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People's Perception on Status of Spring Water, Degradation, and Adaptation Measures: A Case Study from Sarpang, Bhutan

Damudar Dahal[1]*, Toshiharu Kojima[2], Chandra Man Rai[3], Om Katel[4], and Benu Prasad Dahal[5]

Abstract

Springs serve as the primary source of drinking and irrigation water in mountainous region worldwide. Despite the widespread drying up of mountainous springs, the identification of degradation factors at the local level is understudied. This study assessed the status of springs, degradation factors, and potential adaptation measures adopted by local people. The data were collected through household questionnaire survey and field visit in Lhayuel village of Sarpang district. The result confirmed that more than 60% of the people observed decline in spring flow, with older people being more aware of the springs drying up than their younger counterparts. Climate change ($\bar{x}$ = 4.28), road construction ($\bar{x}$ = 4.06), and landslides ($\bar{x}$ = 4.00) were identified as the leading cause of springs drying, based on perceptions measured with a five-point Likert scale. Further, the satellite data showed increasing trend of annual mean temperature (p = .00, R^2 = .34) and decreasing annual total rainfall (p = .00, R^2 =.05) over the past 122 years. To address the drying of springs, people implemented various adaptation measures including the artificial expansion of lakes, fencing around springs, minimizing grazing and timber extraction, and planting native tree species around the springs. This study provides a foundation for identifying spring water issues in mountainous regions and establishes a framework for implementing adaptation measures.

Keywords: Climate change, degradation factors, drying of springs, mountainous region, people's perception

Introduction

Springs, the natural flow of water from aquifers, serve as the primary source of water for drinking, sanitation, and agricultural activities in mountainous communities globally (Tambe *et al.,* 2012; Poudel & Duex, 2017; Adhikari et al., 2021). However, the decline of spring flow in many parts of the Himalayan Range severely threatens the lives and livelihoods of the people (Sharma & Shrestha, 2016; Choden *et al.*, 2018). About 60–70% of the Himalayan population depends directly on springs for their livelihoods, yet nearly 60% of these springs flow have been declining over the last decades (Verma & Jamwal, 2022). In India, approximately half of the three million perennial springs have dried up (Gupta & Kulkarni, 2018; Vijhani *et al.*, 2022). Previous studies were mostly focused on impact of climate change, rather than integrating scientific and traditional knowledge to protect, manage, and

[1*]Graduate School of Engineering, Gifu University, Gifu 501-1193, Japan
[2]Center for Environmental and Societal Sustainability, Gifu University, Gifu, 501-1193, Japan
[3]Utah State University, Department of Wildland Resources, Logan 84321, Utah, USA
[4]College of Natural Resources, Royal University of Bhutan
[5]Independent Researcher
*Corresponding author: damudardahal61@gmail.com
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revive drying springs in the region (Sharma & Shrestha, 2016; Poudel & Duex, 2017; Vijhani *et al*., 2022).

In Bhutan, rural villages and urban towns face water scarcity, despite having the highest average per capita fresh water availability (109,000 m^3) annually (Choden *et al.,* 2018). This is because, most of the springs are located at lower elevations, while human settlements predominantly occupying the upper slopes leading to unequal distribution of water (Jambay, 2021). A national level study found 2,327 springs and streams in the process of drying, and 147 had completely dried up (Phuntshok *et al.,* 2023). In Sarpang district alone, out of 282 springs assessed, 134 of them were on the verge of drying due to deforestation, and climate change (Phuntshok *et al*., 2023). The district represents one of the highest reported cases of spring drying in recent years in Bhutan. Additionally, the recent development activities such as construction of road, and irrigation channel have altered the land-use land-cover patterns, affecting springs.

The drying up of springs has resulted in water scarcity—leading to migration among the affected population within the country (Katel *et al.,* 2024). Addressing this challenge requires a synergistic integration of scientific studies and traditional knowledge, where culture and beliefs play an important role. For instance, limiting deforestation and conducting rituals near springs can contribute to the protection of these vital water sources. Actively involving local communities in springs protection fosters a sense of ownership and responsibility towards water sources.

While the national level studies have examined the climate change vulnerability (Choden *et al.,* 2018; Wangmo *et al*., 2022), the significance of spring aquifers (Jambay, 2021), and water quality (Chathuranika *et al.,* 2023; Dendup *et al.,* 2024), the detailed studies of anthropogenic factors such as climate change, landslides, road construction, deforestation, and waste and chemical fertilisers affecting springs at the local scale are significantly limited. Moreover, there is a lack of comprehensive documentation on people's perceptions regarding the drying up springs and adaptation measures. Understanding local perceptions is crucial because it shapes how communities recognise spring flow changes and respond to them through traditional knowledge and adaptive practices (Adger *et al*., 2013).

