Bringing Bhutan's Dying Water Sources Back to Life

Spring Revival Project

SUPPORTED BY

K2A
KNOWLEDGE TO ACTION

Jambay

ACKNOWLEDGE

We extend our sincerest gratitude to the Knowledge to Action (K2A) team for selecting us as grantee of K2A small grant ‘22 and making our dream a reality. The concern of providing solutions for the drying up of water sources has been a longstanding issue, and it is fortunate to have received support from K2A to implement this project on the ground.

We would also like to express our heartfelt thanks to the reviewer team for their time and effort in processing our proposal and monitoring this project. Your invaluable support has enabled us to work for the community and bring this project to fruition, ultimately helping communities to protect their water sources.

The swissuniversities Development and Cooperation Network (SUDAC) programme deserves special recognition for enabling us to apply our university-acquired knowledge on the ground and put knowledge into action for the benefit of those impacted by dry water sources in the project site.

We would also like to acknowledge and thank the Tarayana Foundation, an NGO in Bhutan, for their support in collecting and analyzing data for the benefit of the community. Additionally, our gratitude goes out to the Royal University of Bhutan and students for their time, laboratory facilities, and equipment for the analysis of water quality assessment from drying springs.

Lastly, we extend our heartfelt thanks to all the community members, local governments, and all the people who have directly and indirectly helped us in implementing this project and believing in us to make a difference in providing new solutions to drying water sources in Bhutan. Your support has been instrumental in bringing this project to fruition, and we are truly grateful. Thank you all!

CONTENTS

ABBREVIATIONS AND ACRONYMS

CSO	Civil Society Organization
DoFPS	Department of Forest and Park Services
EC	Electrical conductivity
GIS	Geographic Information System
GPS	Global Positioning System
HKH	Hindu-Kush Himalaya
ICIMOD	International Centre for Integrated Mountain Development
kml	Keyhole Markup Language
lps	Liter per second
NLCs	National Land Commission Secretariat
µm	Micro meter
NECs	National Environment Commission Secretariat
NGO	Non-Governmental Organization
SDG	Sustainable Development Goal
TDS	Total Dissolved Solids
WMD	Watershed Management Division

INTRODUCTION

1.1 Background and Overview

Access to clean water is essential for human survival and the growth of communities, thus making it part of Sustainable Development Goal (SDG) 6 "clean water and sanitation for all." (Hall, Van & Van, 2014). Unfortunately, drying up of water sources has become a significant issue in many developing countries, particularly in the Himalayan region, including Bhutan (Jambay & Uden, 2023; Jambay & Uden, 2021). This problem has led to numerous concerns, such as water scarcity for drinking and irrigation purposes, which has been consistently reported in the news media in Bhutan. Despite the issue being the flagship program of the nation, the root cause of drying up of water sources remains unknown due to a lack of practical scientific understanding in water sciences (Dema, 2019).

Governments and agencies have been focusing on finding alternate water sources for drying up water sources, which is not a long-term solution. Thus, researchers and academicians from universities have emphasized the importance of understanding why water sources are drying up in the mountains. This project aimed to find out what are some reasons communities say are causing the drying up of spring water sources happening in their areas and what can be done to stop or reduce drying water sources and implement solutions for reviving drying water sources in selected communities of Bhutan.

To achieve this objective, community people were engaged in finding probable reasons for drying up of water sources through training and community consultation meetings. Additionally, other agencies were also trained to understand the issue of drying up water sources and to implement springshed management in the field. The project resulted in demarcation of recharge areas and the formation of water user groups to maintain interventions undertaken with to make it sustainable after the project.

Furthermore, this project introduces the concept of springshed management, which differs from the old watershed concept implemented in the mountains of Bhutan. This concept has been successful in finding solutions to the drying up of water sources in regional mountainous areas. The project emphasized the need to educate local resident, stakeholders and students on this concept of springshed management to provide a sustainable solution to the issue of drying up water sources in Bhutan.

In the following sections, this project delves into more detail about the project's methodology, data collection techniques, and the findings of the study. It also highlights the implementation of the solutions to revive drying water sources in Chubu communities in Bhutan. Additionally, the report explores the concept of springshed management and how it is different from the traditional watershed management approach, which was not so successful in addressing the issue of drying up water sources in the mountains of Bhutan.

Therefore, this project had sheds light on the issue of drying up water sources in Bhutan and the Himalayan region. It also highlighted the importance of understanding the cause of the issue and implementing sustainable solutions to address it with the introduction to the concept of springshed management, which provided a more effective approach to addressing the issue. This project report aims to provide a better understanding of the issue to policymakers, researchers, academicians, and communities in the region

1.2 Springshed vs Watershed: Understanding the Difference

The concept of springshed management differs from that of watershed management, which has been applied worldwide and is also a common intervention in Bhutan. While watershed management takes care of surface water and considers the basin-like land surface for gathering all water together to form a particular river or outlet, springshed management focuses on the areas that lead to the formation of a particular spring (Jambay & Uden, 2021). This is because 67.6% of the population in Bhutan depend on spring water resources for drinking and irrigation, making springshed management a crucial consideration for well-being and sustainable sources (Watershed Management Division [WMD], 2021).

The land surface from where the spring is actually formed or the entire area that leads to the formation of the particular spring is known as the springshed. The management of the springshed starts with the recharge area of the particular spring and extends till the discharge point of the spring (Jambay, Yuden, Tshomo, & Jamtsho, 2022). The recharge areas in mountainous regions often fall on the other side of the mountain, in a different watershed.

One of the mistakes of watershed management in mountainous regions is that two watersheds sometimes combine to form a particular spring. Therefore, to manage a drying spring in this case, both watersheds have to be taken into account. This is where springshed management comes into play, as it is a holistic approach that considers both the discharge area and the recharge area, which are often on different sides of the mountain or watershed in mountainous regions.

In Bhutan, the springs is an essential water source for drinking and irrigation purposes. Therefore, the implementation of springshed management is critical. This management approach considers the entire area leading to the formation of the particular spring, include all attributes in the land surface. By focusing on the springshed, it is possible to ensure a sustainable water source for the community.

The recharge area on one side of the mountain is often critical for the formation of a spring, while the other side of the mountain is not protected under watershed management. However, to manage a particular spring, both watersheds have to be considered. In other words, springshed management is a powerful management system that takes into account the discharge area as well as the recharge area, which may be in another watershed or on another side of the mountain (Jambay & Uden, 2021). This makes springshed management a crucial approach to be applied in mountainous regions around the world. Therefore, springshed management is a slightly different concept from watershed management, as it focuses on a particular spring.

