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Connecting innovation and source conservation for meeting water needs

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ABSTRACT

Springs are the major sources of water in Nepal, but the springs are drying up fast due to, among others, climate change, ill-engineered infrastructure and associated disasters. A huge sum of money is invested in water supply projects and a significant percentage of those have become nonfunctional due to source drying. Most of the projects consider the supply side only- not sustainability. By that, the scarce public investment is wasted. Hydrogeological aspects including climate change, and source conservation were never been realized. Once the sources dry up, projects become redundant. People look for alternative sources requiring scarce public investment. Therefore, the Government of Nepal and development partners like Renewable World (RW) concluded that the sustainability of water projects is crucial and must be considered in the initial phases of project development. It can be assisted and achieved by hydrogeological evidence-based water source conservation planning. To implement it, an interdisciplinary research team of Nepal Water Conservation Foundation and RW conducted a hydrogeological study including the climate impacts and participatory planning applying different sets of tools and methods applied in social and natural sciences such as hydrogeological study, key informant interviews, focused group discussions and policy assessment. Consequently, 10 site-specific source protection and conservation plans for solar MUS schemes were developed. The study found four types of variables: (i) Precipitation and temperature: There was no significant impact of climate change in terms of rise in temperature and precipitation; (ii) Problems related to conservation: The major problems included drying up and displacement of springs by flood, landslide and road constructions; pollution through agricultural runoff, livestock grazing, and contamination by pesticides and chemical fertilizers; disappearance or conversion of traditional wallowing/recharge ponds; contamination and damage by flood; (iii) Innovation: Even a small innovation like Solar MUS can contribute in people's life significantly through lifting water from downhill sources; (iv) Planning: Source protection and conservation plan can be formulated democratically and owned by local government and water user groups and implemented jointly.

Keywords: Hydrogeology, research, conservation, plan, solar MUS

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INTRODUCTION

Water is crucial for all forms of life on Earth (Hossain, 2015; Kilic, 2020). From the earliest days, human settlements and civilizations have grown, prospered and proliferated near a source of water (Fang and Jawitz, 2019; Kummu et al., 2011; McCool, 2008). Water is needed for practically all human activities: drinking, growing food, cooking, bathing, cleaning and industrial uses. The quality of water is usually degraded when it is used, especially when it carries human, agricultural and industrial wastes (FAO and IWMI, 2017).

Springs are the major sources of water for the people of Hindu Kush Himalayas (HKH) region (Chapagain et al., 2017; Negi and Joshi, 2004; Scott et al., 2019; Tambe et al., 2011). Additionally, springs are crucial for supporting wildlife and plants while supplying water for ecosystem services like base flow in rivers (Cantonati et al., 2006; Ghimire et al., 2014; Scott et al., 2019). Concerns about springs drying up, becoming seasonal, or having less water output has grown over time (Adhikari et al., 2021; Dixit, 2019; Poudel and Duex, 2017). Chapagain et al. (2017) found that during the period of 30 years, spring discharge in a mid-hill region of Nepal has decreased by more than 30%. Adhikari et al. (2021) revealed that over the period of past 10 years, discharge of almost 70% of the springs in the western Nepal were declining. A nation-wide spring survey by NWCF and ICIMOD showed that about 74% municipalities of Chure, mid hills and mountains have experienced spring drying up (Dahal et al., 2021).

Springs are part of a complex hydrological system which acts as a medium to transfer groundwater to the surface flow (Bresciani et al., 2016; Toth et al., 2022). The hydrogeology governing the flow and movement of spring is very complex and difficult to understand (Kamp, 1995) which leads to the research and policy gap on springs as well as its management (Shrestha et al., 2017). Many factors play a crucial role in the drying of spring sources among which climate change, land use and land cover change are the major factors responsible for its drying and depletion (Chapagain et al., 2017; Shrestha et al., 2017; Tambe et al., 2012). Among the other factors causing the dying of spring sources includes population growth, altered land use, the expansion of the infrastructure, and now climate change (Dahal et al., 2021). Due to missing of large amount of data as well as difficulty in its analysis and interpretation, it is very difficult to link drying and depletion of springs sources to climate change and other biophysical changes (Shrestha et al., 2017). The problems have become so worse that residents are thinking about leaving their communities and their houses (Dhakal et al., 2020).

People have begun to explore for alternative means of obtaining water, such as using piped water supply, drilling wells to access groundwater, and tapping of rainwater. However, there are still very few initiatives to comprehend and deal with the serious issue of diminishing spring sources (Dahal et al., 2021). Tapping of rainwater, declining water recharge areas, more runoff, less recharge and over-extraction of existing water resources are some of the issues that seem to be almost completely ignored (Sharma et al., 2016; Gyawali et al., 2019). Governmental, non-governmental, or development organizations all play a role in Nepal's water supply, yet none of them seem to care about the issue of groundwater in the hills. The interrelationship and science behind the rainfall, recharge, runoff and the actual water extraction potential seems to be unclear and yet to explore. Springs in Nepal are not properly mapped and explored and the roles and responsibilities for its conservation has not been assigned clearly which hinders its actual conservation (Sharma et al., 2016).

Different studies have shown that the springs can be revived and its discharge can be increased by increasing the water recharge in the upstream areas by construction recharge ponds and pits which helps to tap the precipitation during monsoon and can act as water recharge during dry months of the year (Sharma and Banskota, 2005; Upadhaya, 2009). Increasing the vegetation coverage nearby and in the upstream areas of the spring sources can also help in water recharge in the areas (Negi and Joshi, 1996). Water scarcity and poverty is increasing in Nepal due to various factors like urbanization, haphazard road construction and infrastructure development without its proper planning and without examining its impact on the environmental. Additionally, negligent human behaviors like open defecation, mixing of industrial effluents without its proper treatment, lack of proper solid waste management, lack of WASH knowledge and procedures, and excessive and haphazard use of chemical fertilizers and pesticides in agriculture have severely damaged the water sources in Nepal (Gyawali et al., 2019; Dahal et al., 2021; Adhikari et al., 2021).