To address these gaps, the objectives of this study were to assess the status of springs, identify factors contributing to springs degradation, and explore adaptation measures. This study aims to contribute to the achievement of sustainable development goal six "clean water and sanitation" through protection of springs for a sustainable water supply. In addition, the findings will support decision-makers and local governments to develop targeted action plans to protect and revive drying springs in mountainous regions.

Materials and Methods

Study area

The study was conducted in Lhayuel village (26.92ºN–27.21ºN and 89.75ºE–90.95ºE), Sarpang district of Bhutan (Figure 1). According to the Gewog (sub-district) office record, the village has a total population of 736 people (18 years and above) with an average household size of 4–6 people, mostly inhabited by different castes such as Brahman, Gurung, and Ghalley. The elevation ranges from 900–2000 meter above sea level facing north with a slope of 10–35 degrees. The area experienced an annual average temperature of 11ºC and an annual total rainfall of 2,687 mm based on Climate Research Unit gridded Time Series (CRU TS) satellite data from 1901-2023 (Harris *et al*., 2020). The village also has a community forest (~4 km^2), dominated with *Alnus nepalensis, Ficus* spp. and *Quercus* spp. Several small lakes are located atop a village, situated in the middle of the community forest. The community forest and the state land forest are the primary sources of water, fodders, grazing land, litter leaves, timbers, and firewood for scheme was formalized between Lhayuel community (upstream) and the Gelephu Thromde (Municipality, downstream) to protect springs and address drinking water scarcity (DFO, 2023).

Data collection and analysis

The data on spring's assessment were obtained through household and key informant interviews and field visits in April–May 2022. According to Gewog office record, the village has a total of 124 households, of which four were Gongthong (vacant households) and 120 households were the beneficiaries of the springs. From the total 120 households, 61 respondents were interviewed, applying 50% of the total households in determining the sample size (Katel *et al.*, 2014; Gurung *et al.*, 2023). This method was chosen because of small population size and exploratory nature of the study. The simple random sampling method was used to collect the data due to homogeneous area.

The spring degradation factors were analysed using the 5-point Likert scale to assess people's perception on the drying up springs. We applied method used by Dorji *et al*. (2021) to assign a five-point Likert Scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). First, the result was analysed into mean rank using Friedman test and determined whether there was significant differences in respondents' awareness of factors. This test found significant difference among six factors namely, climate change, landslide, road construction, deforestation, population growth, and waste and chemical fertilisers. Then, we proceeded with post hoc—Wilcoxon Signed-Rank test—for 15 pairwise comparisons of factors.

Additionally, people's perception with demographic variables (independent variables) and observation of springs drying—yes or no (dependent variables) were assessed using chi-

