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Drying of Springs in the Himalayan Region of Nepal: Perspectives of Local Government Leaders on Causes, Consequences, and Conservation Efforts

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Spring water plays a crucial role in sustaining life in the Himalayas. Yet these vital water sources are drying as a result of natural and anthropogenic factors. In July and August 2020, we

conducted phone interviews with leaders from 300 local government units across Nepal to identify the status of spring drying, the main causes, the consequences for local communities, measures adopted, conservation practices, and policies. Springs had dried up in 74% of local government units, with medium to severe problems across 44%. The scarcity of drinking water because of drying springs is the most severe issue, leading to outmigration in the search for water, as reported by 7% of the local governments. Road and infrastructure construction is

the main cause of springs drying up, followed by earthquakes and climate change. Problems of spring drying are more prevalent in the Chure region, followed by the mid-hills and mountains. Local governments have used various strategies to mitigate the problem, such as rainwater harvesting, reforestation, lifting, and boring. Spring conservation work has been included in local governments' annual plans, programs, and budgets, but most of them focus on drinking water. Therefore, the problem must be addressed as quickly as possible with the participation of all stakeholders and following a bottom-up approach.

Keywords: Himalayan springs; key informant interviews; spring drying; water scarcity; local government units.

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Introduction

In the mountainous environment of the Hindu Kush Himalayan (HKH) region, rural communities rely mainly on springs as their primary water sources (Negi and Joshi 2004; Vaidya 2015; Singh et al 2020). In Nepal, springs are used for drinking water, livestock feeding, irrigation, and cultural purposes (Upadhyay 2009; Sharma et al 2016; Molden 2020). These springs are significant to people living in the hills, where snowmelt and flowing river water are inaccessible (Panwar 2020). Despite the importance of springs to the livelihoods of these communities, numerous studies conducted in HKH countries have shown that spring discharge is decreasing or springs are drying, leading to water scarcity and increasing vulnerability among marginalized populations throughout the region (Tambe et al 2013; Sultana 2016; NITI Aayog 2018; Wester et al 2019; Jambay 2021). This also applies to the mid-hill and mountain regions of Nepal (Chapagain et al 2017; Poudel and Duex 2017; Thapa et al 2020). The factors contributing to the decline in spring flow are increased groundwater abstraction, erosion of the topsoil, changes in rainfall patterns, land use and land cover change, forest fires, earthquakes, and infrastructure projects such as road construction (Chinnasamy and Prathapar 2016; Sharma et al 2016; Leder et al 2019). When springs dry up or their

discharge declines, the resulting water shortages add stress to the impoverished mountain settlements (Merz et al 2003; Poudel and Duex 2017).

Globally, especially in mountainous countries, spring sources are significant from the perspective of water supply, as well as biodiversity. However, sources are heavily threatened by anthropogenic and natural causes (Pešić et al 2019). Standardized monitoring protocols and conservation efforts neglect spring sources, because they are considered too small. The increasing demand for drinking water and the decreasing water sources because of drying and pollution result in water scarcity around the globe, posing serious challenges for the future (Chakkaravarthy and Balakrishnan 2019). In Nepal, approximately 3.5 million people still lack access to basic water supplies, and an even larger number of people face seasonal uncertainties of supply, particularly during the dry season (UNICEF Nepal 2018).

In 2011, the Nepalese government established the National Framework on Local Adaptation Plans for Action (LAPA) to mitigate the impacts of climate change and improve livelihoods. The framework emphasizes a bottom-up approach by identifying the most vulnerable villages, wards, and municipalities and promoting simple and effective adaptation strategies (GoN 2011). Although many local government units (rural municipalities and municipalities)

face water scarcity issues, there is no adequate research investigating and quantifying the extent of water scarcity or the reasons behind the drying up of springs across Nepal, through either scientific or social analysis.