To combat this situation, it has now become urgently necessary to follow a multi-pronged strategy for source protection and conservation of springsheds. It is possible only with a detailed hydrogeological study and development of a comprehensive spring source protection and conservation plan and that is implemented by the communities through local government interventions (Dahal et al., 2021).

STUDY SITES

The study site was located in Surkhet Valley spread over 10 different places under the five local government units in Barahatal Rural Municipality, Bheriganga Municipality, Gurbhakot Municipality, Panchapuri Municipality and Chaukune Rural Municipality (Fig. 1). It comprised of water sources provisioned for multi-use water supply systems (MUS) including drinking water, irrigation, sanitation. The Solar MUS were selected jointly by the water users, local governments and supporting partners on the basis of local needs and demands where the researchers did not have freedom to select the sites prior to the study.

Altogether 834 households were benefitted by the Solar MUS project. They include 37 households in Dhanigad, 103 in Jugedhara, 53 in Kharepani, 85 in Basantapur, 195 in Sanneghari, 29 in Devasthal, 176 in Raga Sundarpur, 82 in Jabden Bhaktadi, 35 in Aam Kholi Gotheri and 39 in Upallo Bharyang SMUS.

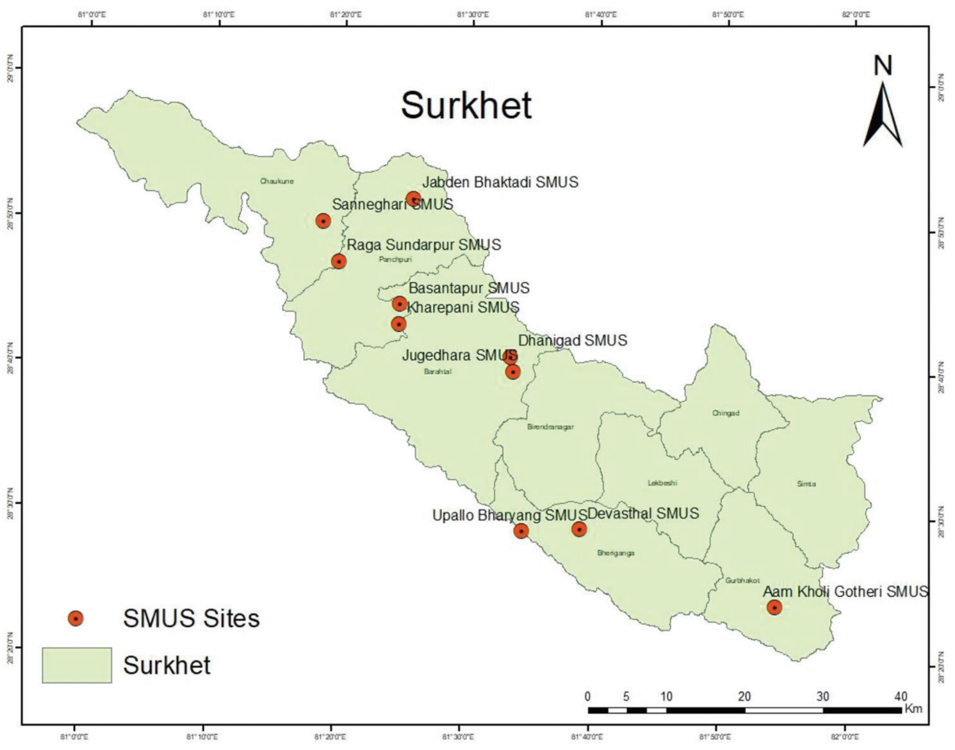

Fig. 1: Location map of the study area.

Methodology

An interdisciplinary research method was applied while designing the research. It comprises primary and secondary data extracted from applied as well as social sciences. Applied science methods such as hydro-geological excavation, site investigation, discharge measurement, hydrometeorology data recording, GIS and remote sensing were utilized whereas social science tools like field observation, focus group discussions (FGDs), key informant interviews (KIIs), and stakeholder consultations were carried out. Additional socio-economic data including policy and legal texts, number of water users were collected from concerned agencies and open sources.

The field level work started with a short scoping of the project area in order to observe its natural and physical characteristics, specifically the general hydro-geological characteristics, springs, spring-sheds, recharge ponds, and other water harvesting and conservation practices.

An observation tour of the sites was conducted to capture its physical characteristics. In particular, the topography; soils; geology; hydrology; types and characteristics of the springs and other water sources; existence and conditions of recharge sites such as ponds, check dams, ditches, and others; land and water utilization; and other relevant information were collected. The springs and ponds located during the observation tour were mapped using GPS machines and discharges were measured on the spot by simple and practical method of volumetric measurement using containers with known volume and stopwatches. A more exhaustive mapping and discharge measurements were undertaken to capture different types of springs and their behavior for a more detailed understanding.

Geological survey identified the regional geology, local geology, hydrogeology of the springs and the springsheds, problems and the mitigation measures associated with the sources.

Focus group discussions (FGD) were conducted on all the ten sites for collecting data to retrieve local knowledge on the water resources, level of awareness and understanding on conservation of natural resources and of water as well as to understand the communities' basic requirements and needs related to water supply. Moreover, key informant interviews (KII) were conducted to supplement the information collected during the observation and FGDs involving 160 persons representing local governments, community groups, water users and stakeholders working in the field of water resource, conservation and development.

Preparation of the plan started after the completion of the desk study and fieldwork (Fig. 2). Inputs for the plan preparation work include: a) findings from the desk study and field observation, b) analysis of the data and information obtained from the primary and secondary sources, and c) KII and inputs from the project personnel working at the sites. The draft plan was shared in a workshop with the project members, local government representatives, relevant line agency representatives, and other experts and resource persons for critical review and comments. The final plans were prepared after refining the draft in light of the comments and suggestions received.

An induction program on source protection and conservation draft plans was organized for the field staff in order to familiarize and train them so that they can hold local level consultation programs in each SMUS site effectively.

