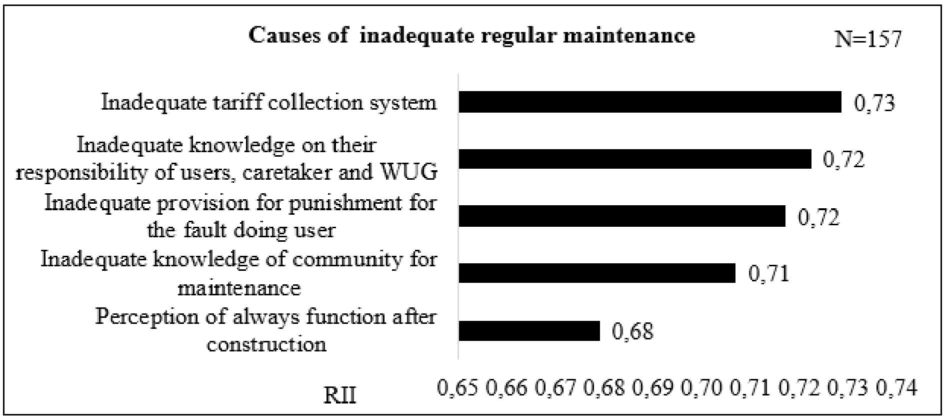

Fig. 15. Causes of inadequate regular maintenance (Questionnaire Survey, 2024)

Effects of inadequate regular maintenance of MUS

No long run of the MUS system with RII value of 0.78 is the relatively major effects of inadequate regular maintenance. Huge economic losses for reconstruction has lesser RII value with 0.74. The details of result are shown in the figure (Fig. 16).

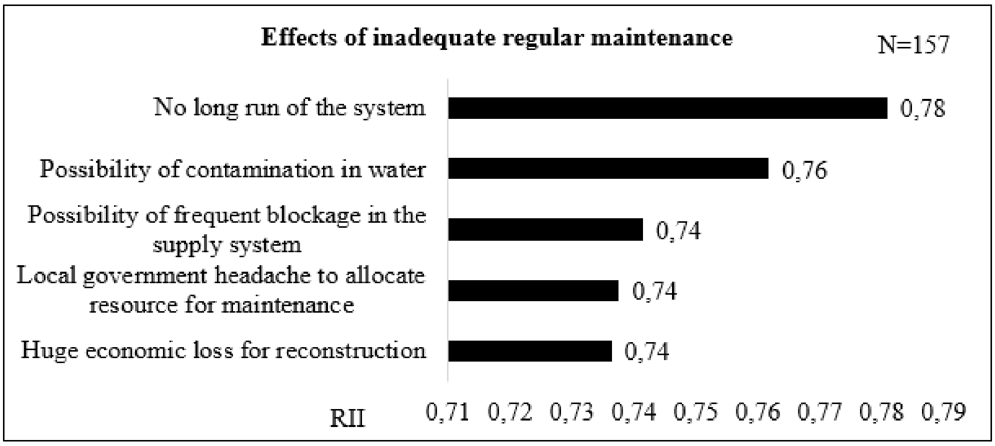

Fig. 16. Effects of inadequate regular maintenance (Questionnaire Survey, 2024)

Causes of no provision of multiple-use water system in palika

The survey shows that the relatively major cause of no provision of MUS in palika is palika official not aware. Whereas the minor cause presents due to the dissolving the district water resource committee. The causes with RII value are shown in the figure (Fig. 17).

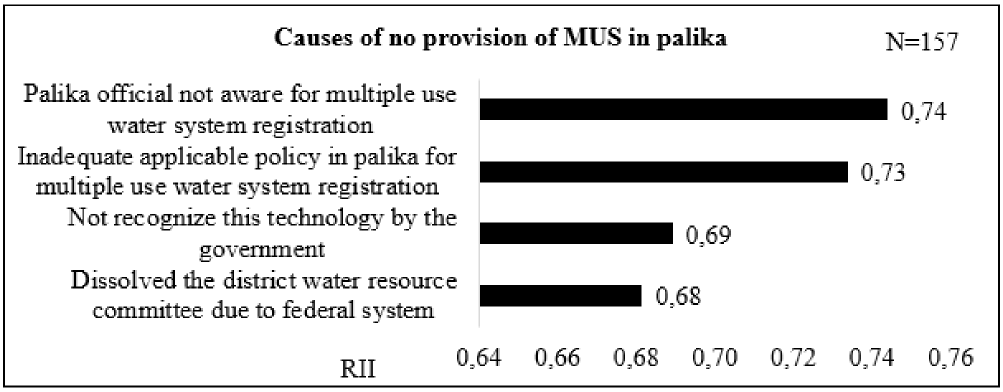

Fig. 17. Causes of no provision of MUS in palika (Questionnaire Survey, 2024)

Effects of no provision of multiple-use water system in palika

The survey shows that the relatively higher effects of no provision of MUS in palika is less possibility of resource allocation to the MUS project. Effects of no provision of MUS in palika with RII value are shown in the figure (Fig 18).

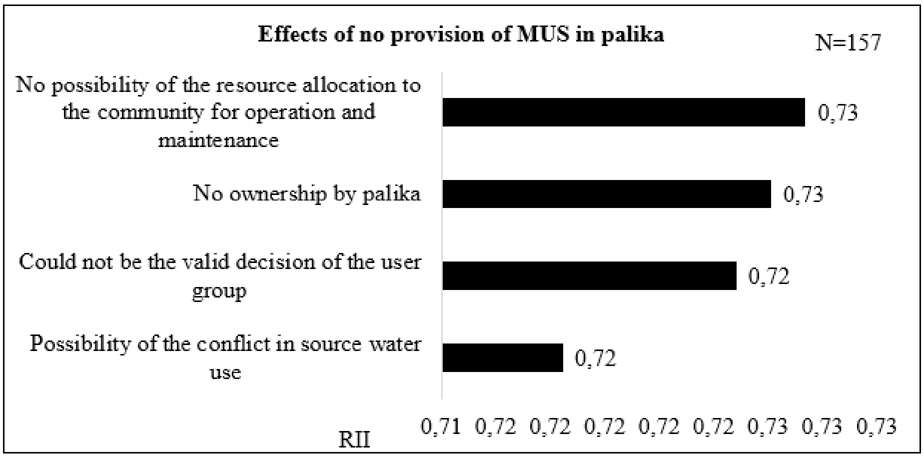

Fig. 18. Effects of no provision of MUS in palika (Questionnaire Survey, 2024)

Causes of inadequate performance of caretaker

Selection of the low performer caretaker and perception of water as the free resource are relatively major cause with same RII value of 0.74. Careless of the caretaker has lesser RII value of 0.7. The details of the result are presented in the figure (Fig. 19).

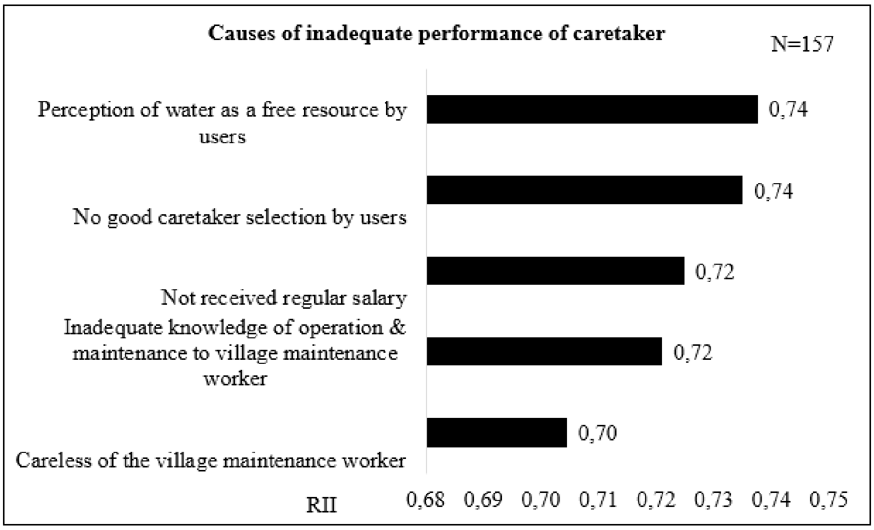

Fig. 19. Causes of inadequate performance of caretaker (Questionnaire Survey, 2024)

Effects of inadequate performance of caretaker

Possibility of the careless in operation of the system is the comparatively major effects with RII value of 0.78. whereas less possibility of general maintenance with RII value 0.75 is comparatively low effects in connection with performance of care taker. Details of the result are presented in the figure (Fig.20).