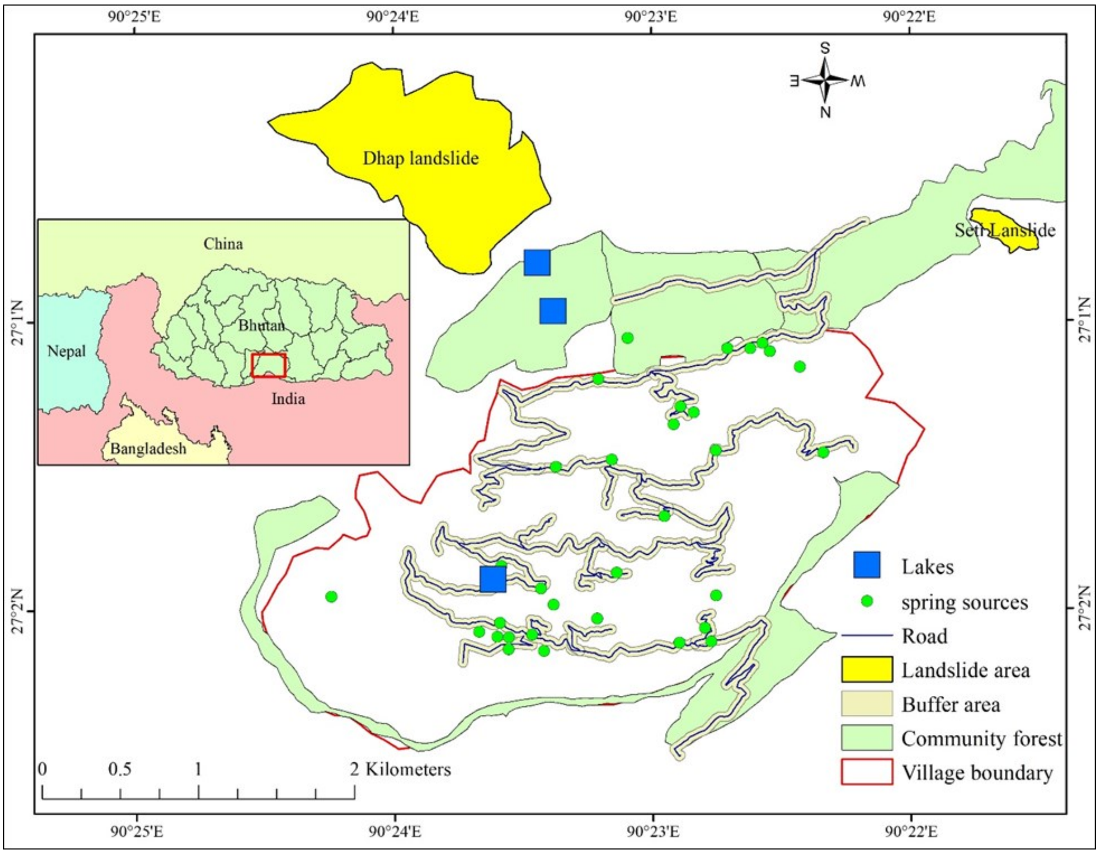

Figure 1: Location of the study area depicting spring sources, road connectivity, landslide area, and community forest

square test. The assumption of the chi-square test was satisfied as the observations were independent of the demographic variables, not normally distributed, and the data consisted of frequency counts. The descriptive and statistical analysis were performed using Statistical Package for Social Science Version 23. The mapping of springs, lakes, roads, and study area was carried out using Global Positioning System, Google Earth Pro, and ArcGIS 10.8.

The people's perception of climate change on springs were further validated with historical temperature and rainfall data. The CRU TS data from 1901–2023 with the resolution of 50 km was used due to absence of in-situ data. The data were downloaded in netCDF file format and converted into excel file format using R studio software. The CRU TS provides monthly mean data and later the data were calculated into annual mean average temperature and total annual rainfall for trend analysis. These datasets were widely used for long-term trend analysis in climate research due to its extensive temporal coverage and consistent spatial resolution, making it ideal for studying climate change patterns over more than a century (Harris *et al*., 2020). All these data were analysed in open source Jupyter notebook environment. Linear regression analysis was done to determine the trend of temperature and rainfall with the help of coefficient of determination (R^2) and probability value (p).

Results and Discussions

Demographic information

The Table 1 shows the demographic information of the respondents. The majority (77%, n = 47) of surveyed individuals were males with most of them aged between 41–60 years old (~49%, n = 30). The majority of the respondents (82%, n = 50) lived in the village since their birth and had no formal education (~57%, n = 35). Farmers in the village practice mixed farming—rearing livestock with most of it being cattle (~62%, n = 38) and growing cereals and vegetables. Most of the farmers had land holding size of less than 5 acres (~62%, n = 38) and their annual income is below Nu. 20,000 (~32%, n = 20). This income figure reflects the household's net savings after meeting essential needs and expenses. The primary sources of income are the sale of livestock products such as cheese and butter and cash crops, particularly cardamom. Nearly all respondents (~91%, n = 56) own both dry and wet land which serve as the primary source of livelihoods in the village.

Spring sources and water sharing-practices

Springs are the main source of drinking water for the people in the village. They are either perennial or seasonal and found in private or state land. Seasonal springs primarily depend on rainfall rejuvenating during monsoon. During this season, farmers use irrigation channels to extract water from streams for irrigating paddy fields. Although about 36% (n = 22) of the households have their own springs, many of them are either inaccessible or polluted (26%, n = 16). The main sources of pollution are surface runoff, human and animal waste, and discharge from paddy fields during the monsoon, all of which drain directly into the spring sources.

The primary issue of water scarcity is perceived to have emerged from mismanagement and poor water-sharing practices during water-scarce months (December–April). People have more accessibility to springs found within the state's land. However, most of the springs are found on private land and solely used by land owners. The water from private land is shared with others only if it is adequate after its use for domestic and agricultural activities. This leads to insufficient water for those who do not have their own spring source. Moreover, springs are located far and at lower elevation from their residence, making it difficult to pump against gravity. In addition, the decline of spring flow has significantly affected the lives and livelihoods of the community as they are compelled to change water sources fre-