The field staff organized local level stakeholder consultations – one on each of the solar SMUS sites on source protection and conservation plan for that particular scheme with the aim to share the draft plan among the users, local governments and other stakeholders and get their feedbacks. Local government representatives, water user's committee, beneficiaries, civil society, media and other related actors working in the concerned sites took part. Such consultations helped to build mutual trust and fostered local government and beneficiary ownership over the plans.

A final discussion program on plan formulation was conducted in Birendranagar, Surkhet with water user's committee members, ward chairs, local government chief/deputy, representatives from Provincial Policy and Planning Commission, ministries, universities, I/NGOs, and media persons. After completing the above mentioned steps and review from experts, final version of water source protection and conservation plans of the 10 sites were prepared and handed over to the local government representatives and water users together.

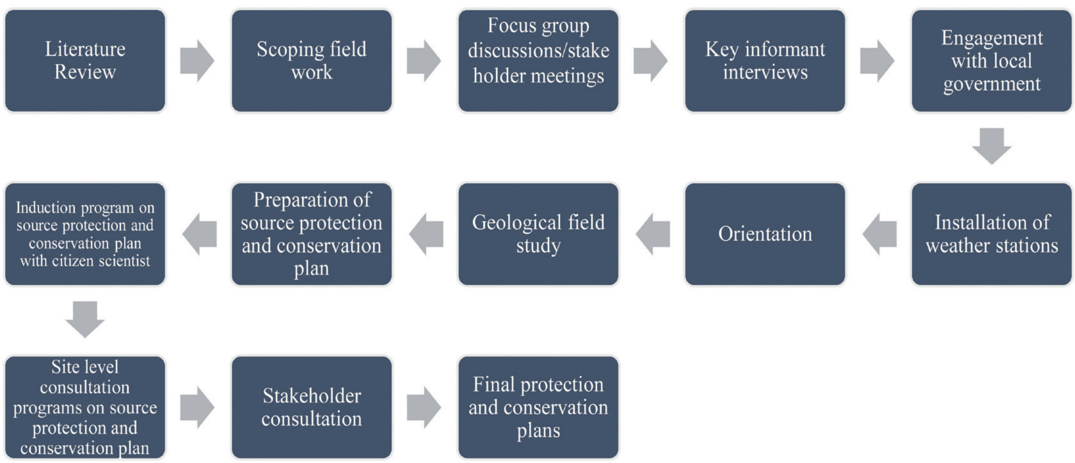

Fig. 2: Methodological framework.

RESULTS AND DISCUSSION

The following sections present the basic findings of the study as regards to the geohydrology of the springs, climatic characteristics and their impacts of water sources, socio-economic observations, and important issues related to the sustainability and need for protection of the sources.

Geology of the project area

Geologically, the spring sources under the study lie in areas covered by all three geological groups i.e., Siwalik group, Surkhet group and Midland group of rocks. Apart from the above groups, a number of spring sources such as Sanneghari spring, Raga Sundarpur spring, Kharepani (Chepang) sources and Basantapur well are located in quaternary deposits represented by different terraces covered by alluvial formation, whereas others are located in colluvial soils. Jabden Bhaktadi, Dhanigad, Jugedhara, Aam Kholi, Devasthal and Upallo Bharyang are fracture type springs originating from the bedrock joints. In these springs, the upper layer is generally jointed and weathered to various degrees and permeable with the bottom layer less jointed and relatively impermeable. These springs originate along the main discontinuity represented by the bedding plane.

Climate scenario and water resources

For the climate study of our region of interest meteorological parameters, such as rainfall and temperature data of the existing meteorological stations in and around Surkhet district for the period of 18-19 years were collected (Source: Department of Hydrology and Meteorology, Nepal). For this study, average annual rainfall, trends of average annual rainfall, average spring rainfall (i.e., driest season), and maximum and minimum temperature in spring season were analyzed and discussed as below:

Dhanigad and Jugedhara SMUS has 1607 ±290 mm average annual rainfall; and the trend of annual rainfall is decreasing over time. This indicates that that this location is receiving less amount of rainfall annually, which may affect the water availability in future. Adhikari et al. (2021) also found that changes in annual precipitation tends to impact the spring discharge in Nepal. The average rainfall of the dry season, spring (March-May) is 125±61 mm, which accounts 8% of the annual rainfall. The trend of the spring rainfall is also decreasing over time, indicating that there will be a serious condition in the future as this area may get less amount of water during this season when people and their domestic animals obviously need more water. As recorded by Adhikari et al. (2021), due to fluctuations in seasonal rainfall pattern, rural households are facing water scarcity during the dry months. Maximum and minimum temperature in the spring season shows that there is no significant climate change impact in terms of warming.

Basantpur and Kharepani SMUS has 1453 ±314 mm average annual rainfall; and it shows it is increasing over time. This is a good indicator for the sustainability of the project. An average rainfall of the dry season, spring (March-May) is 102±49 mm, which works out to 7% of the annual rainfall. The average spring rainfall, on the other hand, appears to be decreasing over time; pointing to a serious issue since in the future this area may get less amount of water during the driest period (i.e., spring season). Based on the magnitudes of maximum and minimum temperature in the spring season it is seen that there is no significant impact of climate change in this season in terms of warming.

Sanneghari SMUS receives an average annual rainfall of 1488±235 mm, and it is decreasing over time, indicating that this location has been receiving lesser amount of rainfall annually. This fact should be given a serious consideration while designing the project to ensure adequate availability of water in the future. The average rainfall of the dry season in the spring (March-May) is 121±50 mm, which accounts for about 8% of annual rainfall. The spring rainfall is also decreasing over time, which is a serious issue, as in the future this area may get less amount of water during the driest period of time (spring season). Maximum and minimum temperature of the spring season reveals that there is no significant climate change impact in terms of warming.