1.3 Common Interventions for Drying Water Sources

Various interventions have been implemented to address the drying up of water sources, but they seem to be short-sighted and do not address the root problem. One such intervention is the shift to new water sources, which results in additional costs for infrastructure and human resources. However, this intervention does not solve the real problem of drying up of water sources.

Similarly, the fencing of water sources to prevent wild animals from accessing them is another common intervention. This practice is viewed as a good intervention required for the drying up of water sources as it stops wild animals from getting drinking water. However, this approach has negative ecological consequences as the wild animals are deprived of drinking water, which is essential for their survival. This leads to a human-wildlife conflict that increases in Bhutan.

Increasing the size of the reservoir or water tank is another intervention implemented to address the drying up of water sources. However, this intervention also has its limitations as the water inflow into the tank is not significant enough to fill the large reservoir. This approach does not address the issue of low water flow due to drying up of water sources.

Borehole drilling is gaining popularity intervention to address the issue of drying up of water sources. However, in the mountainous context of Bhutan, there is limited understanding of aquifers below the ground. Groundwater in the mountains is often the blind spot in Himalayas, and the lack of recharge data can result in the abstraction of groundwater, leading to the drying up of wells (Kulkarni, Desai, & Siddique, 2021). In addition, exploration of groundwater in a fragile mountainous country like Bhutan can be dangerous, as many parts of the country have limestones, gypsum, and dolomite, as seen in Karstic caves (Jambay & Uden, 2021; Ford & Williams, 2013). Poorly implemented drilling can result in sinkholes or land subsidence in the future, posing significant risks to the environment and human life.

Therefore, finding appropriate interventions to address the drying up of water sources is critical. The springshed approach is one such intervention that has shown promise in reviving drying water sources with fewer unintended consequences (Tambe et al., 2012). It is essential to explore and implement sustainable interventions that ensure the long-term availability of water sources while maintaining the ecological balance.

1.4 Water User Group and Community Meetings for Effective Springshed Management

The success of interventions depends on ensuring sustainability, which requires a group dedicated to maintaining the water resources. A water user group is essential to ensure the functionality of water conservation in the group. It is important for the local people and beneficiaries to take accountability for the project, and have a better understanding of the project. Therefore, community consultations were conducted as part of creating awareness about springshed management.

During community consultations, local people were asked about the probable reasons for the recent drying of water sources in their locality. Their inputs were valuable as they have better knowledge of the area. They were also asked to describe how the area was before and what changes have occurred that could have resulted in the drying out of water sources in nearby watersheds. Since these people have resided in the locality for an extended period, they have a better understanding of the area and are an essential part of the project.

The importance of water quality and recharged areas also needs to be conveyed to the local community to ensure the sustainability of the project. Similar training on awareness was provided to students in the university and other relevant stakeholders to better understand the idea and put it into action in the future.

Community meetings played a crucial role in creating awareness about the importance of water conservation and sustainability. The meetings also provided an opportunity for people to share their knowledge and learn from each other as it is crucial to ensure that the interventions implemented are effective and that the water resources are maintained.

MATERIALS AND METHODS

2.1 Existing Community Knowledge Questionnaire

The new concept of springshed management is a vital aspect of sustainable water resource management. However, its success relies heavily on gaining support from local communities and beneficiaries. Therefore, to ensure the successful implementation of this concept, community consultations, meetings, and training sessions were conducted. These sessions aimed to provide relevant stakeholders, including local government representatives, with an understanding of the importance of springshed management. The decision-making process was solely given to the community people, as they are the primary beneficiaries of the project.

During these training sessions, the protection of recharge areas and discharge areas, which are critical for maintaining the springshed's integrity, were emphasized. Furthermore, the condition of the surrounding spring formation was assessed and discussed in detail. To gather more insights into the reasons behind the drying up of water sources, a simple questionnaire was created in goggle foam. The questionnaire aimed to collect information about the participants' understanding of the drying up of water sources, including their knowledge about the possible reasons behind it.

The collected data was analyzed using Data Analysis Software such as SPSS and JASP, and the results were used to develop effective ideas for the successful implementation of the springshed management concept. This approach aimed to empower the local communities and beneficiaries, enabling them to take ownership of the project's decision-making process. Ultimately, the success of the springshed management concept relies on the support and involvement of the local communities and beneficiaries. Therefore, this approach plays a crucial role in ensuring the long-term sustainability of water resources.

2.2 Selection Criteria of Spring for Springshed Assessment

The first step is to ensure that the participants understand the concept of springshed management. Following this, the selection criteria for the spring sources are established. The chosen springs for assessment should have experienced a decrease in their discharge over the past few years, and they should have large springs discharge in the past. The goal of intervention is to revive these drying springs to their previous discharge level. Another crucial factor in the selection process is the number of water users utilizing the spring source. Selecting springs with a large number of water users/households ensures greater benefits for the community.

Additionally, it is important to select springs that are easily accessible to the road network so that people can continue to collect data and measure the impact of the intervention (International Centre for Integrated Mountain Development [ICIMOD], 2018). The discharge of spring water should be measured before and after the intervention. Therefore, the selected springs should be located near the road. It is also recommended to consider culturally important springs and those that have ecological importance for wild animals such as a lake (Jambay, Dema & Dendrup, 2021; ICIMOD,2018).

2.3 Hydrogeological survey

A hydrogeological survey was conducted to identify the recharge areas and surrounding regions of a selected spring, and to investigate the geological conditions that may have influenced the formation of the spring. The survey involved transect walks along the road and river to locate rock outcrops or exposures. The Brunton compass was used to measure the dip direction and strike of the rock exposures in the catchment of the spring to determine the areas that contribute to the formation of the spring. It is important to conduct transects along the dip direction to record and measure all the different rock layers accurately, which helps in analyzing the potential recharge area. The characteristics of the rock types, structure, and permeability were determined as the formation of an aquifer contributing to the particular spring (Advanced Center for Water Resources Development and Management [ACWADAM], 2015).

Once the rock information was collected, the next step was to locate the coordinates collected by GPS on the Google map. To plot the data on the map, the coordinates of all the points were recorded along with the dip and strike of the rocks, using the north direction as a reference. This process provided an insight into how the rocks were aligned based on the dip direction, contributing towards the formation of the spring water sources. The geological information obtained from this survey was critical in identifying the recharge areas and understanding the hydrogeological processes responsible for the formation of the spring.