In recent years, spring studies have started to gain attention through local newspapers and scientific articles. Spring drying issues in different parts of Nepal have been highlighted by various studies, including Chapagain et al (2017); Poudel and Duex (2017); Gurung, Adhikari, Chauhan, Thakuri, Nakarmi, Ghale, et al (2019); Gurung, Adhikari, Chauhan, Thakuri, Nakarmi, Rijal, et al (2019); Shrestha et al (2019); and Molden (2020). However, most studies on springs have fairly limited geographic coverage and mainly cover scientific research. Furthermore, communities from Chure, the mid-hills, and the mountains depend primarily on spring water for their livelihood, so we assessed the status of springs across these regions.

In this paper, we provide socioecological information on the status and usage of springs in Nepal's Chure, mid-hill, and mountain regions. We (1) quantify the proportion of drying springs and the main causes for this, (2) elucidate the consequences of spring drying and local coping mechanisms, and (3) review conservation practices and policies initiated by local governments, identifying critical areas and affected municipalities. Although our study is restricted to information obtained from key informants, we covered most local government units across Nepal. Our findings contribute to a broader knowledge base for policy planning, particularly for the LAPA framework, to prioritize adaptation programs in vulnerable municipalities and areas. Moreover, our results will help in visualizing spring status and local governments' conservation efforts, as well as informing researchers and policymakers.

Material and methods

Study area

Nepal is divided into 4 ecohydrological east-west bands, each with varying elevations. The southernmost band, known as the Terai, encompasses the Ganga floodplain. Adjacent to the Terai is the Chure range, which is characterized by hills below an elevation of 1200 masl and a porous zone called Bhavar. The well-settled mid-hill region, ranging between 1200 and 3000 masl, is situated north of the Chure range. Last, the mountain region, consisting of land above an elevation of 3000 m, encompasses the Himalayan mountain range (Upreti 2001; Bricker et al 2014). In Chure, the mid-hills, and the mountains, most of the population depends on spring sources for domestic water supply, whereas people in the Terai use shallow tube wells and open wells. Nepal has 753 local government units across 77 districts. Our study focused on low- to high-mountain regions, excluding the Terai. Of the 478 local government units in these regions, we covered 64% or 306 local government units in 58 districts (Figure 1).

Data collection

Local government heads or deputy heads were chosen as key informants for this study because of their role in managing water supply and protecting and conserving springs and springsheds, including environmental and forest management, watershed conservation, and physical

infrastructure development. The Constitution of Nepal and the Local Government Operation Act have made local governments responsible for formulating laws, policies and plans related to local resource management, including spring and springshed management, and effective implementation, so their officials are well informed about the situation. All of these criteria were considered before selecting local government officials as our key informants. Checklists for the survey were prepared, including questions about the status of springs, causes of their drying, mitigation measures, and policies and programs adopted by the local governments to guide spring conservation activities.

Because of COVID-19 travel restrictions at the time of data collection, from July to August 2020, the key informant interviews were conducted by phone and generally lasted 30–40 minutes. This was the first time the phone interview method had been used in Nepal for spring data collection. This new approach enabled us to reach most local governments across Nepal within a short period, which would have been impossible to accomplish through field surveys within the scope of this study. This method is cost- and time-effective, and it makes it possible to gather multiple points of view, cover wide geographic ranges, and easily reach respondents. Because we were unable to observe the responses firsthand, it was necessary to validate the aggregated data. Disadvantages of this method include that respondents are free to end the conversation at any time and that no visual aids can be used during the interview. Local government contact information was obtained from the Ministry of Federal Affairs and General Administration websites, Google, and Wikipedia. To ensure the success of the telephone-based survey, a detailed data collection, transcription, coding and decoding, tabulation, and triangulation plan was carefully prepared and tested. Information from 300 interviews was included in the data analysis; 6 responses were excluded because of insufficient data and information.