Table 1: Demographic information of the respondents

Element	Group	No. of respondents (*n*)	Proportion (%)
Gender	Male	47	77
	Female	14	23
Age	21–40	19	31.1
	41–60	30	49.2
	Above 60 years	12	19.7
No. of years lived in the village (years)	1–10	1	1.6
	11–20	3	4.9
	21–30	7	11.5
	Since birth	50	82
Occupation	Farmer	50	82
	Government job	3	4.9
	Business	3	4.9
	Others:	5	8.2
Income (Nu.)	Below 20,000	20	32.8
	21,000–50,000	19	31.1
	51,000–100,000	12	19.7
	More than 100,000	10	16.4
No. of family members	1–3	15	24.6
	4–6	44	72.1
	7–9	2	3.3
Education level	Illiterate	35	57.4
	Sanskrit	4	6.6
	Non-formal education	5	8.2
	Primary	9	14.8
	Secondary	5	8.2
	Graduate	3	4.9
Land holding size (Acre)	1–5	38	62.3
	6–10	18	29.5
	More than 11	5	8.2
Domestic animals	Cattle	38	62.3
	Goats and sheep	1	1.6
	Cattle and Goats	18	29.5
	Cattle and sheep	2	3.3
	None	2	3.3
Main land-use	Dry land	5	8.2
	Both dry and wet land	56	91.8
Distance between water source and resident (km)	Less than .5	23	37.7
	.5–1	17	27.9
	More than 1	21	34.4

quently every year. People are forced to seek alternative water sources, including sharing with households or walking longer distance to fetch water. Consequently, instances of water conflict emerged when residents were dissatisfied with the inadequate amount of water for various activities.

Approximately 49% of the respondents (*n* = 30) reported a decline in spring flow over the past decades, attributing this trend largely to anthropogenic factors and mismanagement. People perceived insufficient water for human consumption due to mismanagement and poor -water sharing practices, and impacts from anthropogenic activities. Similar problems are prevalent in hilly areas of Nepal and in many Asian countries (Reddy *et al*., 2017; Wangmo *et al*., 2022; Thapa *et al*., 2023; Pandit et al., 2024). Molden (2020) highlighted that the root cause of water scarcity is how you manage it. The problem seems relevant in the context of Bhutan because the annual per capita water availability is 109,000 m^3/s (Choden *et al.*, 2018). This suggests that water scarcity in Bhutan, despite high per capita availability, is more a consequence of poor management and governance than of actual shortage.

People's perception on the status of spring water

Figure 2 shows the quantity and quality of spring water, and flow trend over the last 10 years. About 27.9% (16.4%–39.4%) of the respondents observed sufficient water flow at the source, while, 13.1% (4.7%–21.5%) observed insufficient water for drinking during water-scarce months (Figure 2a). Additionally, almost ~50% (35.7%–59.3%) of the respondents noted a decrease in spring flow over the past 10 years (Figure 2b). Regarding water quality, approximately 40% (27%–