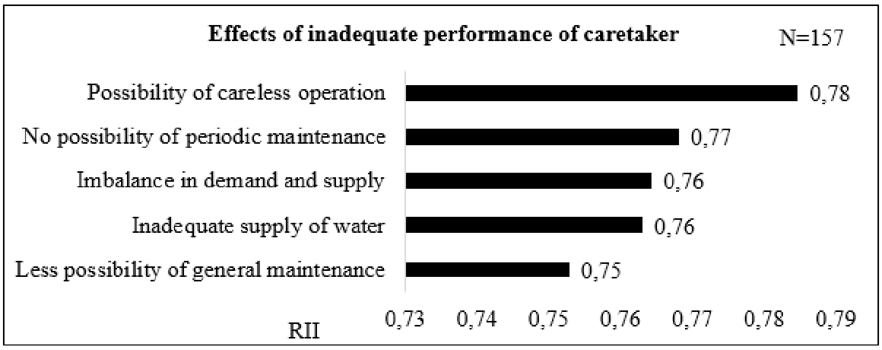

Fig. 20. Effects of inadequate performance of caretaker (Questionnaire Survey, 2024)

Causes of irregularity in water tariff collection

Community perception of water as the free resource is found that the comparatively major causes of the irregularity in water tariff collection with RII value of 0.75. Less income source of the users is found that the comparatively minor causes with RII value 0.71. The details of the result are presented in the figure (Fig. 21).

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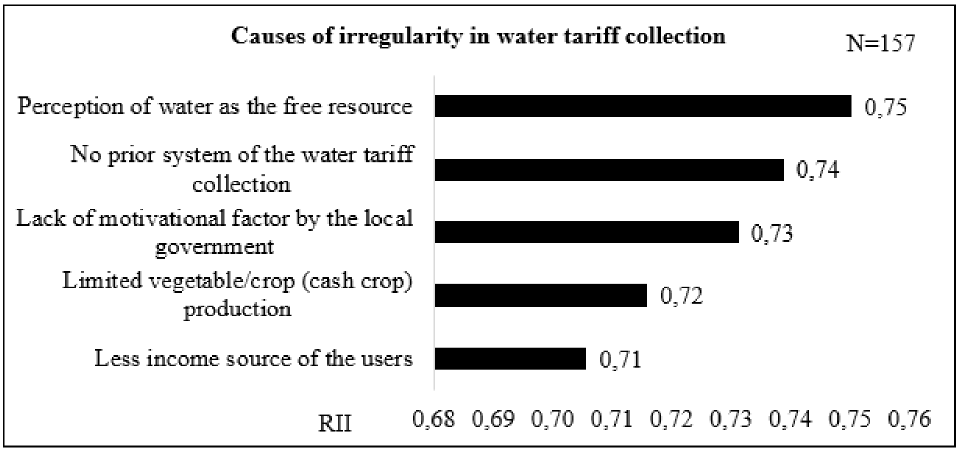


Fig. 21. Causes of irregularity in water tariff collection (Questionnaire Survey, 2024)

Effects of irregularity in water tariff collection

Insufficient cost for the system recovery, less ownership feeling and less chances of the maintenance are the major effects with RII value of 0.77 and less possibility of purchasing sphere part for the maintenance and could not work caretaker freely are the minor effects with RII value of 0.76 of the problem irregularities in water tariff collection. Details are shown in the figure (Fig.21).

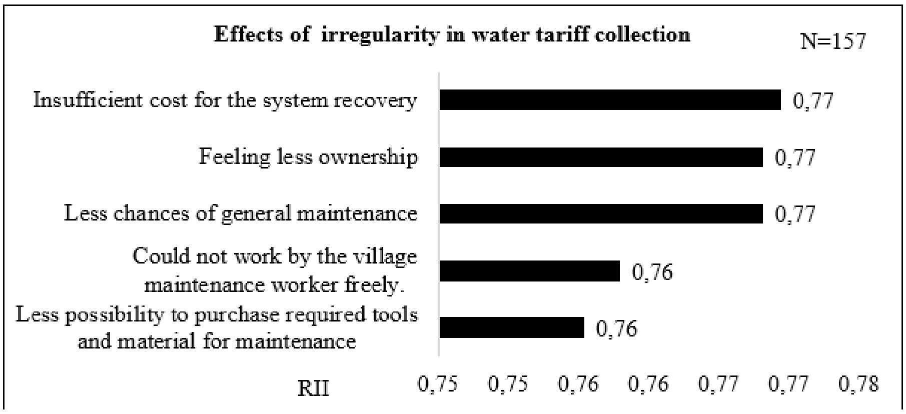


Fig. 22. Effects of irregularity in water tariff collection (Questionnaire Survey, 2024)

Causes of no proper practice of scheme insurance

Study shows that lack of awareness in community and no practice of insurance of the all the components are relatively major causes of no insurance of the scheme with RII value of 0.78. Similarly; inadequate O&M fund establishment and no easy access of the insurance company are relatively minor cause with RII value of 0.75 for no insurance of the scheme. The details are presented in the figure (Fig. 23).

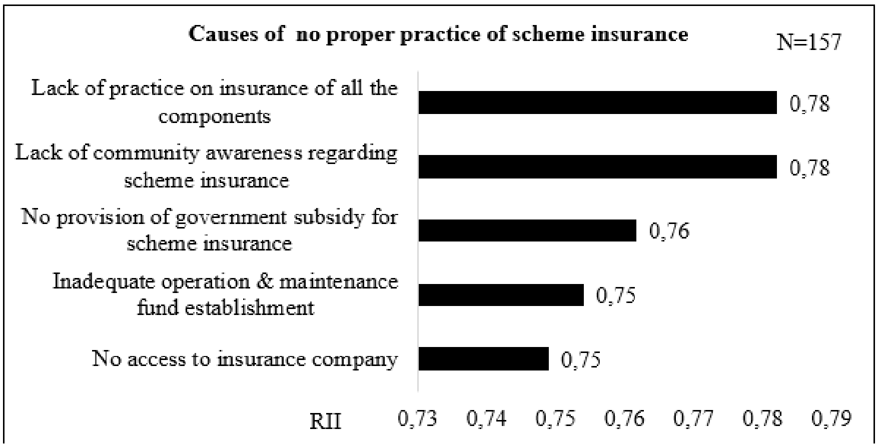


Fig. 23: Causes of no proper practice of scheme insurance (Questionnaire Survey, 2024)

Effects of no proper practice of scheme insurance

Study shows that, RII value for no risk cover and high-cost burden to community after damage the scheme is 0.76. Which indicate that, no risk will cover and high-cost burden to community after damage the scheme if there is no practice of the scheme insurance. Similarly; possibility of decreasing the wellbeing status of community and high-cost burden to local government has relatively lesser RII value of 0.73. The details are shown in the figure (Fig. 24).