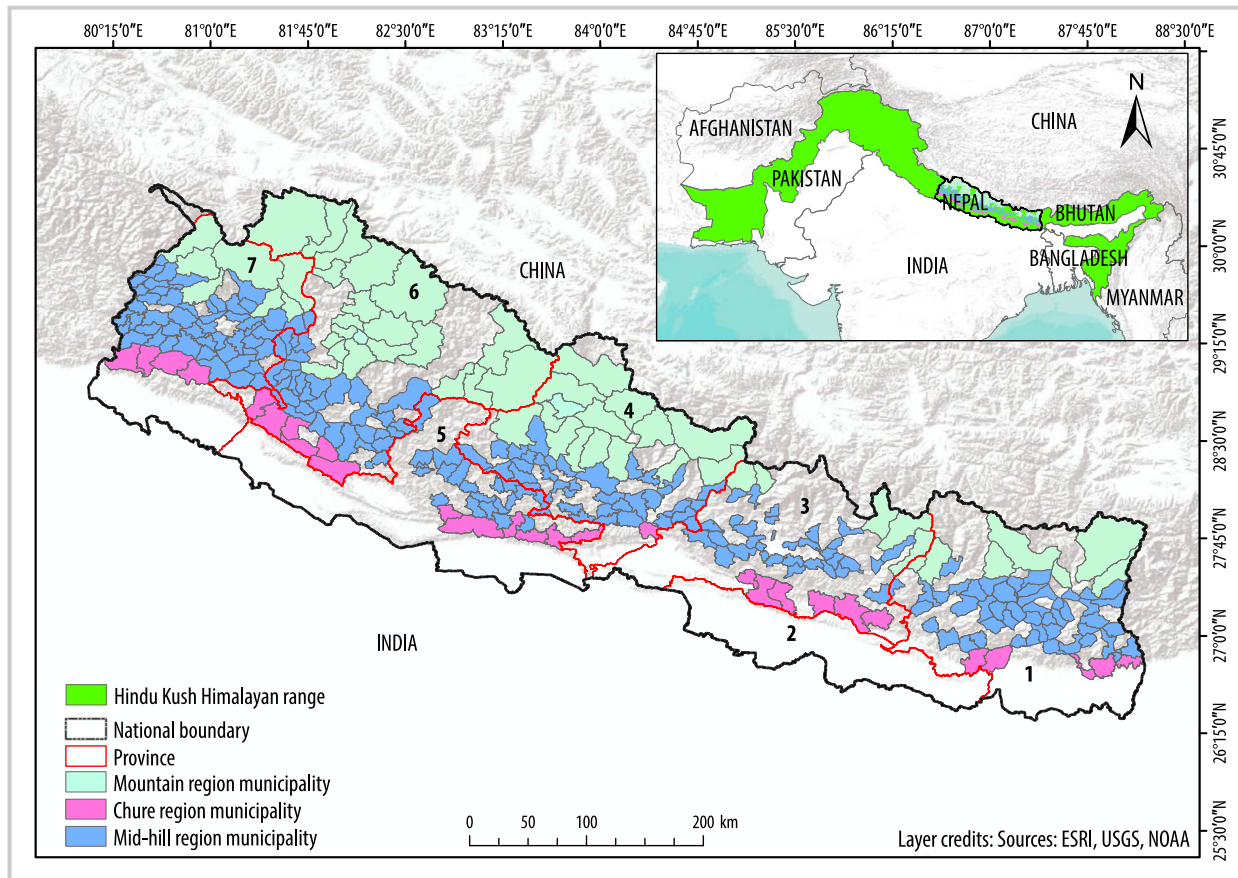
From May to July 2021, the collected data were validated in the field. Local governments in the eastern, middle, and far-western regions of Nepal were selected for field verification (Appendix S1, *Supplemental material*, <https://doi.org/10.1659/mrd.2023.00007.S1>). We visited local government units where entire villages had been abandoned because of the drying up of springs and water scarcity. Furthermore, we visited local governments that had started spring conservation work with the help of other organizations, as well as local governments that had initiated spring conservation work themselves.