Devasthal and Upallo Bharyang SMUS sites receive an average annual rainfall of 1532±293 mm and the trend analysis show that it is decreasing over time which indicates that appropriate measures should be taken to ensure optimum water availability. The average rainfall of the dry season (March-May) is 107±59 mm, which accounts for about 7% of the annual rainfall. The spring rainfall is also found to be on a decreasing trend, which is a serious issue, as in the future this area may get less amount of water during the driest period of time (spring season). Based on the magnitude of maximum and minimum temperature in the spring season there is no significant climate change in terms of warming.

Raga Sundarpur SMUS has an average annual rainfall of 1607±308 mm and shows a decreasing trend over time. This fact should be seriously considered during the time of design of the project so that this may not affect water availability. Similarly, the average rainfall of the dry season (March-May) is 108±52 mm, which accounts for about 7% of the annual rainfall. When the trend of the spring rainfall is analyzed, it is also seen to be decreasing over time. This is a fairly serious issue as in the future this area may get less amount of water during the driest period of time (spring season). Maximum and minimum temperature in the spring season shows that there is no significant climate change impact in terms of warming.

Jabden Bhaktadi SMUS receives an average annual rainfall of 1186±159 mm, which is trending towards a gradual decrease over time. This implies that this location has been receiving lesser amount of rainfall annually, which should be seriously considered during the time of design of the project so that this may not adversely affect water availability. Similarly, the average rainfall of the dry season (March-May) that amounts to 120±48 mm which is about 10% of the annual rainfall. An analysis of the trend of spring rainfall shows that it is also decreasing over time, which is a rather serious issue as in the future this area may get less amount of water during the driest period of time (spring season). The increasing trend of difference of maximum and minimum temperature in the spring season shows that there is no significant climate change scenario in terms of warming.

Aam Kholi Gotheri SMUS has an average annual rainfall of 1353±321 mm, which is trending towards a regular decrease over time. This implies that this location has been receiving less amount of rainfall annually, which should be seriously considered during the time of design of the project so that it may not suffer from water shortage during critical times. The average rainfall of the dry season (March-May) is 106±60 mm, which accounts for about 8% of annual rainfall. When the trend of the spring rainfall is analyzed, it is found to be increasing over time, which is a good signal as it indicates increasing water availability during the driest period of time (spring season), when people and their domestic animals face a severe shortage of water. The increasing trend of difference of maximum and minimum temperature of the spring season shows that there is no significant climate change scenario in terms of warming.

Problems

The hydrogeological study revealed various problems related to spring source conservation. The major problems included drying up and displacement of springs by flood, landslide and road constructions; pollution through agricultural runoff, livestock grazing, and contamination by pesticides and chemical fertilizers; disappearance or conversion of traditional wallowing/recharge ponds; contamination and damage by flood. In Dhanigad SMUS, it was found that there is high possibility of slope failure, both upslope and down slope, and of losing the water source altogether. The landslide of 2014 AD (2071 B.S.) damaged this site, and there is always a possibility that such landslide can again result in displacement of the spring. Dhakal et al. (2020) also reported that landslide is also the major factor causing drying and displacement of spring sources in Nepal. In Jabden Bhaktadi SMUS, water collection tank has been covered by landslide due to which new tank has been constructed in the area which resulted in loss of financial as well as human resources. In Jabden Bhaktadi SMUS, the land was also subducted while constructing the SMUS. In Dhanigad, road was constructed using heavy machinery near the source in both upstream and downstream areas without making provision for side drains. There was a possibility of road construction nearby the Jugedhara spring sources. In Devasthal SMUS, the source of water shifted to new location due to road construction using heavy machinery. After one and half months, the source shifted back to near the previous location due to the vibration caused by passing vehicles plying on the road. Aam Kholi spring sources also recorded disturbance due to road construction. Infrastructure development as well as road construction has become a major challenge in mountain watersheds as it damages the springs sources as well as exposes the aquifer ultimately resulting in its drying (Green Roads for Water, 2018; Dhakal et al., 2020).

There was the possibility of mixing of runoff to the spring sources from upstream areas in most of the SMUS sites. Chance of contamination in the spring source due to inappropriate use of chemical fertilisers and pesticides in agriculture is high in Dhanigad, Jugedhara, Devasthal, Kharepani, Aam Kholi, Jabden Bhaktadi and Upallo Bharyang SMUS. Basantapur, Sanneghari and Raga Sundarpur SMUS lies in the low-lying areas, hence there is a chance of inter-mixing with flood water during monsoon season. Gurung et al. (2019) also recorded high phosphate concentration during pre-monsoon season in springs of western watersheds due to the mixing of runoff from agricultural lands. Xing et al. (2008) also found that use of fertilizers and pesticides in the upstream areas impacts greatly in the downstream areas especially during monsoon in middle mountain watersheds. The settlement in the upstream area has increased the chances of source contamination by human waste during the monsoon in most of the springs. In Devasthal SMUS, the flash flood resulted in the flooding of the septic tank of one of the households in the upslope area, which contaminated the drinking water and caused a diarrheal outbreak in the area. Due to flood water in Aam Kholi Gotheri SMUS, intake was damaged and siltation problem was observed in the SMUS.

Loss of vegetation and little or no vegetation in the upstream areas has resulted in many problems in spring sources. Dhanigad spring source is prone to landslide due to very little vegetation in the upstream area. People are cutting trees near the Jugedhara spring sources whereas there is no vegetation in the upper part of Sanneghari SMUS. In Thulokhola watershed, due to deforestation, tapping of enough rainwater was not possible which resulted in drying of both the spring as well as surface water sources (Poudel and Duex, 2017). Dhakal et al. (2020) also found that deforestation is one of the major factors contributing to the drying of spring sources. In Jugedhara SMUS, conflict between water users for irrigation and for drinking was recorded. Due to the conflict between irrigation water users and drinking water users' communities that caused a drinking water scarcity in the village for a week. Due to increased pressures on the existing sources and decrease in water flow in the spring sources, conflict arises between local users as well as upstream and downstream areas (Devkota et al., 2018).