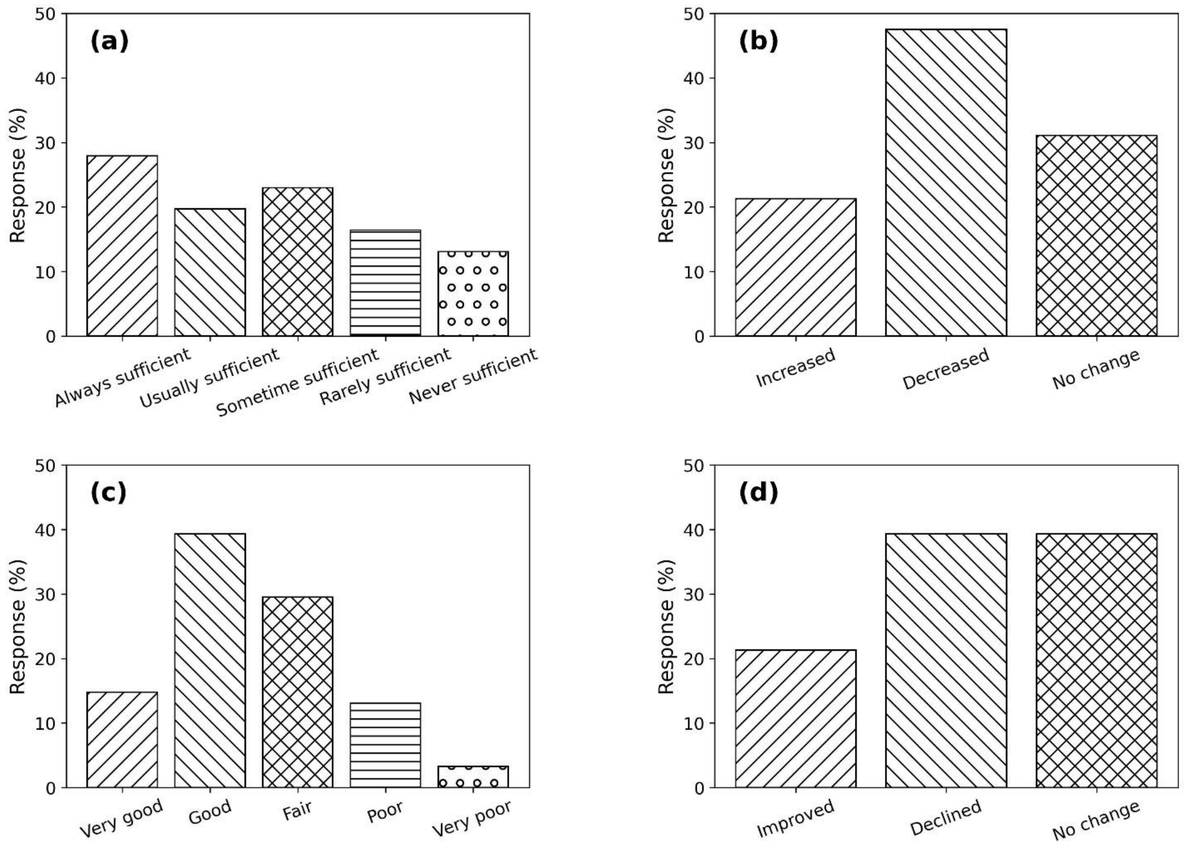

Figure 2: Spring water status (a) present spring water quantity status, and (b) spring water quantity trend in the past (c) present spring water quality status, and (d) spring water quality trend in the past

51.6%) of the respondents perceived that water quality is either decreased or remained the same over the years (Figure 2d). Local people attributed the decline in water quantity and quality to recent development activities in the village, and climate change.

Analysis on drying of springs with demographic variables

A chi-square test revealed important insights into the social dimensions of springs drying awareness (Table 2). The result showed a significant association between the age of the respondents and the observation of drying springs ($\chi^2 = 8.91$, $df = 3$, $p = .03$). Older people were more aware of the drying of springs, as they have spent more time in the village than the younger generation. Those who had lived in the area for longer duration often possess valuable knowledge and experience regarding how water volume fluctuates over time. A marginally significant relationship was found between gender and awareness of spring drying ($\chi^2 = 1.83$, $df = 1$, $p = .17$), which could be pointed to difference in role of gender in the society or for household activities. However, further investigation with larger sample size is needed to explore whether gender-specific roles or responsibilities influence awareness levels.

Conversely, there was no significant association between the awareness level of people on springs drying with other demographic variables such as education, occupation, and land holding size (Table 2). This suggest that formal education or economic background may not necessarily enhance awareness about spring water drying up. Rather, it reinforces the value of long-term residency and lived experience in understanding springs flow. Having lived in the village for decades, their observation allows them to recognize gradual changes in water availability in their surrounding environment (Singh *et al*., 2017). Additionally, older generation possess traditional knowledge such as seasonal flow patterns, location of springs and methods of conservation. These traditional knowledge gives better understanding and management of springs.

Potential spring degradation factors

The Friedman test showed that there was statistically significant differences in respondents' perception of spring degradation factors. The test revealed a significant difference among the factors (χ^2 (5) = 55.834, $p < .001$), indicating that participants did not rate all degradation factors equally. The mean rank scores showed that climate change ($\bar{x} = 4.28$, $SD = 1.24$), road construction ($\bar{x} = 4.06$, $SD = 1.35$), and landslides ($\bar{x} = 4.00$, $SD = 1.27$) were rated as having a higher impact on spring degradation compared to deforestation ($\bar{x} = 3.44$, SD = 1.10), population growth ($\bar{x} = 2.73$, SD = 1.49), and waste and chemical fertilisers ($\bar{x} = 2.49$, $SD = 1.23$). While the standard deviations suggest moderate variability in responses, reflecting some differences in perceptions among respondents.

Figure 3 shows the post-hoc Wilcoxon Signed Rank test for 15 pairwise comparison of factors. The result revealed statistically significant differences for waste and chemical fertilisers, and road construction ($Z = -4.685$, $p < .001$), population growth, and road construction ($Z = -4.134$, $p < .001$), waste and chemical fertilisers and climate change ($Z = -4.694$, $p < .001$), and population growth and climate change ($Z = -4.686$, $p < .001$). These findings suggest that participants perceived that these factors differ significantly in their impact levels. However, non-significant comparison was observed for climate change and road construction ($p = .414$), and landslide and road construction ($p = .878$). The top-rated factors such as climate change, road construction, and landslides were viewed as the most impactful contributors to springs degradation. Each of these factors are discussed further at the local context in the following sections.

Table 2: Chi-square test between demographic variables and peoples' perception on drying of springs

		Did you observe springs drying?				
Variables		Yes	No	Value	*df*	Significance
Gender	Male	29	15	1.83	1	0.17
	Female	8	9			
Age (Years)	below 20	2	3	8.91	3	0.03
	21–40	7	12			
	41–60	19	6			
	Above 60	9	3			
No. of years lived in the village (Years)	1–10	0	1	4.01	3	0.26
	11–20	1	2			
	21–30	3	4			
	since birth	33	17			
Occupation	Farmer	28	22	3.23	3	0.35
	Government Job	3	0			
	Business	2	1			
	Others	4	1			
Education level	Illiterate	21	14	3.29	5	0.65
	Sanskrit	3	1			
	Primary	7	2			
	Secondary	2	3			
	Graduate	1	2			
	Non-formal education	3	2			
Land holding size (acre)	1–5	23	15	0	2	0.99
	6–10	11	7			
	10 and above	3	2			