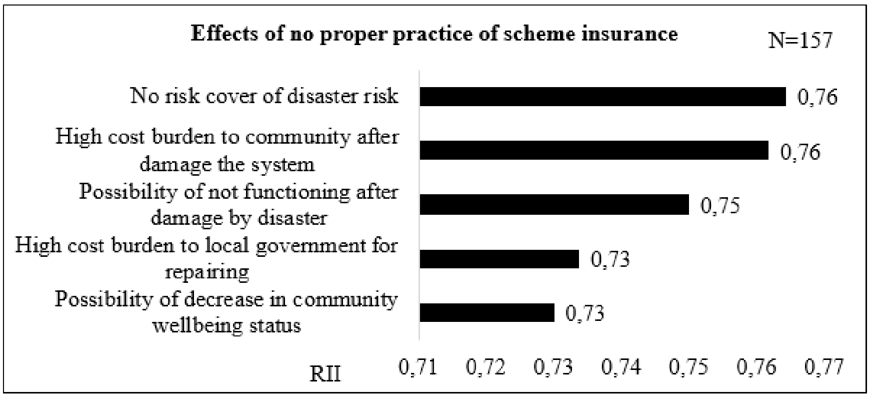


Fig. 24. Effects of no proper practice of scheme insurance (Questionnaire Survey, 2024)

Causes of variation of pipe alignment and pipe size than in design

There were five options to respond, as a result of the survey it can be concluded that the inadequate knowledge of MUS to the community is relatively major cause with RII value of 0.73. Similarly; preference of short alignment during the implementation is relatively minor cause with RII value. The details of the causes of the alignment changing are shown in the figure (Fig. 25).

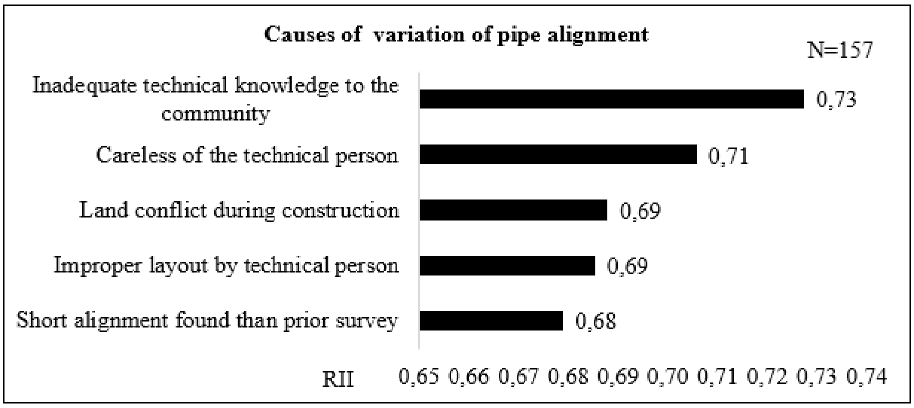


Fig. 25. Causes of variation of pipe alignment (Questionnaire Survey, 2024)

Effects of variation of pipe alignment and pipe size than in design

Relatively major effects of pipe alignment change shown by study is possibility of not flowing expected water according to the design with RII value 0.76. Whereas possibility higher labor cost through the pipe alignment change has lesser RII value of 0.71. The details are shown in the figure (Fig.26).

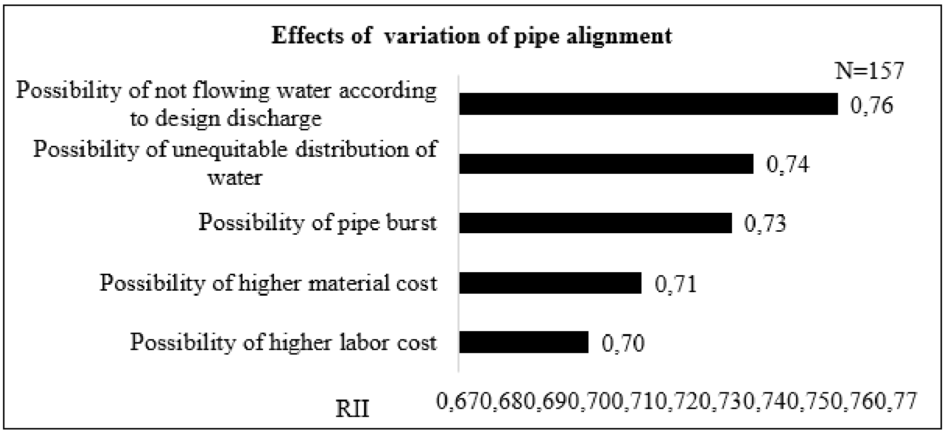


Fig. 26. Effects of variation of pipe alignment (Questionnaire Survey, 2024)

Causes of water source depletion

The respondents were asked to answer with five options. Comparatively haphazardly road construction with RII value of 0.78 is the major cause of source depletion and comparatively depletion of the water table through deep boarding with RII value of 0.70 is the minor cause of source depletion. The details with analysis are show in the figure (Fig. 27).

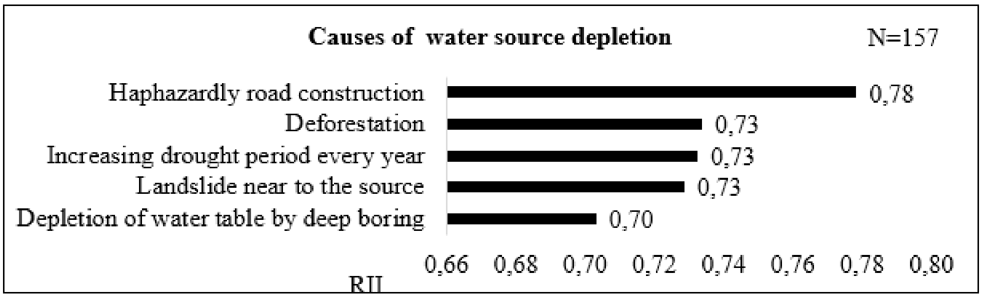


Fig. 27. Causes of water source depletion (Questionnaire Survey, 2024)

Effects of water source depletion

The study shown that the relatively higher effects of source depletion is not functioning of both single and multiple-use system with RII value of 0.79 and minor effects on possibility of social conflicts with RII value of 0.75. The details of the analysis are shown in the figure (Fig. 28).

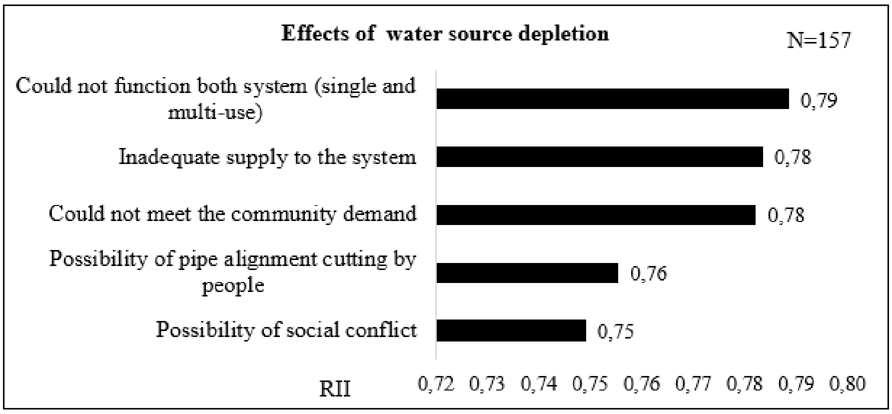


Fig. 28. Effects of water source depletion (Questionnaire Survey, 2024)

Causes of inadequate management of O&M fund

The study has shown that no regular meeting of WUG is relatively major cause with RII value 0.76 and nonexclusive WUG with RII of 0.68 is the comparatively lesser cause of inadequate management of O&M. The detail RII value with all the cause are shown in the figure (Fig. 29).