Open grazing was recorded nearby Basantapur SMUS. Wardrop et al. (2018) found that herding cattle nearby water sources increases the chance of its contamination and to increase the water quality both the fecal contamination as well as livestock contamination needs to be addressed. Ponds and *Aahals* used to exist in the past but with modernization, these traditional facilities are no longer in existence. With modernization, livestock farming has declined dramatically which resulted in drying of such wallows and ponds and it has become a major factor in declining and drying of spring sources in mid-hills of Nepal (Sharma et al., 2016).

Solutions as plans

The Solar MUS schemes exhibited diverse characteristics in terms of their locations, geology, hydrology, and other physical characteristics, and some common aspects as well. Therefore, the common indicative activities listed in the plans included:

Considering a possibility of slope failure in Dhanigad SMUS (Fig. 3) both upslope and down slope with the high possibility of losing the water source altogether due to slope failure, hence for the protection of the spring source it was recommended to construct a gabion wall construction and removal of the unstable stones from the upslope. To minimize conflicts between water users of irrigation and drinking water in Jugedhara SMUS (Fig. 4), the small irrigation channel as well as surface runoff and the water from the canal should be prevented from mixing up with the spring sources.

As Kharepani SMUS is a dug well of about 6 m depth below the ground level partially fed by ground water mostly depends upon the seepage from the Bheri River, water shortage arises in dry seasons when the river level recedes to a minimum, water seepage to the source becomes limited insufficient to supply

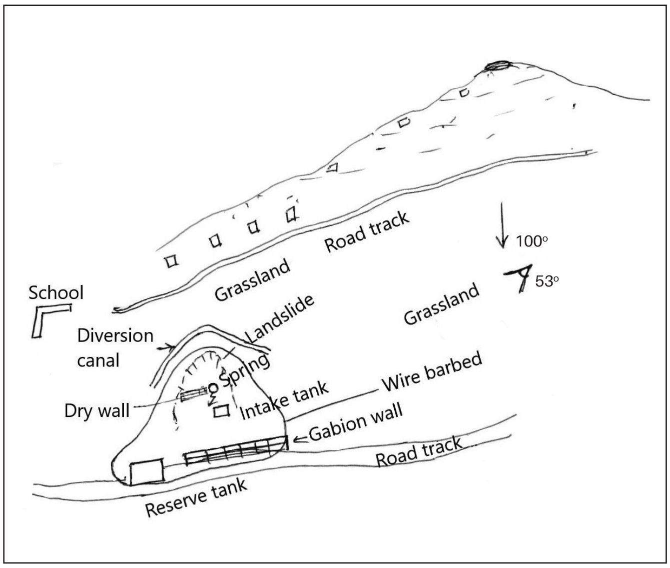

Fig. 3: Dhanigad SMUS.

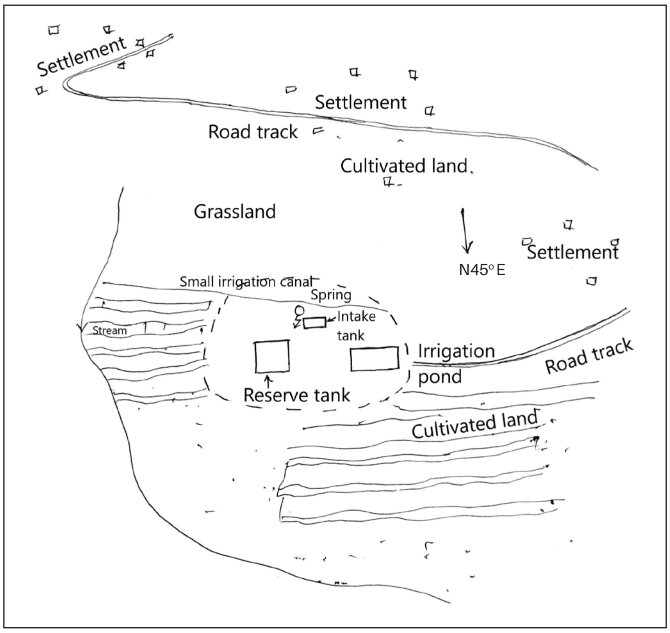

Fig. 4: Jugedhara SMUS.

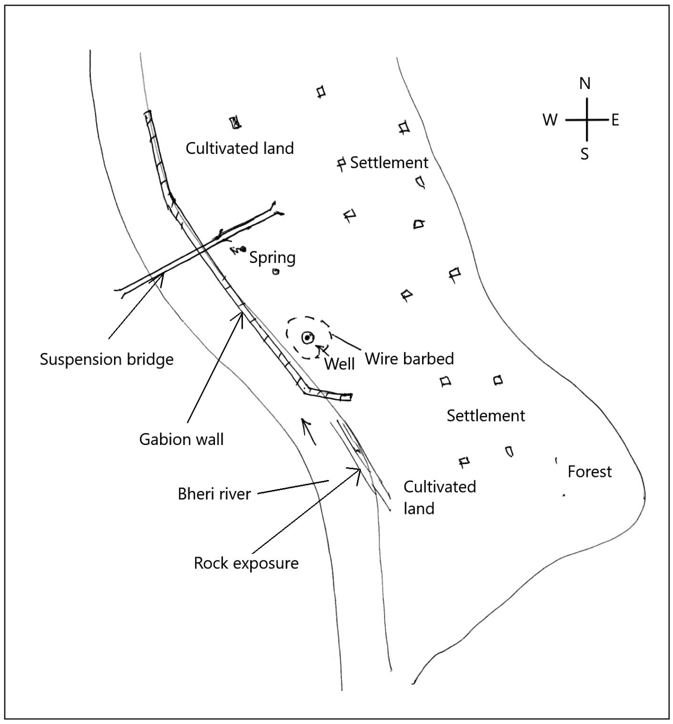

Fig. 5: Kharepani SMUS.