Climate change

The people's perception on drying of springs were further validated with temperature and rainfall data (Figure 4). The regression analysis shows significant increasing trend of mean annual temperature over the past 122 years (p = .00, R^2 = .34), with an average increase of .01°C. The R^2 value of 34 indicates that 34% of the variation in temperature is explained over the years, suggesting a moderate and consistent warming trend. In contrast, the annual total rainfall shows a significant decreasing trend (p = .00, R^2 =.05) with an average decline of 2.16 mm per year. The lower R^2 value of .05 indicates that only 5% of the variation in rainfall is explained each year, implying that rainfall patterns are highly variable despite the overall downward trend. These findings indicate a clear sign of climate change in the region, with increasing temperature and decreasing rainfall. Several studies in Himalayan range showed increasing temperature and rainfall patterns (Sharma & Shrestha, 2016; Pandit *et al.,* 2024). Similarly, Tambe *et al*. (2012) has reported that climate change has caused springs depletion based on people's perceptions, and rainfall and temperature trends. Such shifts can exert immense pressure on existing springs by reducing groundwater recharge and altering hydrological cycles, thereby affecting spring flow.

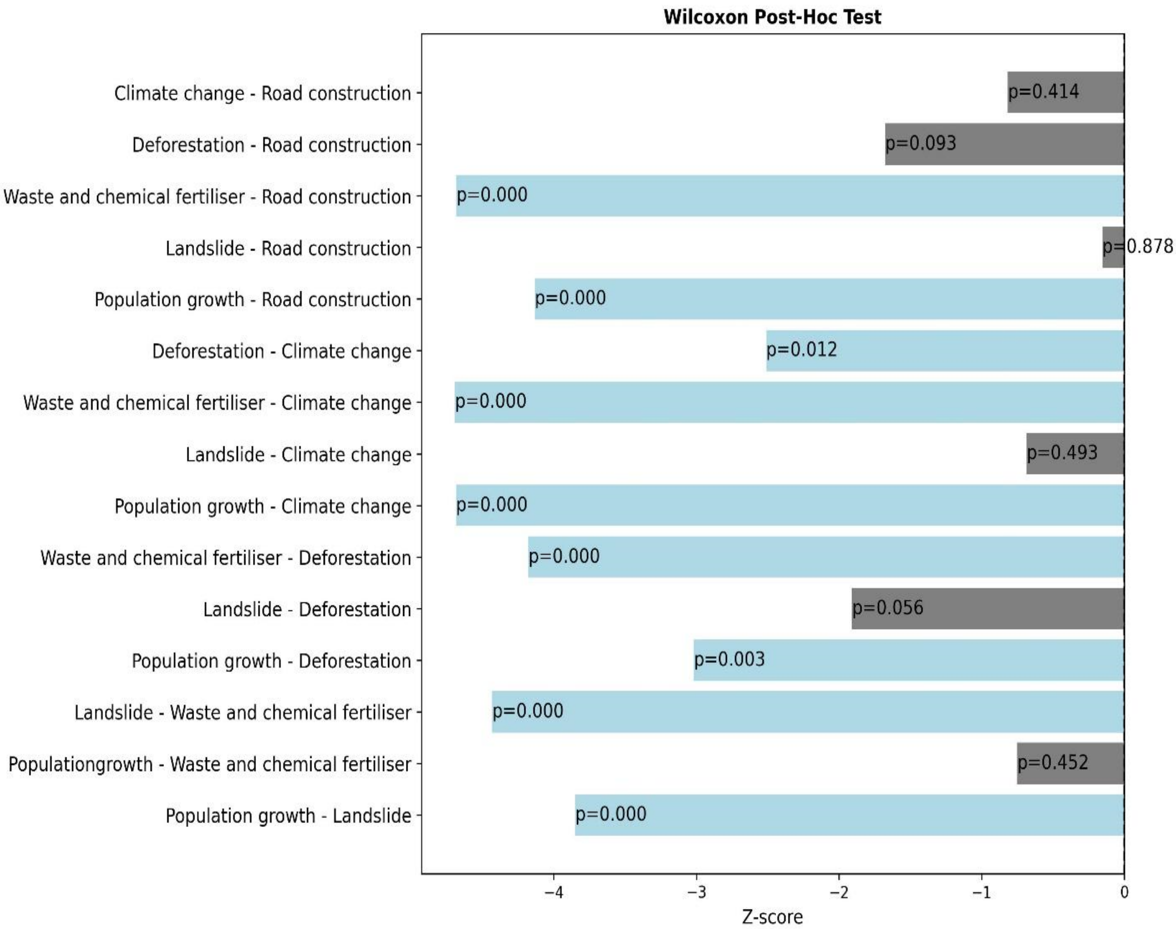

Figure 3: Pairwise comparison of spring degradation factors. The blue and gray bars indicates significant and non-significant level, respectively, with z-score on x-axis