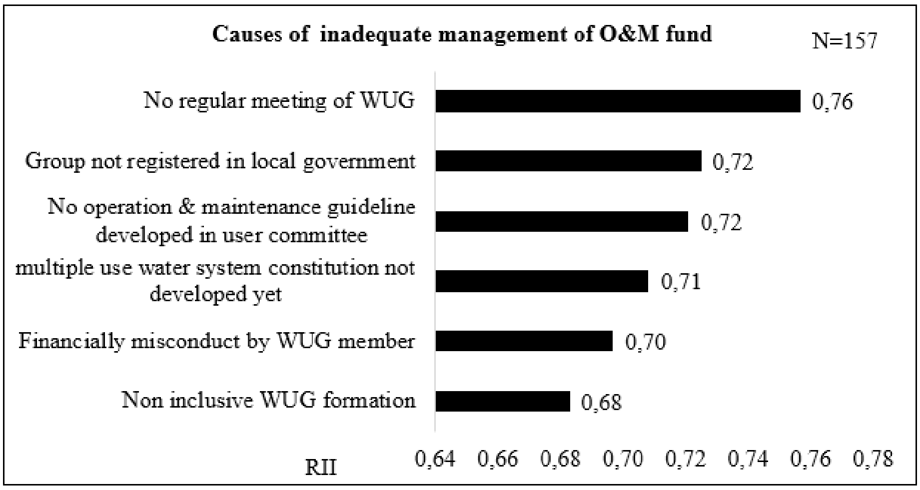


Fig. 29. Causes of inadequate management of O&M fund (Questionnaire Survey, 2024)

Effects of inadequate management of O&M fund

Result shown that less chances on the sustainability is the relatively higher effects of inadequate management of O&M fund with RII value of 0.8. whereas less chances to pay skilled labor cost during maintenance is the relatively minor effects of inadequate O&M fund management. Other all the effects with their RII value are presented in the figure (Fig. 30).

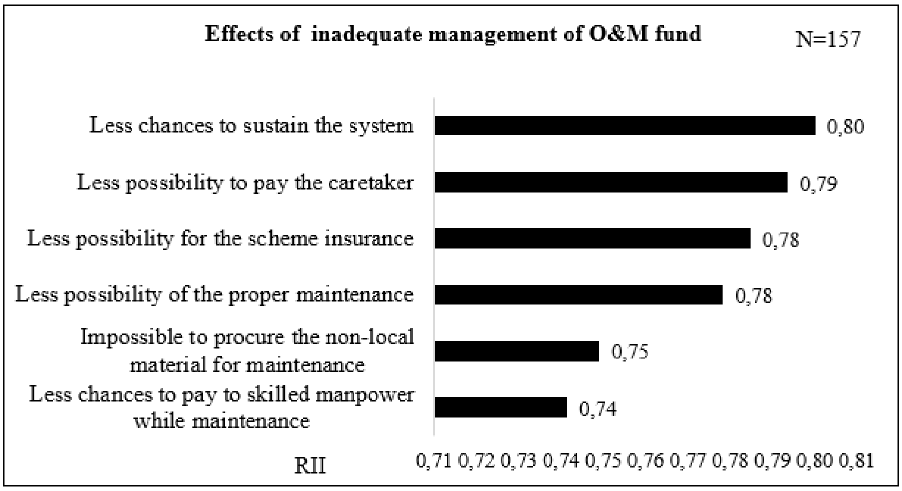


Fig. 30. Effects of inadequate management of O&M fund (Questionnaire Survey, 2024)

Causes of water losses from the tap/offtake and pipe line

There were five options of the causes for the water losses. In which careless of the user has highest RII value of 0.76 indicates the relatively major cause and nailing of the pipe line found that comparatively minor causes of the water losses with RII value of 0.71. The details are shown in the figure (Fig. 31).

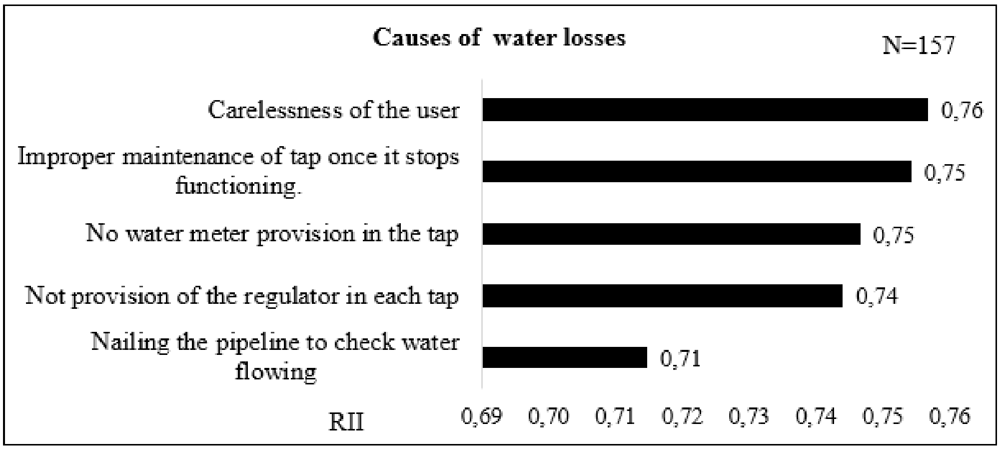


Fig. 31. Causes of water losses (Questionnaire Survey, 2024)

Effects of water losses from the tap/offtake and pipe line

Relatively major effects of water losses shown by survey are possibility of the improper functioning of the system, deficiency of water to other user and social conflict with RII value of 0.78 whereas comparatively less impact on emptiness of RVT and possibility of not flowing water for irrigation with RII value of 0.77. Details are shown in the figure (Fig. 32).

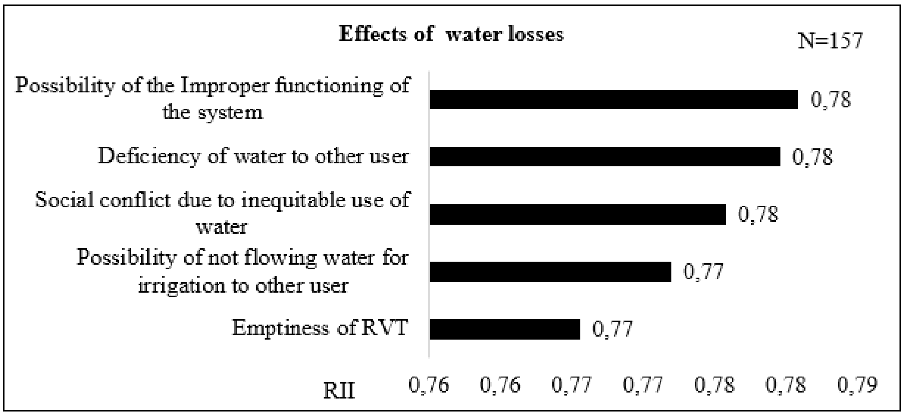


Fig. 32. Effects of water losses (Questionnaire Survey, 2024)

Causes of inadequate knowledge of multiple-use water system in community

Comparatively major causes of inadequate knowledge of MUS to the community is less capacity building activity to them, shown by the survey with RII value of 0.76. And, lack of education is relatively minor cause with RII value of 0.71. All causes with RII value are presented in the figure (Fig. 33).

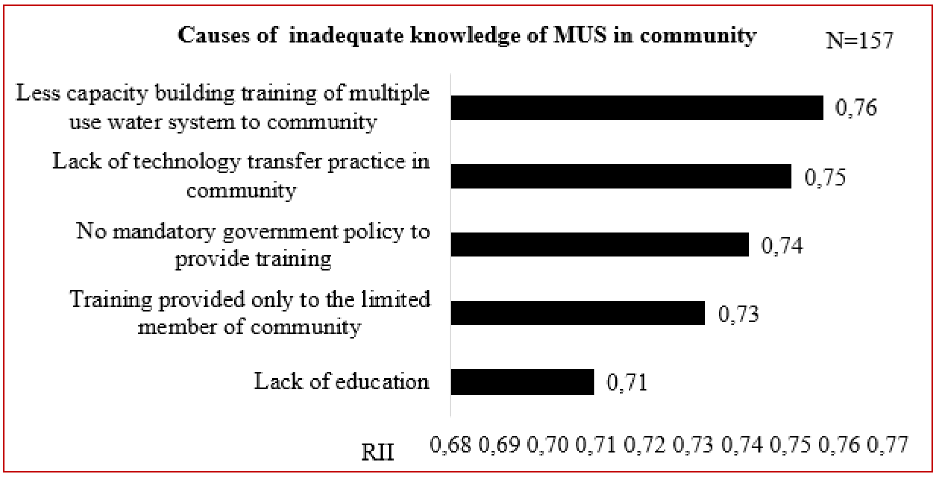


Fig. 33. Causes of inadequate knowledge of MUS in community (Questionnaire Survey, 2024).