2.4 Demarcating Spring Recharge Area with CorelDRAW software

To create a hydrogeological map of a spring, Google Maps was used to plot the location, which was later imported into CorelDRAW software. In order to display the contribution of the land surface to the springs, the dip amount of each rock formation was drawn using CorelDRAW software. The data was then plotted for a 3D cross-section of the hydrological mapping of recharge areas for the spring that was under investigation. The resulting map provided a visual representation of the potential recharge areas, making it an essential tool for planning interventions to revive drying water sources in this project (ACWADAM 2015).

2.5 Measurement of Spring Discharge and Water Quality

To measure the discharge of the spring, a stopwatch and bucket method were used. In order to analyze the variations in discharge over time, it is necessary to ensure that data is collected on a monthly basis. Thus, the establishment of a water user group is essential for the proper monitoring of spring discharge over a period of 2 to 3 years.

Also, in order to evaluate the water quality of the spring, a water tester probe was utilized to obtain in situ measurements of several key water quality parameters such as temperature, pH, conductivity, salinity, and electric conductivity. The aim of this study is to perform a comparative analysis of these water quality parameters before and after an intervention in the future. Additionally, the recorded parameters will provide valuable insights into other related parameters that can be monitored over time to gain a better understanding of changes in the water quality of the spring (Government of Sikkim, 2014).

RESULTS AND DISCUSSION

3.1 Demographic and Socioeconomic Data

Citizen science was blended with water science to gather information from people on the drying spring water sources. To gain a better understanding of the causes of water sources drying, questions created using google forms were asked to 31 local residents in the community. It was important to understand the socio-economic background of the people in the area. The binomial test results showed that the proportion of male and female participants was not the same, with 77.5% of participants being female. This could be because most of the males were involved in working and had to travel to other places for earning a livelihood for their family.

Water scarcity is a problem associated with females, and it was appropriate that more than half of the participants were female. This result was statistically significant at a *p* level of 0.05. Also, demographically, most of the participants were young adults between the ages of 21 and 35 years old, representing 41.9%, followed by adults between the ages of 35 and 55 years old (Table 3.1).

Most of the participants were also not educated, and those who were educated had traveled to the city for jobs. Those who lived in the village were mostly illiterate but had good information on nearby water sources. Therefore, most of them were farmers by occupation (77.4%). The majority of participants in the villages represented middle-income people with an annual income of Nu 30,000 to Nu 100,000, as shown in the table below.

Table 3.1: Binomial test results of participants

Variable	Level	Counts	Total	Proportion	*p*
Gender of the respondent	Female	24	31	0.774	0.003
	Male	7	31	0.226	0.003
2. What is your age?	1). Less than or Equal to 20	2	31	0.065	< .001
	2). 21-35	13	31	0.419	0.473
	3). 35-55	11	31	0.355	0.150
	4). > 55	1	31	0.032	< .001

Variable	Level	Counts	Total	Proportion	p
	4). Greater than (>) 55	4	31	0.129	< .001
3. Which is your highest level of education?	1). None	17	31	0.548	0.720
	2). Literate	1	31	0.032	< .001
	3). Literate (no formal school but can read and write)	2	31	0.065	< .001
	4). Primary school	2	31	0.065	< .001
	5). High school	5	31	0.161	< .001
	6). Others	4	31	0.129	< .001
4. Occupation	1). Farmer	24	31	0.774	0.003
	2). Student	1	31	0.032	< .001
	4). Employee	3	31	0.097	< .001
	5). Retried	1	31	0.032	< .001
	6). Others	2	31	0.065	< .001
5. What is the annual average income (Nu.) of the family?	1). Less than 30,000	8	31	0.258	0.011
	2). 30,001 - 100,000	14	31	0.452	0.720
	3). 100,001. 500,000	9	31	0.290	0.029

Note. Proportions tested against value: 0.5.

From these findings, it can be inferred that the people living in this area can have a good understanding of water sources but lack ideas on how to reduce or stop water sources from drying up due to not being educated. Also, most of them are women who are staying at the village and facing water scarcity. Women are a fragile population group living in the community under study (Tomberge et al., 2021). Thus, it is imperative to come up with solutions that consider the specific needs of this group while addressing the water scarcity issue.

3.2 Angry local deities cause water drying

In the context of water management science, it is crucial to understand the beliefs and perspectives of local communities (Moggridge, Thompson, & Radoll, 2022). During community meetings, it was found that a significant number of people attributed the drying up of water resources to the displeasure of local deities caused by the lack of cleanliness in water surroundings. This belief was expressed by many participants, and the study aimed to assess the extent of this belief in the community. The findings indicated that 80.64% of the participants held this belief, suggesting the importance of considering traditional beliefs when applying modern science in water sciences.

Furthermore, a statistically significant difference was observed between believers and non-believers when using chi-square analysis, a significant deviation from the hypothesized values was found ($\chi 2$ (4) = 10.391, p = .034). This result reinforces the significance of the traditional beliefs held by the community and highlights the need for interventions that align with these beliefs.

Table 3.2: Perception that local deities caused dry water sources

	The local gods are upset, causing the springs to dry up		
Age of Respondent	**No (%)**	**Yes (%)**	**Total**
1). Less than or Equal to 20	2 (100)	0	2
2). 21-35	3(23.08)	10(76.92)	13
3). 35-55	1(9.1)	10(90.1)	11
4). > 55	0	1 (100)	1
5). Greater than (>) 55	0	4(100)	4
Total	6(19.36)	25(80.64)	31

Therefore, any interventions aimed at addressing water management issues in this community should be tailored to align with the community's traditional beliefs. Ignoring or neglecting these beliefs may result in limited participation and support from the community, thereby reducing the effectiveness of the interventions. Instead, interventions should be designed to incorporate the community's traditional beliefs and practices to increase community engagement and support.

3.3 Banana Planting Intervention to Increase Water Flow

The intervention of planting banana was believed to increase water flow, and this study encountered this assumption. Many water sources have banana planted near the spring water with the belief that it would increase water flow because water could be seen inside the banana.

To check this assumption, a questionnaire was conducted to reveal the local community's understanding of how banana contributes to the increase or decrease of water flow. The assessment found out that 77.419% of participants believed that banana would result in an increase in water flow, while 12.903% believed that banana is causing the spring to decrease flow (Figure 3.1). This shows a clear divide in the understanding of the impact of banana on water flow.