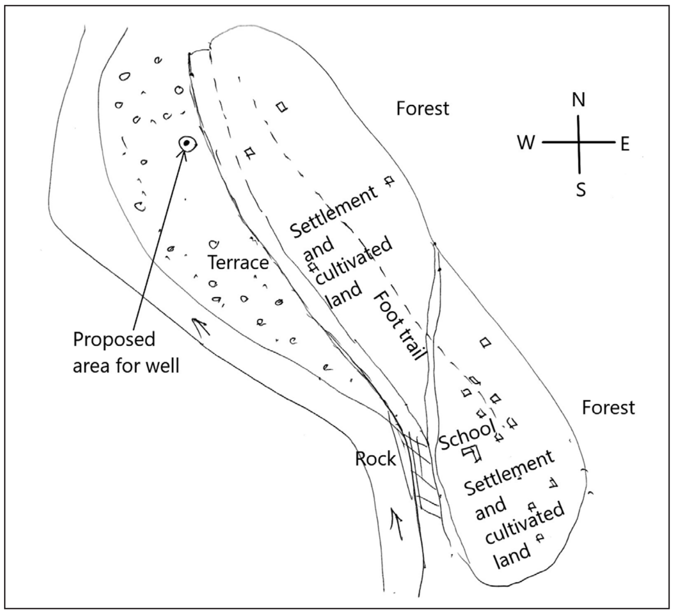

Fig. 6: Basantapur SMUS.

water to the user households (Fig. 5). Therefore, it is suggested that the selected alternate source should be excavated to at least 1-2m deeper than the dry season water level in the river and the water should be pumped into the existing collection well using solar pumps. Likewise, there occurs flooding problem from Bheri River during rains and chance of chemical contamination from upper side agri lands as the farmers use chemical fertilizers and pesticides in agriculture. It is recommended among others that source protection structures should be constructed to avoid such contaminations.

From the study, it was found that Bheri-Babai inter-basin water transfer can have an adverse impact on the water level of Basantapur SMUS (Fig. 6) hence, depth increment of the proposed well and a dam- construction of stone masonry wall around the proposed well area for preventing the flood water entering the well is recommended. It was also found that there is a possibility of contamination of source water due to lack of proper management of toilets in the upper settlement of the source as well as chances of mixing of runoff from the farmland with the Sanneghari SMUS (Fig. 7). Hence it was recommended to construct a side drain in the terrace above the spring source to control the runoff from the farmland and settlement to the water source. Similarly, it was advised to control use of hazardous chemical fertilizer and pesticides in agriculture. The spring source lies at the river bend, where bank cutting by the flood is prominent, so to minimize the cutting of the left bank and also to control spring water contamination by

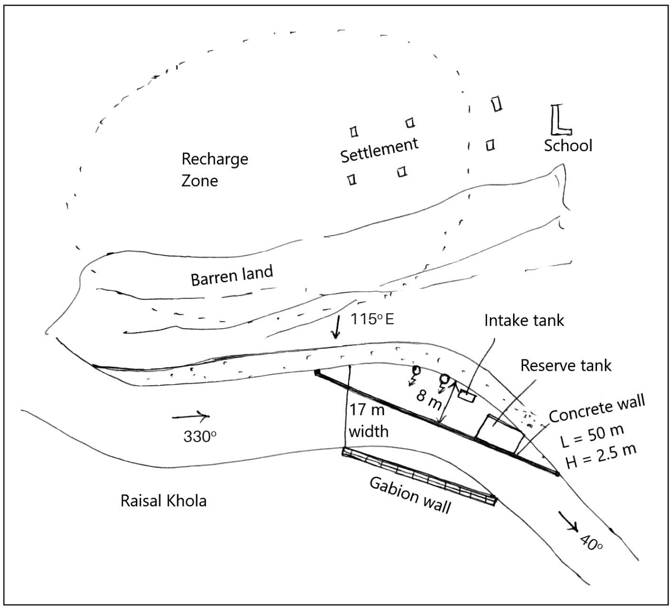

Fig. 7: Sanneghari SMUS.

the river flow especially during the floods, concrete wall needs to be constructed at the middle part of the stream along the direction of spring flow.

In Devasthal SMUS, road construction nearby the source increased the possibility of spring source shifting due to vibration caused by passing vehicles, hence use of bulldozer around the source should be prohibited as well as road extension should be done with manual labor and tools and not mechanized tools (Fig. 8). There was no vegetation around Raga Sundarpur SMUS, hence plantation needs to be done around the source (Fig. 9). The source also has the problem of bank cutting, hence it is recommended to construct concrete wall to protect the spring source and the reserve tank and also divert flood water to the other side. The source is near the agricultural land hence use of hazardous pesticides and chemical fertilizers in agriculture needs to be minimized for further contamination of the source.

The water user committee has low knowledge about water conservation in Jabden Bhaktadi SMUS (Fig. 10), hence it is recommended to conduct discussion program between spring water owner groups and water user groups (upstream-downstream linkage) and jointly organize the plantation program between community forest group from spring water source area and people from KHANE PANI AAYOJANA. In Aam Kholi Gotheri SMUS, there is high probability of flooding and pollution of spring water in the rainy season and high debris flow causing overall instability in the area, also intake is likely to be damaged by the nearby stream (Fig. 11). To minimize such problems, it is recommended to construct gabion walls, concrete wall and storm water diverting ditches to divert the flow of muddy water from the water source.