Effects of inadequate knowledge of multiple-use water system in community

Comparatively major effects of inadequate knowledge of MUS to the community is difficult for long run the scheme with RII value of 0.77. And, possibility of unequitable water distribution with RII value of 0.71 indicate relatively minor effects. All effects with their RII value are presented in the figure (Fig. 34).

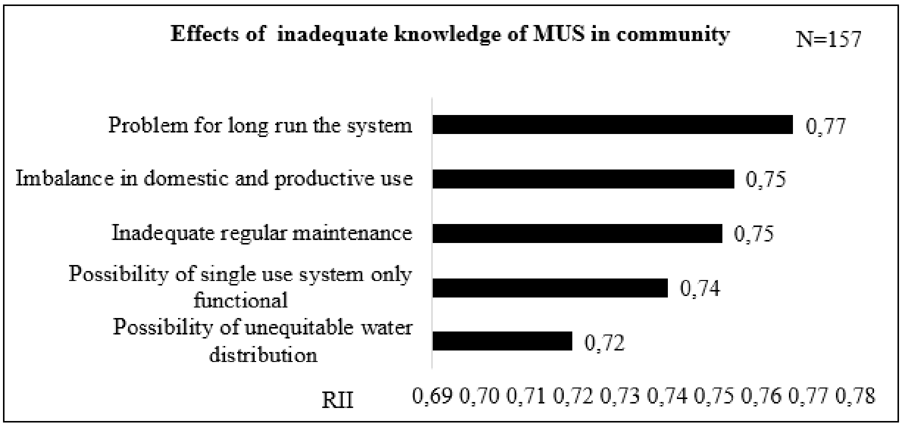


Fig. 34. Effects of inadequate knowledge of MUS in community (Questionnaire Survey, 2024).

Causes inadequate participation in meeting

Relatively major cause identified through the questioner survey for the inadequate participation from female and marginalized people in meeting is due to the discrimination among ethnic group with RII 0.73 and other relatively minor important cause is social hierarchy with RII of 0.71. Other causes with their RII value are shown in the figure (Fig. 35).

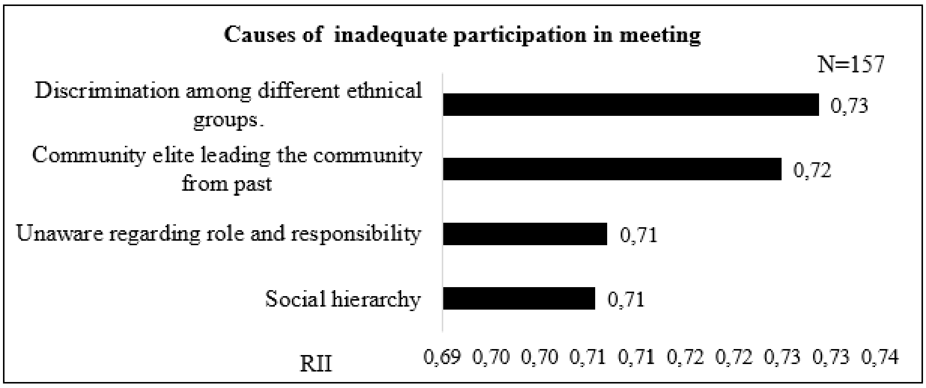


Fig. 35. Causes of inadequate participation in meeting (Questionnaire Survey, 2024)

Effects inadequate participation in meeting

Relatively major effects identified through the questioner survey by the inadequate participation of female and marginalized people in meeting is less motivation to pay for water with RII value of 0.76 and relatively minor effects is identified as low chances to address their problem with RII of 0.74. All the effects with their RII value are shown in the figure (Fig. 36).

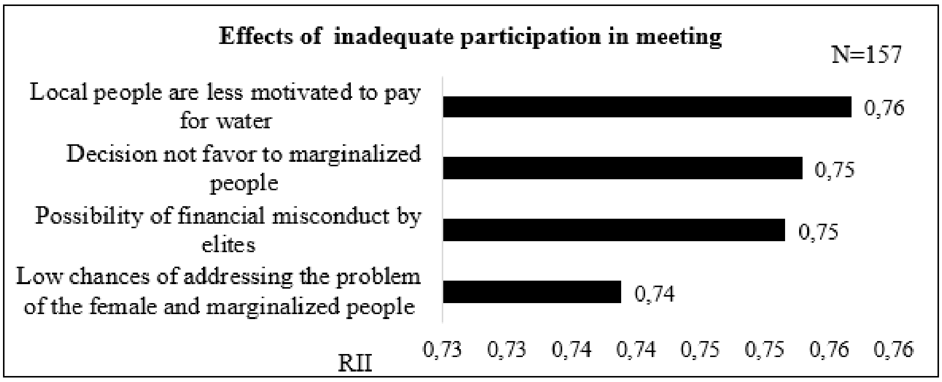


Fig. 36. Effects of inadequate participation of female and marginalized people in meeting (Questionnaire Survey, 2024).

Causes of inappropriate irrigation practice according to the land and crop pattern

There were four options, among them less aware on the micro irrigation technology ranked higher with RII value of 0.75 which indicate those causes are relatively important cause. Insufficient technical manpower in the R/M and less knowledge on irrigation pattern receives lower rank of RII 0.7 indicates relatively minor cause. All the causes associated with inappropriate irrigation practice are shown in the figure (Fig. 37).

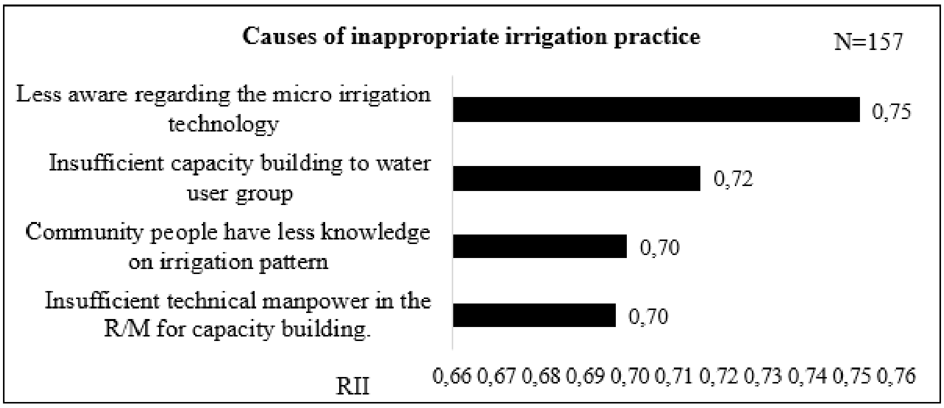


Fig. 37. Causes of inappropriate irrigation practice (Questionnaire Survey, 2024)

Effects of inappropriate irrigation practice according to the land and crop pattern

There were four options, among them less possibility of expected crop production ranked higher with RII value of 0.76 indicates relatively major effects and soil erosion receives lower rank of RII 0.73 indicate comparatively minor effects. All the effects associated with inappropriate irrigation practice are shown in the figure (Fig. 38).