Landslides

The two major landslides that occurred several decades ago cover an approximate area of 1.52 km^2. People observed that the landslides altered the seepage of rainwater, redirecting the overland flow and consequently affecting nearby springs recharge. Landslides significantly disrupt the natural flow of groundwater and alter the surrounding landscapes. Topographic factors and vegetation removal contributes substantially to the recurrence of landslides, as vegetation plays critical role in maintaining the stability of rocks and soils (Mirus *et al.,* 2017). Additionally, Pan *et al.* (2017) found that the concave topography and occurrence of previous landslides exacerbated the risk of recurrence of the event. Insights from respondents and field observations suggest that surface runoff from the surrounding landscape into landslide prone zones has significantly reduced spring flow.

Road construction

People perceived that road construction is the major contributing factor to drying springs. The road constructed within the village is approximately 24 km traversing through the community forest and springs. Out of 33 perennial springs found within the village, 18 of the springs fall within the buffer zone of 30 m from the nearest road (Figure 1). This will have impact on the surface runoff, springs, and groundwater recharge zones. Additionally, people have observed the indiscriminate dumping of construction materials along the gorges, leading to the burial of springs.

Springs are under pressure in mountainous areas because the roads were mostly constructed along the hilly areas cross-cutting through water sources. Numerous studies further substantiated these observations, emphasizing that degradation of areas have contributed to the recent drying of springs (Adhikari *et al.,* 2021; verma & Jamwal, 2022; Pandit *et al*., 2024). The disturbances from vibration will lead to water seepage through various soil and rock pores, thereby redirecting the ground water flow downstream. As a result, it is difficult for people to access water and are often forced to search for alternative source.

Cattle grazing and deforestation

Almost all households rely on livestock as their alternative source of livelihood and income. In recent years, people have observed a decline in number of cattle by nearly 50% in the village compared to the past. Although, the farmers adopt controlled grazing for local cattle and stall feeding for cross-breed jerseys, there is a common practice of releasing cattle into the nearby forest during scarcity of pasture or fodder. These cattle congregate near springs for water, cooler temperatures, and of

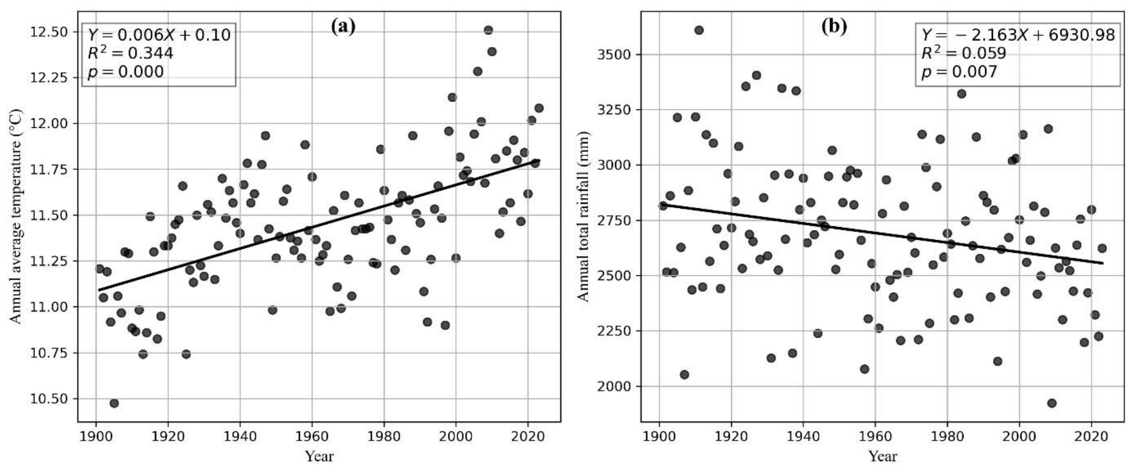

Figure 4: Trend analysis of meteorological data (a) temperature and (b) rainfall

pasture or fodder. These cattle congregate near springs for water, cooler temperatures, and green foliage. The trampling effect has a detrimental impact on springs leading to changes in channel morphology, soil compaction, erosion, and sediment deposition. According to village representative, the impacts from cattle grazing has been decreased over the years. Additionally, community depends heavily on community forests and periphery watersheds for firewood, fodders, and construction materials. These interconnected pressures from livestock practices and forest dependence highlight the urgent need for water management strategies to protect vital spring sources.