In Upallo Bharyang SMUS, chemical fertilizer used in agriculture might pollute the water and creates a quality problem and sources and quantity of water is decreasing whereas water users and its consumption pattern is increasing (Fig. 12). There is also chances of the mixing of runoff from the school and the settlement located upslope and barren land around the springs are also increasing. To minimize such

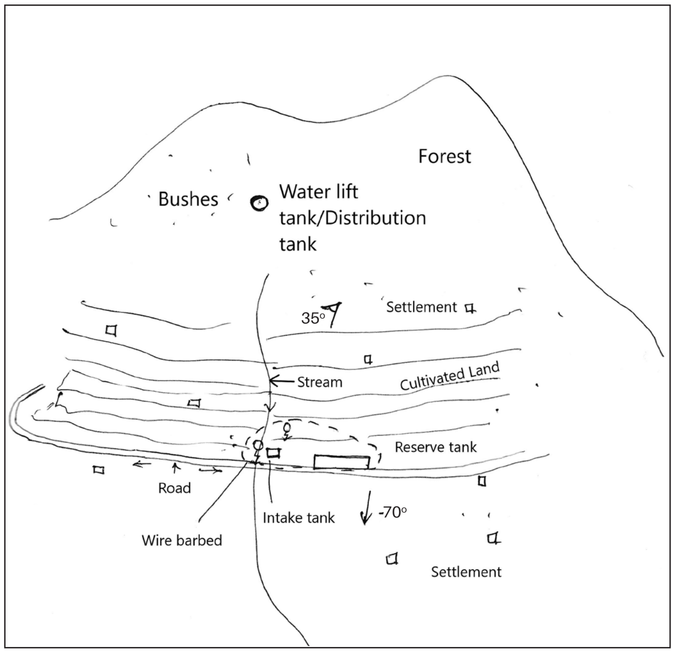

Fig. 8: Devasthal SMUS.

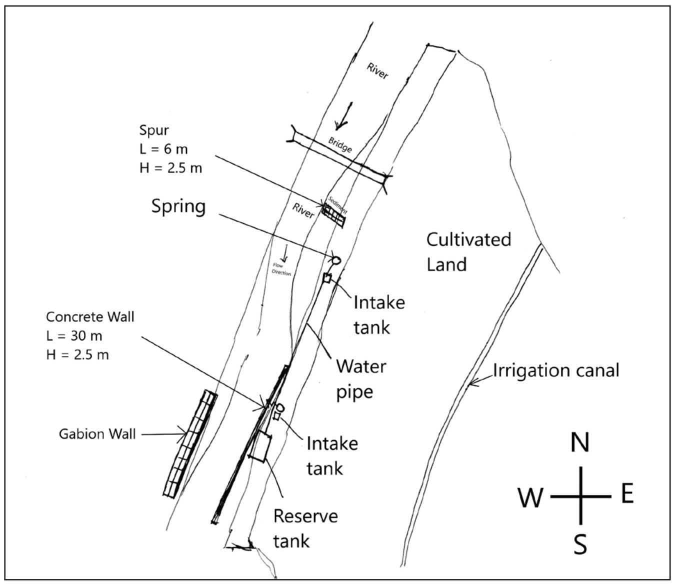

Fig. 9: Raga Sundarpur SMUS

problems awareness needs to be increased and prohibit the use of hazardous chemical fertilizer as well as pesticides in agriculture. Some of the most common source conservation measures recommended are as under:

- Construction of gabion wall, concrete wall and side drain to divert water flow from upstream areas to the spring.
- Removal of the unstable stones from upslope.
- Construction of a drainage channel upslope to divert surface runoff from the escarpment during the monsoon.
- Plantation of Khar or other local grass type vegetation for soil conservation above the gabion wall to cover all the landslide escarpment and let the vegetation grow thick. It can be cut in the dry season and allowed to grow back in the spring season.

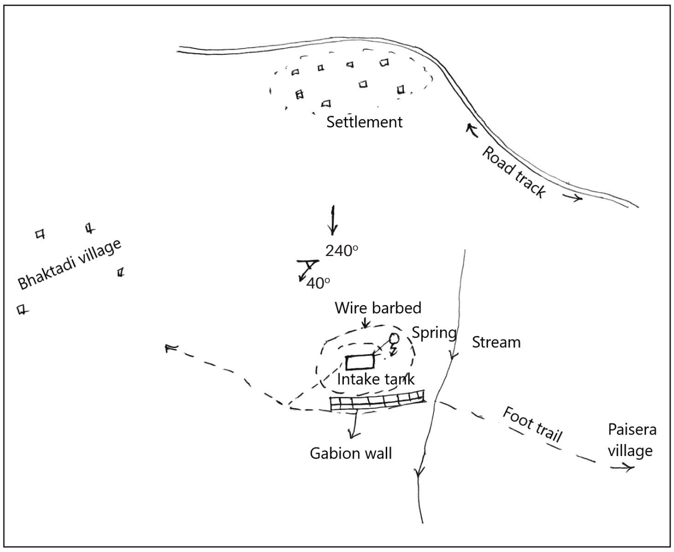

Fig. 10: Jabden Bhaktadi SMUS.

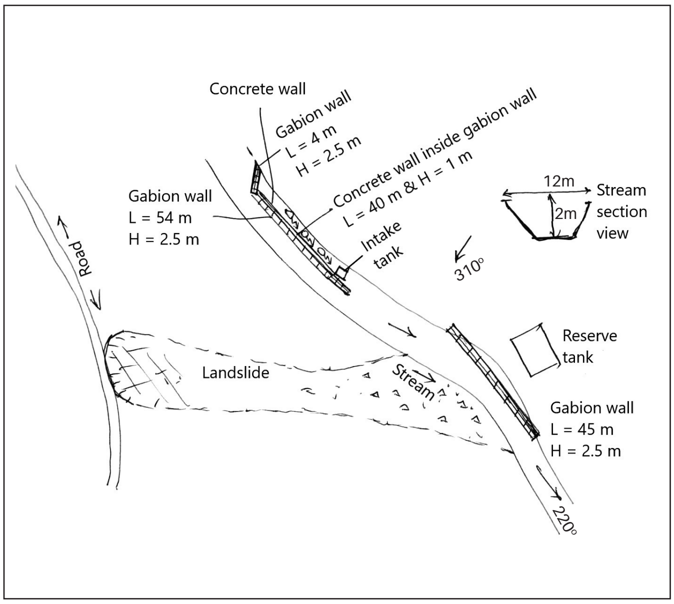

Fig. 11: Aam Kholi Gotheri SMUS.