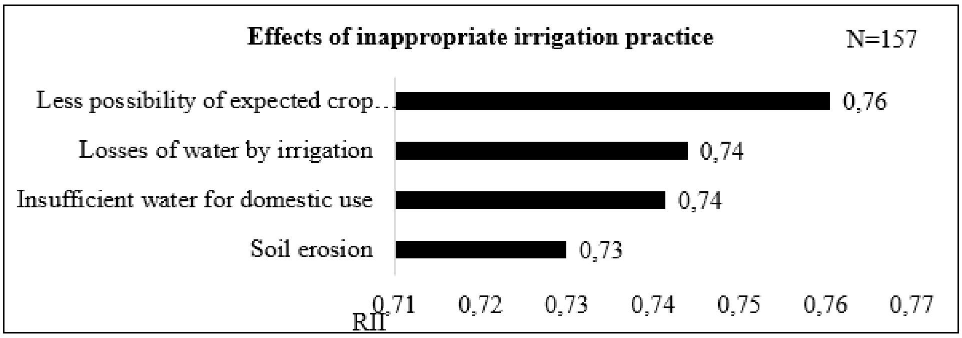


Fig. 38. Effects of inappropriate irrigation practice (Questionnaire Survey, 2024)

Causes of inadequate regular meeting of multiple-use water system user group

There were five options, among them not realizing the important of meeting ranked higher with RII value of 0.72 which indicate this cause is relatively important. Inadequate meeting place receives lower rank of RII 0.64 indicates relatively minor cause. All the causes associated with the problem of meeting are shown in the figure (Fig. 39).

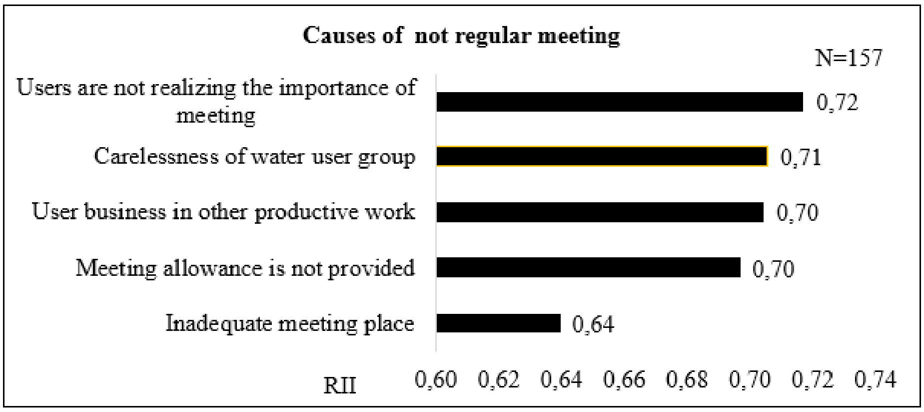


Fig. 39. Causes not meeting of user group (Questionnaire Survey, 2024)

Effects of inadequate regular meeting of multiple-use water system user group

There were five options asked to respond to the responder, among them less possibility of sustainable plan ranked, improper recognition fault people & punishment, insufficient discussion regarding MUS and less possibility of addressing voice of vulnerable people receives equal RII value of 0.77 ranked highest indicates relatively major effects and possibility of misconduct ranked lower with RII 0.76 indicate comparatively minor effects. All the effects associated with inadequate regular meeting are presented in the figure (Fig. 40).

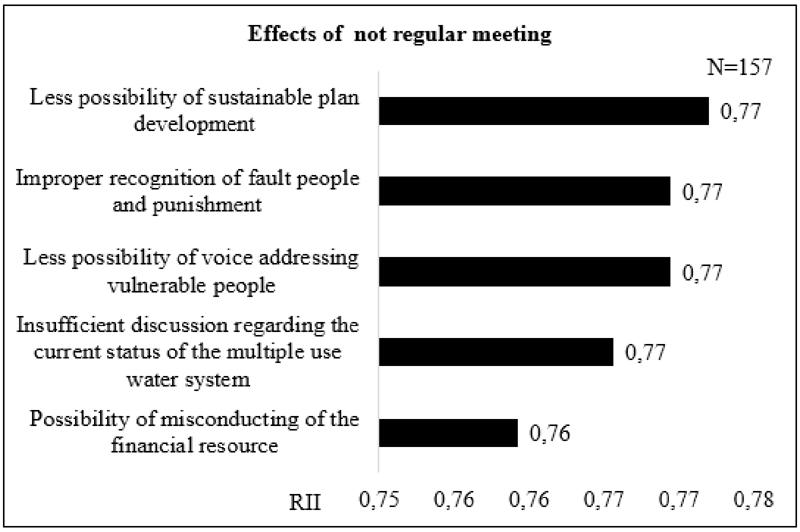


Fig. 4. Effects of not regular meeting (Questionnaire Survey, 2024)

Causes of full water trapping from

The survey has shown that the higher water demand and lack of water source conservation are major causes with highest RII value of 0.75 and no proper provision for leaving water for greenery is minor cause with lower RII of 0.69. All the causes associated with the problem of full water trapping are shown in the figure (Fig.41).

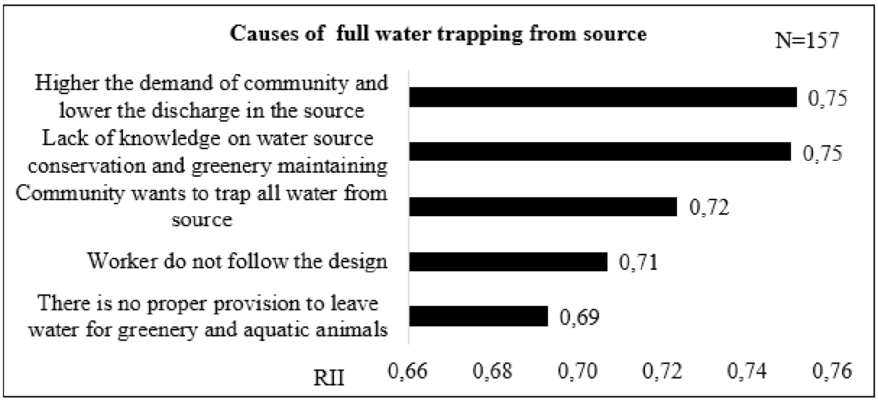


Fig. 41. Causes of full water trapping from source (Questionnaire Survey, 2024)

Effects of full water trapping from source

The survey has shown that disturbance to the downstream aquatic animals and drier the downstream land are the major effects with highest RII value of 0.78 and no possibility not meeting community water demand is minor cause with lower RII of 0.71. All the causes associated with the effects of the problem of full water trapping are shown in the figure (Fig.42).

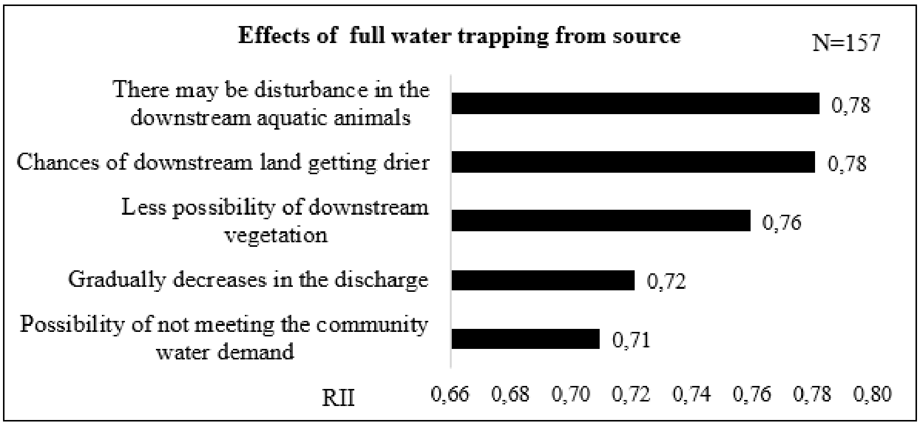


Fig. 42. Effects of full water trapping from source (Questionnaire Survey, 2024)

Causes of improper site selection for the multiple-use water system

Among the five options, no formation of WUMP has highest RII value of 0.77 indicates relatively major cause and conflict of interest of staff has lowest RII value of 0.68 indicates relatively minor cause of improper site selection. All the causes with their RII value are shown in the figure (Fig. 43).