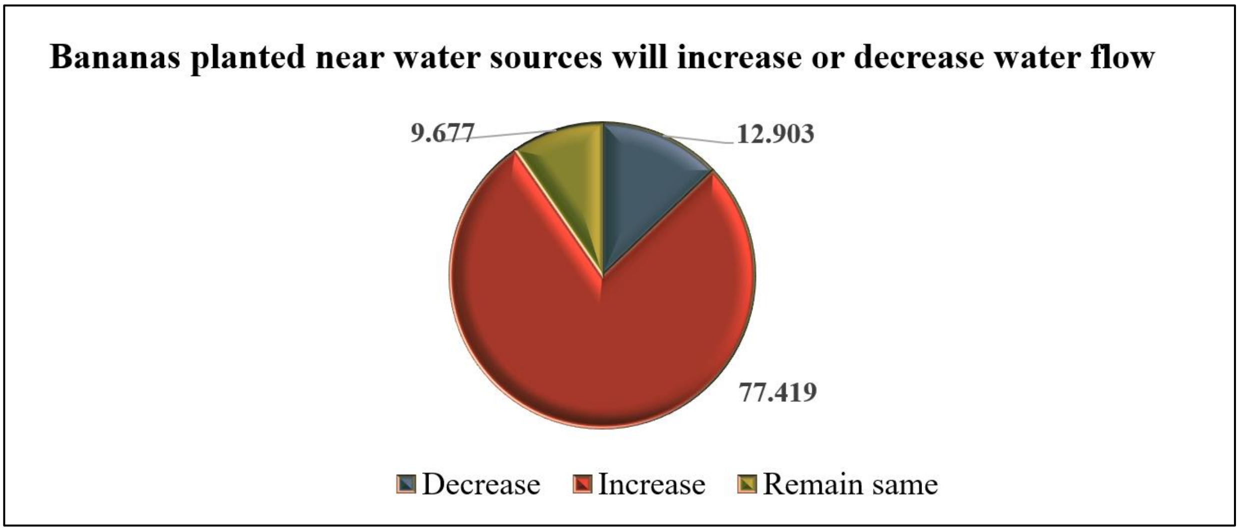

Table 3.1: Perception on banana planting intervention to increase water flow

It is crucial that these people understand the impact of bananas before planting them in water sources, as this is currently happening commonly. According to XXX, banana does not produce any water, but it stabilizes the land and provides shade while holding some water. However, it is important to note that it also sends a lot of water during evapotranspiration, which could lead to a decrease in water flow. It is necessary to educate the local community on the impact of banana on water flow to achieve the desired results.

3.4 Community's View on Local Spring Water Flow Changes

The purpose of this study was also to assess the opinions and perceptions of the community regarding the flow of springs water in their locality compared to past years. The study revealed that a majority of the local people, i.e., 74.19%, have observed a decreasing trend in spring flow over the past few years as shown in table 3.3. This decline has raised concerns among the local people about the possibility of their water sources drying up completely, as has happened in some parts of Bhutan (WMD, 2021).

Moreover, it was interesting to note that 20.83% female have also reported an increase in the discharge flow of springs, which is also possible. However, all the male participants stated that the flow of springs had decreased compared to past years. The local people narrated having big streams in the past, which have now turned into dried-up gullies in the area. This highlights the severity of the problem and indicates the urgent need for remedial action.

Table 3.3: Perception that local deities caused dry water sources

Gender of the respondent	When compared to past years, how has water flow at your drinking source changed in your village? Did it			
	Decrease (%)	**Increase (%)**	**Remain the same (%)**	**Total**
Female	17(70.83)	5(20.83)	2(8.3)	24
Male	6(85.71)	0	1(14.29)	7
Total	23 (74.19)	5(16.13)	3(9.98)	31

Although the finding is not statistically significant when analyzed using a chi-square goodness of fit ($\chi 2$ (2) = 1.818, $p > .05$), it is still a matter of concern. The study's suggested that the local people have a clear understanding of the changes happening in their environment and that they were worried about the possible consequences. These findings can be used as a basis for policy decisions and planning, which can help mitigate the negative impacts of the declining spring flow. It is essential to engage the local people in such planning and decision-making processes to ensure that their concerns are addressed effectively.

3.5 Water Tank Placement Causing Source Drying Confusion

During the investigation of the drying up of water sources, there was a difference in opinion among the community regarding the construction of water tanks near the discharge point. It was a confusion among the people, on whether building water tanks near the water sources leads to the drying up of water sources in their areas.

The analysis of the responses showed that females had a balanced opinion on the issue of drying up and not drying up while constructing water tanks near the water sources as shown in table 3.2. However, males had a skewed opinion where most of them thought that constructing water tanks near the source resulted in the drying up of water.

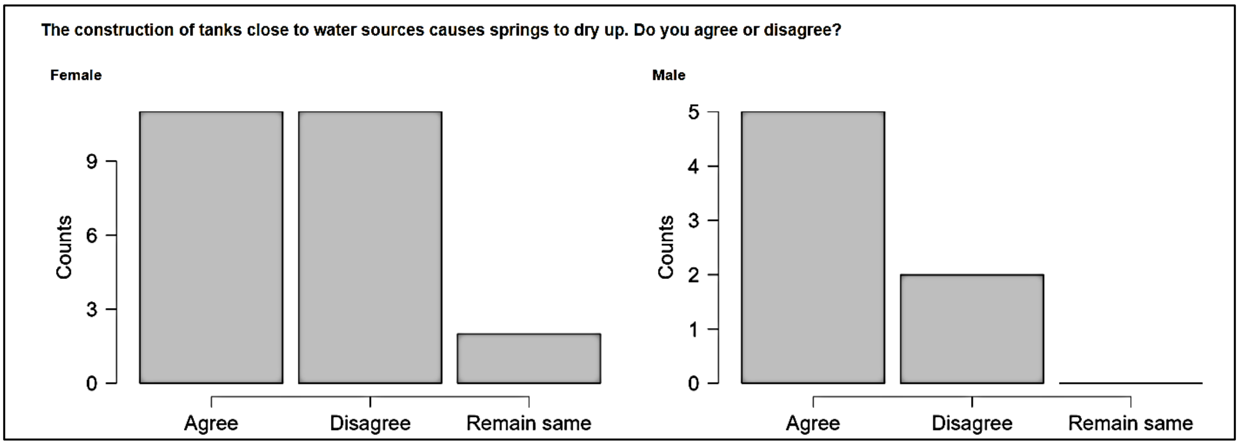

Table 3.2: Confusion on tank placement causing source drying

Scientifically, it is essential to understand that the construction of a water tank is not causing the water source to dry up. While constructing water tanks, geological formations near the water outlet are disturbed, resulting in changes in the water outlet or flow path direction (Jambay & Uden, 2023). Therefore, it is not the water tank that causes the drying up of water sources, but the disturbance caused during construction.