Population growth

Recent development activities—such as road and irrigation connectivity, water supply systems, and educational facilities—have encouraged the return of some residents who had previously migrated to urban areas in search of better opportunities. Out of 21 households that had left, 17 returned, while four permanently resettled elsewhere. This increase in population has placed additional pressure on already scarce natural resources, including timbers, firewood, fodders, and water. Moreover, the growing demand for water for both domestic and agricultural use has further strained springs, leading to a noticeable decline in water availability at the source. As a result, inadequate drinking and irrigation water will compel economically active households to migrate to water-sufficient areas. Therefore, the springs should be protected and conserved for the sustainable water supply year-round.

Waste and chemical fertilizer

Farmers sometime use chemical fertilisers, including suphala and urea, as well as weedicides and pesticides in their agriculture field. These chemicals are carried downstream via surface runoff, significantly degrading water quality. Additionally, solid waste such as plastics, and animal and human waste were observed along the water channels. The contamination of spring water not only poses risks to human health but also disrupts the fragile ecosystem. One of the elder farmers shared his concern *"There used to be a time when no chemical fertilisers and pesticides were applied in the field. I used to apply organic manure from livestock. Since 2010, I have observed a shift in farming practices, such as using chemicals and mechanised farming tools. The chemicals have destroyed underground organisms, plant roots, and soils. The impact of this trend is anticipated to have long-term consequences on spring water".*

Adaptation measures to address drying springs

In 2023, a formal agreement on a PES scheme was established between Gelephu Thromde and the Lhayuel community to address ongoing water scarcity. The PES framework plays a critical role in promoting the sustainable management of watersheds, thereby ensuring a consistent and reliable water supply for downstream users. As part of the agreement, upstream and downstream communities committed to the protection of springs. Gelephu Thromde pledged to collaborate with the upstream community and provide annual payments for ecosystem services in return for their efforts in spring conservation. To support this initiative, a monthly fee of Nu. 10 will be collected from each water user (DFO, 2023). The upstream community have undertaken proactive measures to mitigate landslide risks and enhance spring recharge. These include expanding existing lakes, constructing check dams, and redirecting overland flow away from landslide-prone areas. The PES scheme has been successful globally in protecting water resources by ensuring equitable benefits for both upstream and downstream communities, leading to improved water security and sustained flow (Bhatta *et al*., 2014).

In addition to scientific approaches, local communities followed cultural and religious methods for safeguarding springs. The origin of a spring is often believed to be the dwelling place of a snake deity (Nag) and is revered as a devithan—a sacred site associated with local deities. People routinely offer prayers and perform rituals at these sites, seeking blessings for timely rainfall and the continued flow of water. Such beliefs and practices are widespread in many regions of Nepal, where cultural reverence for springs play a vital role in water source protection (Poudel & Duex, 2017; Thapa *et al*., 2023). The involvement of local communities in spring management is therefore not only practical but also deeply rooted in cultural and religious values that encourage stewardship of this resource. Traditional methods involve fencing spring sources to prevent disturbances, particularly from livestock. Additionally, native species such as Ficus spp. and banana and fodder plants are planted around the springs to rejuvenate flow, reduce soil erosion, and enhance groundwater infiltration. Furthermore, activities such as overgrazing, timber harvesting, and fodder collection are strictly prohibited near spring catchments. These traditional practices, combined with scientific approaches, can significantly enhance the revival and sustainable flow of springs.

Conclusion and recommendation

In summary, this research has underscored the people's perception on drying of springs, identified spring degradation factors and adaptation measures. A notable finding revealed that more than half the surveyed population has witnessed a decline in spring flow over the years. The analysis has identified climate change, road construction, and landslides as the key contributors to the drying of springs. The satellite data also showed increasing trend of annual mean temperature and decreasing annual total rainfall. Additionally, people perceived poor water-sharing practices and mismanagement as exacerbating water scarcity during dry months. To address the drying of springs, people implemented scientific and traditional measures such as artificial expansion of the lakes, minimizing grazing and timber extraction, planting native tree species, and conducting rituals at the water source. Thus, this study lays a foundation for root cause of spring degradation factors at the local level and establishes a framework for implementing necessary adaptation measures. Further, it highlights the need for integrating local knowledge with scientific data to address spring degradation in mountainous region.

Here, we recommend the following spring management strategies and policies to protect and revive the drying springs: (1) adopting a scientific approach to springs protection by considering recharge and discharge zones, (2) conducting a comprehensive environmental impact assessment prior to the start of any development activities, (3) implementing PES scheme where both the downstream and upstream water users are benefited, and (4) formulating and implementing a scientific and traditional approach of managing and water-sharing practices. This study is exploratory and based on qualitative insights, and it is limited by the lack of detailed quantitative data. Future research should focus on a detailed study across a broader mountainous region to understand the complex drivers of drying springs.

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