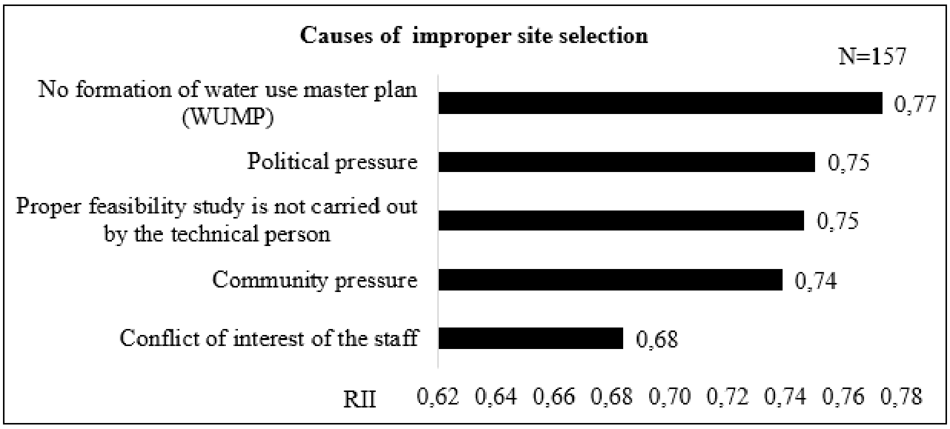


Fig. 43. Causes of improper site selection (Questionnaire Survey, 2024)

Effects of improper site selection for the multiple-use water system

Among the five options, chances of structural damage by landslide/flood have highest RII value of 0.79 indicates relatively major effects and possibility of higher per capita cost has lowest RII value of 0.75 indicates relatively minor effects of improper site selection. All the effects with their RII value are shown in the figure (Fig. 44).

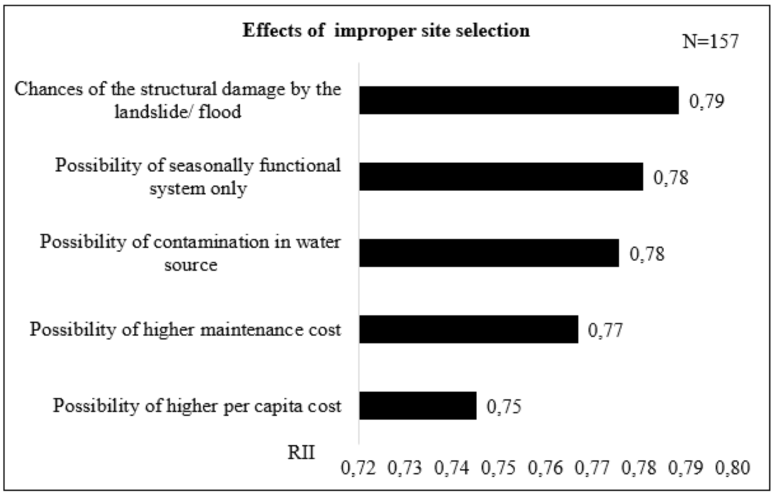


Fig. 44. Effects of improper site selection (Questionnaire Survey, 2024)

Cause of no proper environmental study and plan for mitigation

Improper monitoring for the environment issues and no consideration of environment issues during PF receive the highest RII value of 0.73 indicates comparatively major cause and short time frame for constriction and higher project cost have lowest RII value of 0.71 indicates comparatively minor cause. All the causes associated with improper environmental study are shown in the figure (Fig. 45).

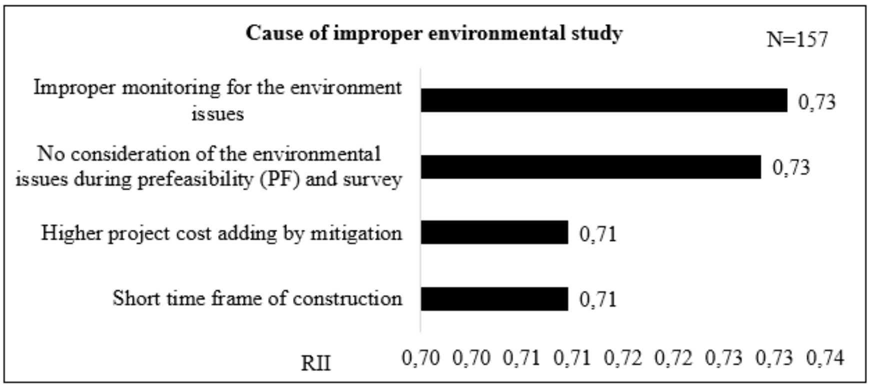


Fig. 45. Cause of improper environmental study (Questionnaire Survey, 2024)

Effects of no proper environmental study and plan for mitigation

Possibility of soil erosion and possibility of landslide have the highest RII value of 0.78 indicates comparatively major effects and possibility of flood/flash flood and disturbance in ecosystem have lowest RII value of 0.77 indicates comparatively minor effects. All the effects associated with the problem of improper environmental study and mitigation plan are shown in the figure (Fig. 46).

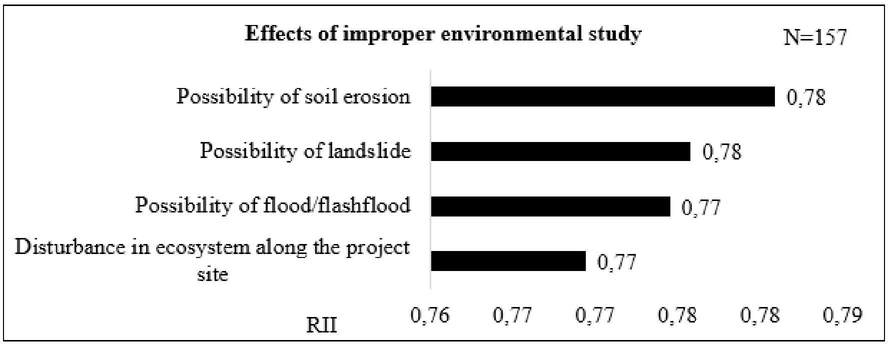


Fig. 46. Effects of improper environmental study (Questionnaire Survey, 2024).

Major solution associated with sustainability of MUS

There were 21 options asked regarding the solution of the problem and responds were ranked with their RII value. The highest RII value indicates the major solutions and lesser RII value indicates relatively minor solutions. On the basis of respondents, construction work with presence of technical person and regular repair maintenance has highest RII value of 0.84 whereas provision of water meter in each tap and offtake has lowest RII value of 0.78. All the solutions with their RII value is presented in the figure (Fig. 47).