Furthermore, constructing water reservoirs below the world level does not disturb the geological formations and provides provisions for water purification and water for wild animals. However, there can be some issues related to water quality. Therefore, instead of constructing water tanks near the water sources, constructing water reservoirs below the world level can be a viable option to ensure water conservation without disturbing the natural flow of water sources.

3.6 Home Water Use Trends: Understanding Changes

The drying of water resources is a fact that has been reported nationally, with 67.6% of water sources being reported as dried up (WMD, 2021). While this trend is a cause for concern, it is also important to understand the changing trends in water use at home. As nations develop, water usage tends to increase due to the adoption of modern technology such as European toilets, which require a significant amount of water to flush.

To understand how water usage has changed in the local community, an assessment was conducted to determine whether there has been an increase or decrease in water usage over the past years. The results in table 3.4 showed that 90.32% of the participants reported an increase in water usage. Interestingly, all female participants reported an increase in water usage, while 28.57% of male participants reported a decrease in water usage. However, statistical analysis using the chi-square test at a significance level of .05 indicated that there was a significant increase in water usage in homes in these communities ($\chi 2\ (2) = 7.506$, $p = .023$).

Table 3.4: Perception on changes of home water use trends

Gender of the respondent	Water usage at your home has increased or decreased over the past few years.			
	Decreased (%)	**Increased (%)**	**Remain same (%)**	**Total**
Female	0	23 (95.83)	1(4.17)	24
Male	2(28.57)	5(71.43)	0	7
Total	2(6.45)	28(90.32)	1(3.23)	31

The combination of drying water resources and increased water usage at home is causing water scarcity in the community. To address this problem, there is a need to revive the drying water sources that have experienced a significant decrease in discharge (National Environment Commission [NEC], 2007). It is essential to develop and implement sustainable water management practices that promote efficient water use and ensure that the available water resources are used effectively.

3.7 Perception of Artificially Digging Holes to Increase Spring Water Flow

The intervention in this study involved digging contour trenches on recharge areas for harvesting the rainwater in the forest. To assess the effectiveness of this intervention, the assessment was conducted before the implementation of the intervention. The survey aimed to understand the perception of the local community on whether artificially digging holes in the forest could increase spring water flow. The survey revealed that many males and females felt that creating recharge pits could benefit the spring water flow as shown in figure 3.3.

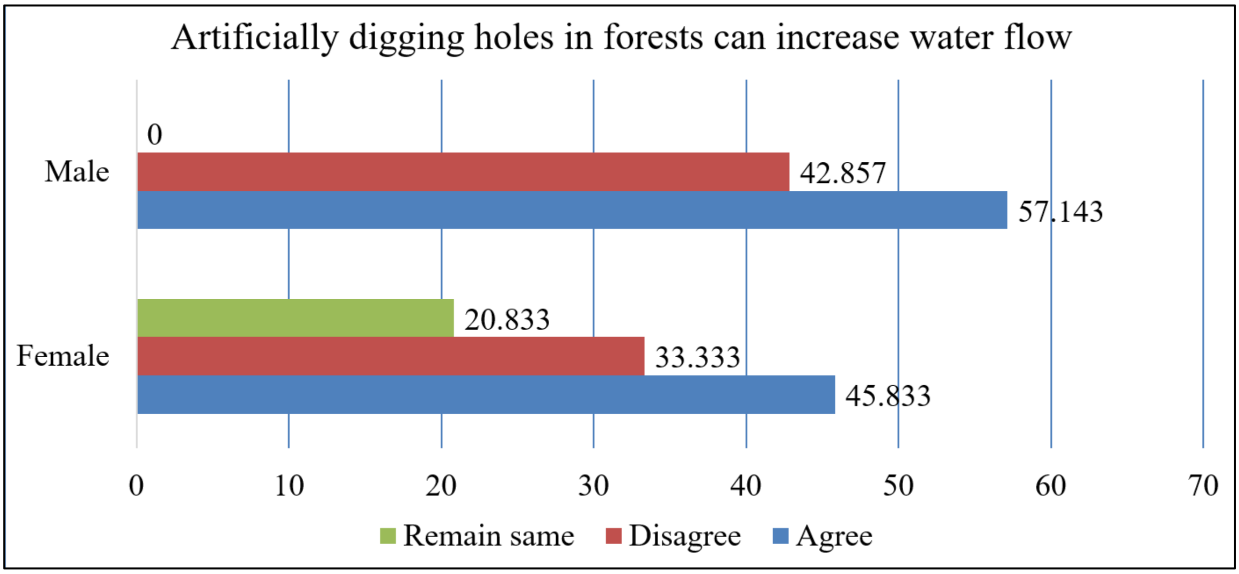

Table 3.3: Confusion on tank placement causing source drying

After creating awareness on the concept of recharge pits, the project team implemented the intervention on the identified recharge areas. The team created a map indicating the recharge areas where the intervention would take place. The project team conducted regular check-ins with the community to ensure that the intervention was successful. The check-ins were essential to ensure that the community understood the intervention and its purpose.

3.8 Lungchuna Spring: Water Quality Description

The spring selected for this project is Lungchuna Spring, located above Chubu communities in a dense chirpine forest. This spring was once a significant stream used by farmers. However, it has now dried up to a small spring that is the source of drinking water for the Chubu community. There are concerns that the spring may dry up completely, as nearby spring Gangakhar Phensum has also experienced a decrease in flow. The discharge for this spring recorded was 0.21 liter per sescond (lps) using Bucket and stopwatch method

The water quality of Lungchuna Spring water samples collected from the spring were tested in situ for pH levels, turbidity, temperature, total dissolved solids, and conductivity. The results of the tests revealed that the water from Lungchuna Spring is of good quality and suitable for drinking. The pH level was neutral, and the turbidity was low, indicating the absence of suspended particles in the water. The temperature was also within the acceptable range for drinking water, and the total dissolved solids and conductivity levels were low, indicating low mineral content in the water.