- Management of the system in such a way that the water from the small irrigation channel and surface runoff do not mix with the water at the spring sources.
- Construction of barbed wire fence around the system.
- Keeping the whole area near the sources free from any garbage, waste or dungs.
- Controlling physical and chemical contamination.
- Grazing control in the vicinity of the spring sources
- Controlling overuse of hazardous chemical fertilizer as well as pesticides in agriculture.
- Do not use bulldozer or create vibration around the source.
- Road extension proposed in the area should be done with manual labor and tools, not with heavy machinery.
- Fill the land dug by the dozer in front of the source with stone and shingles.

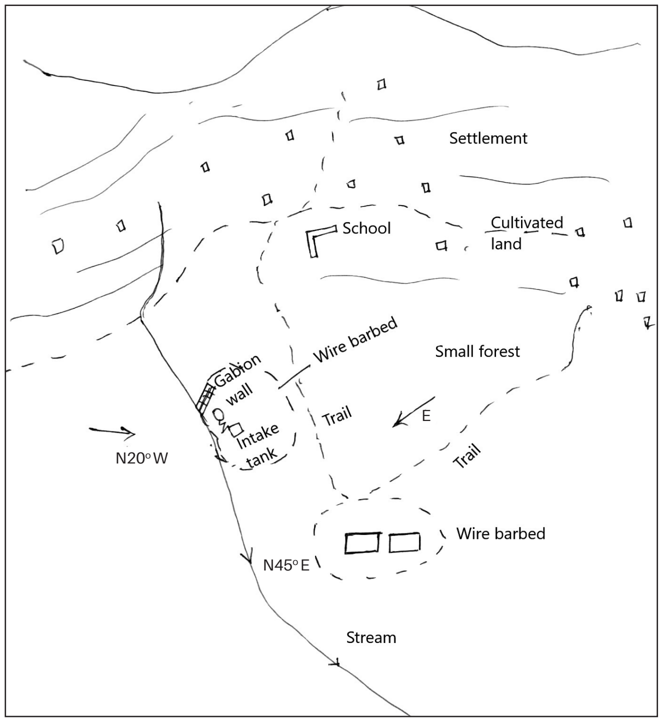

Fig. 12: Upallo Bharyang SMUS.

- Maintain the distance between spring and intake tank.
- Forest conservation around the spring sources.
- Construction of the recharge ponds in the springshed area.
- Revival of the old ponds above the spring source.
- Run programs for raising awareness against overuse of pesticides and chemical fertilisers.
- Conduct public awareness programs to keep the vicinity clean of any rubbish.
- Construct barbed wire fence around the source area to keep it clean.
- Perform water quality test.
- Conduct stakeholder consultations between land owners and water user groups for a good upstream-downstream linkage.
- Jointly organize plantation program with participation of people from community forest group, spring water users and the drinking water project (*khane pani aayojana*).

The activities recommended for the individual SMUSs are divided into two categories. The first set of activities are those that are needed for source protection such as physical construction and other direct interventions. The second set of activities refers to the conservation of the sources and includes long-term activities like planting and maintenance of vegetation, capacity building, monitoring, etc. Therefore, projects need to prioritize the activities and implement them in a number of stages. Detailed plans including detailed drawings and work schedules must be prepared before undertaking the tasks.

CONCLUSION

Even a small innovation like water lifting technology can contribute in people's life significantly through lifting water from downhill sources where alternative sources of water supply are not available. Technological connections were made to the water lifting scheme with a solar power generated electricity to reduce the operation cost as well as provide power to the pumps where electricity lines are not connected. Methodologically, an inter-disciplinary research method was adopted blending natural as well as social science methods and by a diverse team of experts through cocreation. Started as a project having specific terms of references set at the beginning, the knowledge recording, evidence generation and policy process was evolved over the project period as a co-creation exercise through dialogues and creative thinking. It connected hydro-geological science to impacts of climate change on water and spring sources and people. It included a participatory action research that informed the policy making and planning process by involving policy makers, community leaders and water users. Consequently, it helped to build user's ownership over the plans and policies with commitments to implement it. The participation of stakeholders in different stages of the research, planning and decision-making processes right from the project conception, planning and implementation became instrumental to build consensus among the actors.

Moreover, it highlighted the importance and need of springshed level conservation approach in drinking water schemes urging a policy shift from existing watershed conservation and source level protection mindset and practice such as fencing of water collection structure, well area concretization. The actors and stakeholders in the process accepted the fact that such interdisciplinary researches can be instrumental to influence policy level interventions for the sustainability of water supply schemes, and institutionalization of spring source conservation approach in the policy where water pollution, source depletion, springs drying up, and growing water demands are evident.

From the research and evidence-based policy making practice, a policy shift has occurred particularly in drinking water supply projects where hydrogeological study for evidence-based policy making started. It underscored the need of a springshed conservation approach moving ahead from traditional approach of source protection and watershed conservation, and meteorological database for spring conservation policy making and livelihood enhancement were utilized. Participatory planning process was used to generate local ownership. It demonstrated that local governments should come forward to conserve springshed adopting evidence-based policy making for water security and sustainability. Likewise, hydro-meteorological data should be used as adaptation tools under the uncertain climate conditions especially in agriculture

That considering the growing water demands for drinking water, sanitation (in the ODF context having at least a toilet at every household), livestock feeding and irrigation (at least for kitchen garden), crops if available, and worldwide water scarcity due to climate change and haphazard developments taking place rapidly in rural, peri-urban and urban areas, spring sources are being inadequate to meet the demands and under serious threat of drying up. In such a situation, we may not be able prevent the climate change impacts and other disasters, we can, of course, protect and conserve existing spring sources from collective and concerted efforts. It can be achieved through developing plans based on the evidences generated from scientific studies and connecting the communities with innovative ideas and technologies. In this noble cause, local communities especially of the springshed areas, users and local governments should come together with will and commitment to protect and conserve the existing sources as specified under this study by prescribing and implementing proactive measures. For this, local governments should take the lead and local communities join hands together to translate these plans into reality for the sustainability of the water supply and SMUS systems installed and planned for the near future. Moreover, the constitution, laws and policies of Nepal have entrusted this responsibility to the local governments, so is the duty too.

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