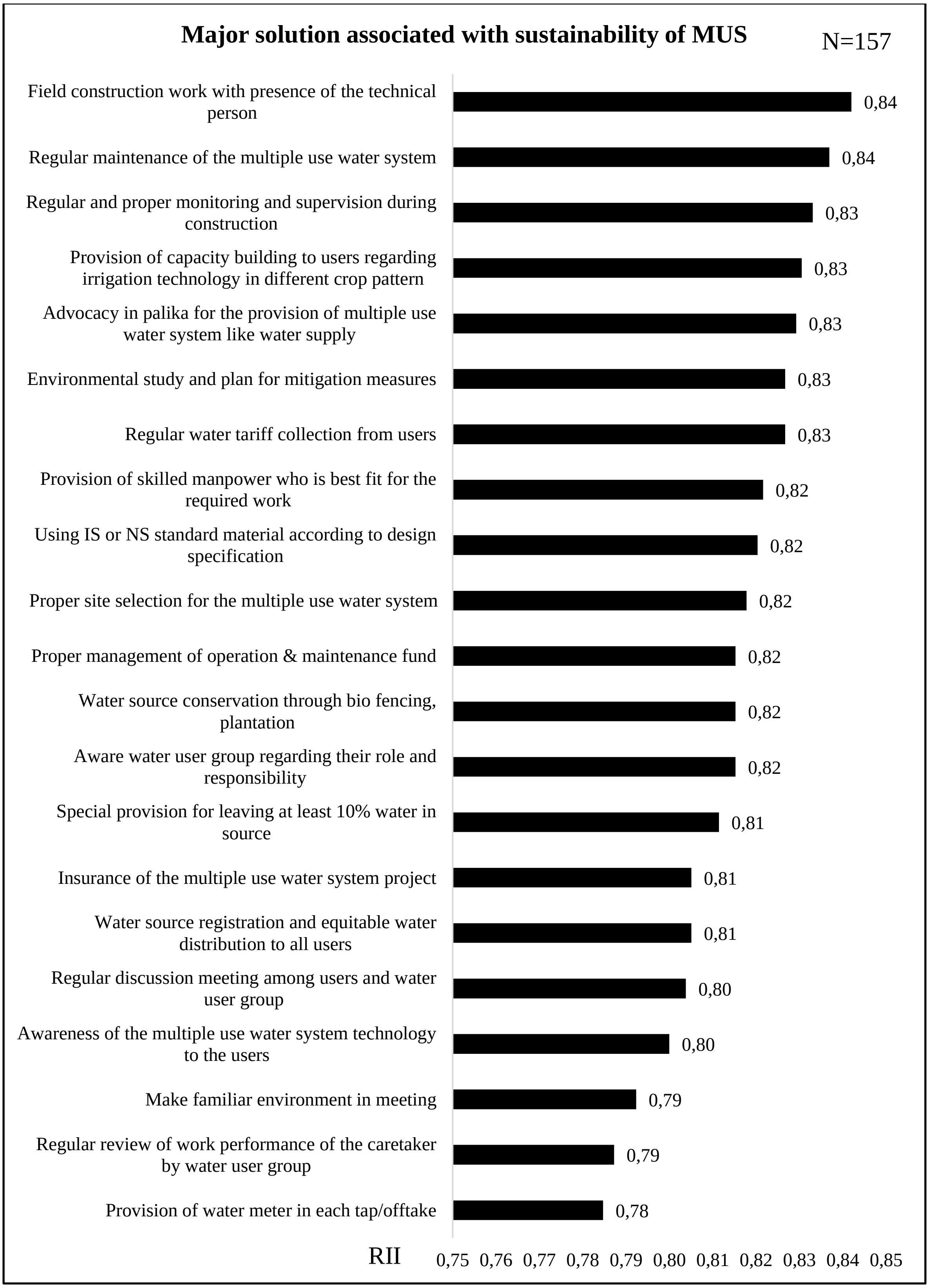
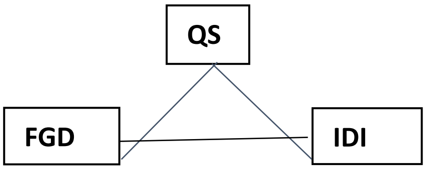


Fig. 47. Major solution associated with sustainability of MUS (Questionnaire Survey, 2024).

Triangulation of the Results

The common outcomes from the questionnaire survey, in-depth interview, and focus group discussion are presented here:



A. There is no practice of regular repair and maintenance of the scheme for the long run of the scheme
B. No practice of the scheme insurance to transfer the disaster risk of damage and losses
C. Operation and maintenance fund establishment and management problems with difficulties of the water tariff collection are the major problem found.

Similarly; the result shows that the construction works with the presence of the technical person during construction and the operation and maintenance system need to be established along with water tariff collection and insurance of the scheme with the capacity building activity to the users for the irrigation pattern for the sustainable system establishment.

This study evaluated the effectiveness and sustainability challenges of Multiple Use Water Systems (MUS). Using a mixed-methods approach combining both quantitative and qualitative data, the research sheds light on critical factors affecting the performance, sustainability, and community engagement of MUS schemes across high hill areas of Karnali. The major issue identified across MUS schemes was the poor management of operation and maintenance (O&M) funds by Water User Groups (WUGs), receiving the highest Relative Importance Index (RII= 0.80). Local government struggle to mobilize and manage resources for routine maintenance and emergency repairs for the long-term viability.

Low level of community awareness regarding the purpose and benefits of MUS (RII= 0.79), which indicate insufficient outreach and capacity building. Additionally, less practices of maintenance. Other systemic gaps include the lack of scheme insurance, weak monitoring and supervision, and poor governance practices, such as irregular WUG meetings and inexperience in tariff collection. Furthermore, shortage of technical manpower in rural municipalities makes it difficult to ensure timely inspections, technical backstopping, and repair issues. Communities reported deteriorating MUS infrastructure, limited maintenance opportunities, and growing financial burdens on WUGs, particularly in disasters or climate-induced damage. These findings reflect broader trends in rural water management in Nepal, particularly in remote high hill regions, where weak institutional systems and lack of disaster preparedness.

Despite these challenges, the study also identified several pathways to strengthen MUS effectiveness in Karnali. Chief among them is construction with close technical supervision (RII= 0.84) and regular repair and maintenance (RII= 0.84). Capacity building of WUGs (RII= 0.83) and the institutionalization of water tariff systems (RII= 0.83).

This study reveals key implications for enhancing the sustainability of Multiple Use Water Systems (MUS). A clear government policy and integration of MUS into local development and climate adaptation plans are needed. Strengthening Water User Groups (WUGs) through capacity building, transparent tariff collection, and regular maintenance is essential. Local governments require improved technical manpower and governance systems to support on functionality. Community awareness, inclusive participation, and scheme level insurance are also critical. To ensure long-term success, a holistic, community led, and climate-resilient approach must guide MUS planning and implementation. This study is carried out for academic purposes. The study limits on the water supply and irrigation use of the water source. The area of study is Khatyad rural municipality of Mugu district. The respondents were those who were practicing single-use systems or multiple-use systems along with experts, and who are supporting to implementation of those interventions. It does not cover solutions to all the problems of other districts. Due to the limited time frame, only a limited number of respondents are taken for the study. Thus, the findings of this study may or may not be generalized in other places in the country.

To address the challenges associated with Multiple-Use Water Systems (MUS), it is recommended that construction be closely supervised by technical experts, with detailed environmental assessments and mitigation plans in place. Regular maintenance by the Water Users Group (WUG) is vital for the long-term sustainability of the system. Additionally, capacity-building efforts should be increased to improve community knowledge of MUS operations, ensuring clear roles and responsibilities for both the WUG and users. It is also important to establish provisions for a paid caretaker, scheme insurance, and regular water tariff collection through WUG meetings. The study further suggests that local governments implement a source registration system and develop policies for WUG and source registration. Future research could focus on evaluating the effectiveness of these recommendations, the role of community involvement with operation and maintenance funds that support the sustainability of MUS.

D. Conclusions

The study investigated the major problems associated with the effectiveness of the multiple-use water system of the Khatyad rural municipality of Mugu district. 157 responses were collected from the questionnaire survey. Those responses were analyzed through the relative importance index (RII) using Microsoft excel. In-depth interview (IDI) and focus group discussion (FGD) was also conducted during the study. Inadequate management of operation and maintenance funds in the water user group (RII 0.80) is identified as the major problem associated with the effectiveness of the multiple-use water system (MUS). Similarly; inadequate knowledge of multiple-use water systems to the community (RII 0.79), inadequate maintenance practice and not regularity in water tariff collection (RII 0.78), no scheme insurance (0.77), inadequate monitoring supervisions (RII 0.76) are the major problems explored from the study.

The major causes of the problem were no regular meetings (RII .76), no prior practice of water tariff collection (0.73), less capacity building training on operation maintenance and basic system functioning (RII 0.76), no knowledge and prior practice of scheme insurance (RII 0.78) and there is also less technical manpower in the rural municipality (RII 0.76) for the regular monitoring and supervision were identified from the research. No long run and no sustainability of the scheme (RII 0.80), fewer chances of maintenance (RII 0.77), the high-cost burden to WUG, and no risk cover from the disaster damage (RII 0.76) are effects found from the study. Construction work with close supervision from the technical person (RII 0.84), Regular repair and maintenance of the scheme (RII 0.84), Capacity Building to WUG (0.83), Regular water tariff collection (RII 0.83) were the major solution analyzed from the study.

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