Lungchuna Spring

Location: Yebesa, Chubu Gewog, Punakha district
Coordinates: N27°38'7.872 " E89°50'3.12"
Elevation: 1712 masl
Discharge: 0.21 lps, Bucket and stopwatch method
Household Dependent: 22
Population Dependent: 105
Status: Dying, Perennial spring

Water Quality - **Physical Analysis**
pH: 7.34 | **Salinity:** 34.2 ppm | **EC:** 58.4 µs/cm | **Temperature:** 24.6°C | **TDS:** 42.3 ppm

Chemical Analysis
Nitrate : 0 mg/l | **Iron:** 0 mg/l | **Phosphorus:** 0.7 mg/l | **Fluoride:** 0.5 mg/l | **Chloride:** 32.6 mg/l

Figure 3.4: Lungchuna spring source

3.9 Hydrogeology:

The study revealed that Lungchuna spring, which originates in a chirpine forest, has been drying up since 2002, along with the nearby Gawa Phuntsum spring. This indicates the urgent need to revive these springs, which can be initiated by demarcating recharge areas in the springshed. The moderately forested recharge area of Lungchuna spring is also covered with thick trees, providing fewer open spaces for interventions. The recharge area is located on a steep slope, and the intervention was carried out in areas that were moderately inclined above the spring, just above the cliff, to reduce the chances of flooding. The entire springshed is composed of schist with thin layers of quartzite rock and a thick layer of soil and grassland on top. The marking of rock outcrops was challenging due to their rare visibility on the surface. However, the study used river transects to map the rock strata, which were found to be dipping from 25 to 45 degrees to the southwest.

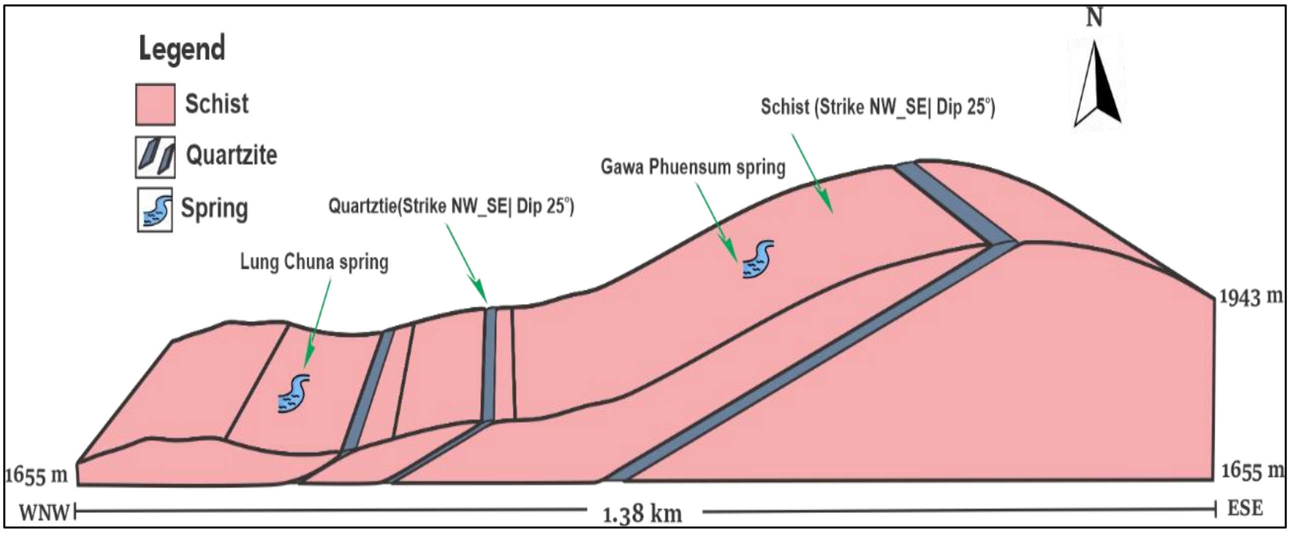

Figure 3.5: Hydrogeological layout of the Lungchuna and the Gawa Phuntsum spring source

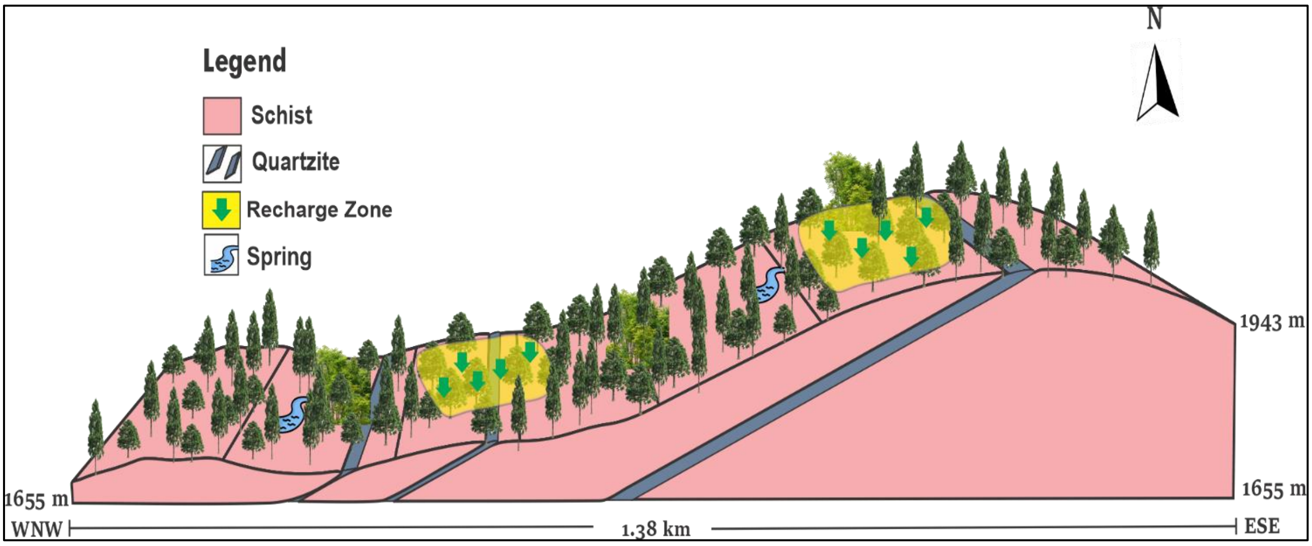

Figure 3.6: Potential recharge areas of the Lungchuna and Gawa Phuntsum springs

Figure 3.7: Hydrogeological field assessment of the Lungchuna and Gawa Phuntsum spring source

Centre Coordinate of Recharge Zone: **UPPER** 27.638401, 89.839503, 1920 masl; **LOWER** 27.636614, 89.834926, 1731 masl

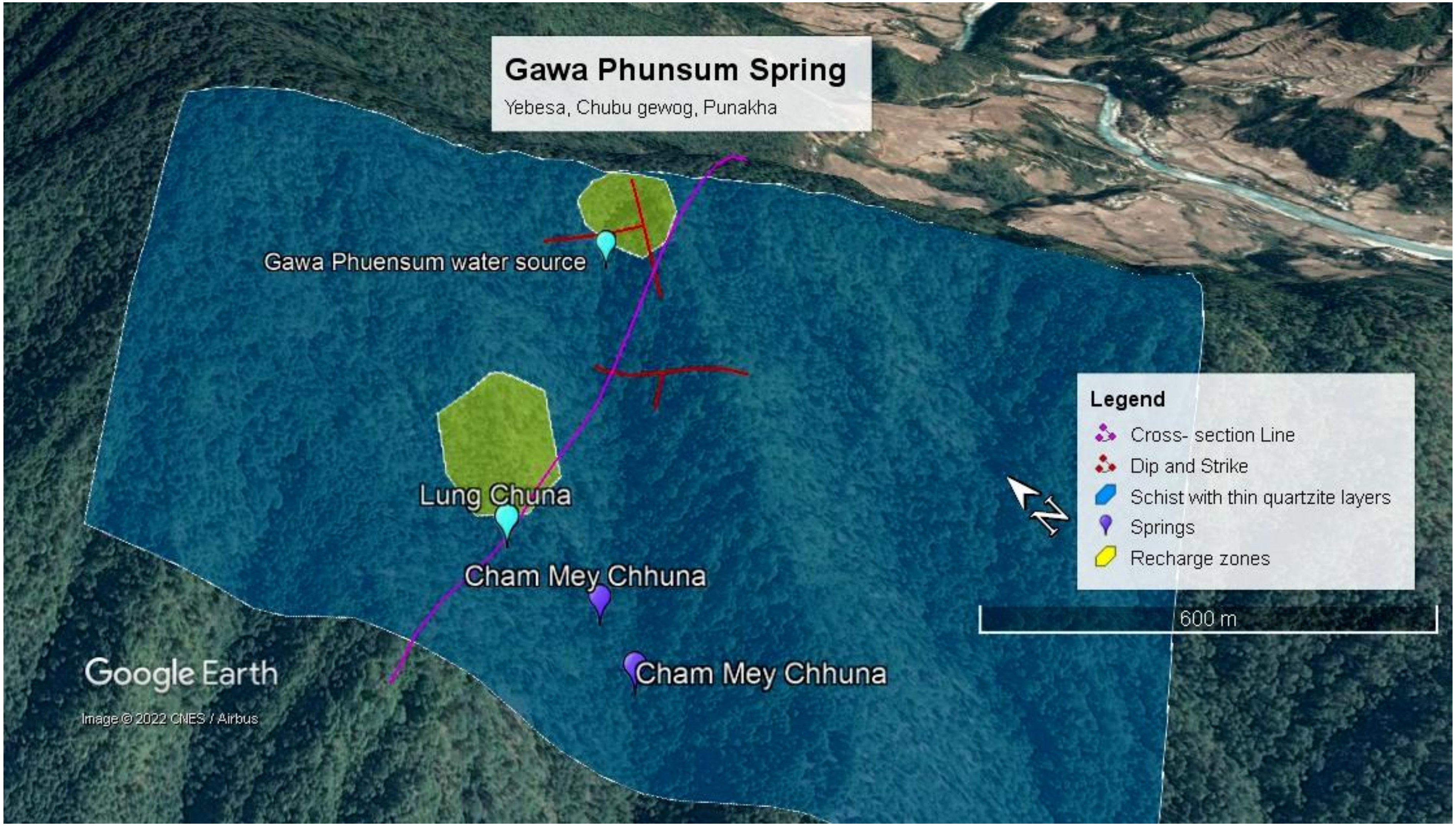

Figure 3.8: Location of the recharge area of the Lungchuna and Gawa Phuntsum spring source on Google Earth

3.10 Recharge interventions to increase mountain aquifer and spring discharge

In this project, an intervention was carried out to increase the recharge of the aquifer in the recharge areas of the Lungchuna spring in Chabu. The objective was to capture rainwater and allow it to percolate down into the aquifer, thereby increasing the discharge of the spring. To achieve this, 52 contour trenches were constructed in open spaces with a slope of up to 30 degrees. The trenches were 5 to 10 meters long, 0.6 meters deep, and 0.6 meters wide, and were designed to capture rainwater (ICIMOD, 2018).

The design of the trenches was adjusted based on the slope of the land. Shallower trenches were dug in a staggered manner on recharge areas with slopes between 30 and 45 degrees. The spacing between rows of trenches was kept approximately 5 to 10 meters. This intervention is expected to have a total capacity to hold 12 liters of water per filling of all trenches, excluding 30% of the actual capacity kept for the provision of evapotranspiration.

Figure 3.9: Community creating contour trenches on recharge area

The implementation of this intervention is expected to result in increased recharge of the aquifer, thereby increasing the discharge of the Lungchuna spring in Chabu. This could potentially have significant benefits for the local community, including improved access to water resources and increased agricultural productivity. Further studies are required to monitor the effectiveness of this intervention and evaluate its long-term impact on the groundwater recharge and discharge dynamics of the area.

The recharge areas should be cleared and debris removed on an annual basis to facilitate efficient harvesting of rainwater. To accomplish this task, the community members have decided to gather before the rainy season or irrigation work to clean the recharge areas and trenches. By doing so, the infiltration of rainwater into the aquifer can be increased, resulting in a higher spring discharge. This community-led approach to cleaning the spring and recharge areas is deemed vital for the sustained improvement of spring discharge. Thus, Gawa Phunsum Tshogpa, a water user group, is taking ownership and monitoring these recharge areas.

LIMITATIONS AND CHALLENGES

The successful execution of the project from data collection to implementation on the ground was not without its limitations and challenges. One of the most significant challenges was obtaining permission to intervene on the ground and dig on forest/state land, which took a long time and ultimately delayed completion of the intervention plan as scheduled. With constant following up repeatedly with the National Land Commission (NLCs)and Department of Forest and Park Services (DoFPS), a progress was made to speed up the process.

Another challenge was mobilizing the community people and organizing a community meeting and consultation. Many community members were involved in agricultural work during the same season, which made it difficult to gather all the water users of a particular spring. Furthermore, some were busy and could not participate.

Also, during the community meetings and consultations, the we encountered facility difficulties such as a lack of projectors, electric connections, and suitable halls. To overcome these challenges, the we took our own projector.

Moreover, managing the expectations of the large number of people involved in the project was a challenge. Some participants had high payment expectations, which was difficult to fulfill due to budget constraints. We communicated to the participants that the project's main focus was on implementing practical, on-the-ground solutions to address the water crisis, and the benefits would be realized after few years of the project's completion. We tried to emphasize the project's objectives, but managing participant expectations remained a limitation.

Despite these challenges, we are proud to have successfully implemented the project. The team learned from the experience, and similar projects will be planned in other sites, taking into account the lessons learned from this project. Overall, while the project was not without its limitations, we are confident that it has made a positive impact and laid the foundation for another success.

.

BIBLIOGRAPHY

ACWADAM. (2015). *Springwater management in mountains: Hydrogeology based approach.* Advanced Center for Water Resources Development and Management.

Dema, C. (2019, July 1). Water flagship programme from 2021. *Kuensel.* https://kuenselonline.com/water-flagship-programme-from-2021/

Ford, D., & Williams, P. D. (2013). *Karst hydrogeology and geomorphology*. John Wiley & Sons.

Government of Sikkim. (2014). *Dhara Vikas Handbook.* Rural Management and Development Department, Government of Sikkim.

Hall, R.P., Van, K. B., & Van, H. E. (2014). The human right to water: the importance of domestic and productive water rights. *Sci Eng Ethics*, 20(4), 849-68.

International Centre for Integrated Mountain Development. (2018). *Protocol for reviving springs in the Hindu Kush Himalaya: A practitioner's manual.* Kathmandu, Nepal

Jambay. (2021). Assessment of water resources with reference to mountain aquifers and spring hydrology in Bhutan. In R. M. Bajracharya, B. K. Sitaula, S. Gurung, N. Raut (Eds.), *Sustainable Natural Resource Management in the Himalayan Region: Livelihood and Climate Change* (pp. 191 - 205). New York, USA: Nova Science Publishers, Inc

Jambay, Yuden, T., Tshomo, U. & Jamtsho, S. (2022). *Recharge area mapping of drying water source: springshed assessment at Yagyur and Khengzor in Pemagatshel*, Bhutan. Tarayana Foundation.

Jambay & Uden, K. (2023). *Springshed: Identifying Recharge Areas of Drying Springs and Lakes with Water Quality in Southwestern Bhutan* (Volume II). Thimphu, Bhutan: Tarayana Foundation.

Jambay, Dema, T., & Dendrup, T. (2021). *A field guide for the identification of wetlands and freshwater plants in western watersheds of Bhutan*. Punakha, Bhutan: College of Natural Resources.

Jambay & Uden, K. (2021). *Springshed: Identifying Recharge Areas of Drying Springs and Lakes with Water Quality in Southwestern Bhutan* (Volume I). Thimphu, Bhutan: Tarayana Foundation.

Kuensel. (June 18th, 2018). Water shortage in water abundant Bhutan https://kuenselonline.com/water-shortage-in-water-abundant-bhutan/

Kulkarni, H., Desai, J., & Siddique, M. I. (2021). Rejuvenation of Spring water in the Himalayan Region. *Water, climate change, and sustainability*, 97-107.

Moggridge, B.J., Thompson, R.M. & Radoll, P. (2022). Indigenous research methodologies in water management: learning from Australia and New Zealand for application on Kamilaroi country. *Wetlands Ecol Manage*, **30**, 853–868 (https://doi.org/10.1007/s11273-022-09866-4

National Environment Commission. (2007). *Bhutan Water Policy*. Royal Government of Bhutan.

Tambe, S., Kharel, G., Arrawatia, M. L., Kulkarni, H., Mahamuni, K., & Ganeriwala, A. K. (2012). Reviving dying spring water: climate change adaptation experiments from the Sikkim Himalaya. *Mountain Research and Development*, *32*(1), 62-72.

Tomberge, V.M.J., Bischof, J.S., Meierhofer, R., Shrestha, A., & Inauen, J. (2021). The Physical Burden of Water Carrying and Women's Psychosocial Well-Being: Evidence from Rural Nepal. *Int J Environ Res Public Health*. 18(15):7908. https://www.mdpi.com/1660-4601/18/15/7908

Watershed Management Division. (2021). *Assessment and mapping of water resources in Bhutan*. Watershed Management Division, Department of Forest and Park Services, Ministry of Agriculture and Forest, Royal Government of Bhutan

Annexure I : Data Collection Sheets

Hydrogeological Data Collection Sheet

Si. No.	Latitude	Longitude	Elevation	Village name	Dip amount	Dip direction	Strike direction	Plane	Lithology	Remarks
1					N					
2					N					
3					N					
4					N					
5					N					
6					N					
7					N					
8					N					
9					N					
10					N					
11					N					
12					N					
13					N					
14					N					
15					N					
16					N					
17					N					
18					N					
19					N					
20					N					
21					N					
22					N					

Springs' Data Collection Sheet I

Code	Latitute	Longitude	Elevation	Village	Name/contact of informant	Name of water source	Uses	Nos. of household dependent	Population dependant	Status of water source	Drying since when (years)	Reason (drying/dried up)	Remarks
1													
2													
3													
4													
5													
6													
7													

Springs' Data Collection Sheet II

	Parameters											Score					
Code	pH	TDS (ppm)	Temp (°C)	Salinity (ppt)	EC (µS/cm)	Discharge (l/s)	Date of discharge measurement	Time	Type of Discharge	Type of Spring	Ownership	Infrastructure Perception	Quantity Perception	Quality Perception	Reliability Perception	Dependency Perception	Time to fetch
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	

Annexure II: Capturing Field Work: A Visual Journey of Training, Data Collection, and Implementation

Annexure II: Capturing Field Work: A Visual Journey of Training, Data Collection, and Implementation