Results and discussion

Status of spring drying and its causes

During the key informant interviews, 74% of local governments reported dried-up spring resources in their municipalities, and 58% had experienced spring displacement. Most spring sources had moved from upper to lower elevations, causing an issue with the water supply for people living in higher areas. In recent decades, communities had noticed declining water in springs, leading to more springs drying up. Most local governments had also experienced water shortages during the dry seasons, usually March to May. Dry springs were reported by 79% of local

FIGURE 1 HKH range in green boundary, with location of Nepal (inset) and map of study area showing the surveyed local government units of Nepal, which include the Chure, mid-hill, and mountain regions. Red boundaries indicate provinces, and they are (1) Koshi, (2) Madhesh, (3) Bagmati, (4) Gandaki, (5) Lumbini, (6) Karnali, and (7) Sudurpaschim.



governments in the Chure region, 76% in the mid-hill region, and 64% in the mountain region. The drying of springs in the Chure region is accentuated by the geologically young and loose, unconsolidated sediments derived from soft rocks, such as mudstone and sandstone (Singh 2017). Furthermore, forest degradation and sand mining are weakening the water-holding capacity of the Chure hills, causing off-season flow in streams. The water sources and Chure forests hold water for the Terai belt (Pokhrel 2013), and declining water-holding springs in the region could pose a future water threat to the Terai region.

The key informants categorized the scale of the problem into 1 of 4 levels: no problem, low, medium, or severe. Results showed that 16% of local government units had no problem, 39% had a low problem, 39% had a medium problem, and only 5% had a severe problem with spring sources drying. Local governments that reported severe problems because of the drying of springs are shown in Appendix S1 (*Supplemental material*, <https://doi.org/10.1659/mrd.2023.00007.S1>). The low and medium ratings by 78% of key informants might result from these local government units using lifting, drilling, and boring technologies to meet water demands.

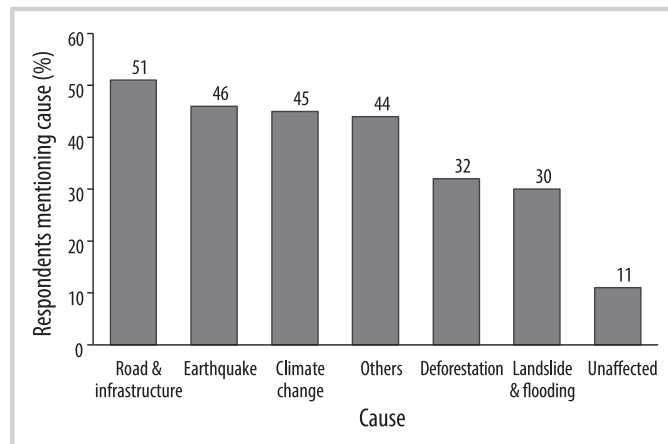
At the province level, there were differences in the status of springs: Bagmati had the highest percentage of spring drying, whereas the lowest percentage was found in Karnali (Table 1). In Bagmati Province, the highest percentage of

spring drying occurred in the Chure and mid-hill regions, whereas in Sudur-Paschim Province, for example, this was the case in the mountain region. Comparing the 3 main regions, the mountains had the lowest percentage of drying springs, particularly in Koshi Province (Table 1). The eastern part of Nepal saw slightly more dried-up springs (78%) than the western part (71%). Other studies in the Melamchi watershed area, Jhimruk watershed, far western region, and various locations in the mid-hills correspond with the general picture presented here (Gurung, Adhikari,

TABLE 1 Percentages of dried-up springs in 6 provinces of Nepal and in the Chure, mid-hill, and mountain regions within each of these provinces.

Province	Overall (%)	Chure (%)	Mid-hills (%)	Mountains (%)
Koshi	71	77	74	43
Bagmati	88	100	86	80
Gandaki	72	78	70	73
Lumbini	71	83	58	—
Karnali	64	75	70	52
Sudurpaschim	81	50	84	86
Mean (%)	74	76	73	65

FIGURE 2 Distribution of responses from key informants regarding the main causes of drying of spring sources in the local government units of Nepal ($n = 300$).

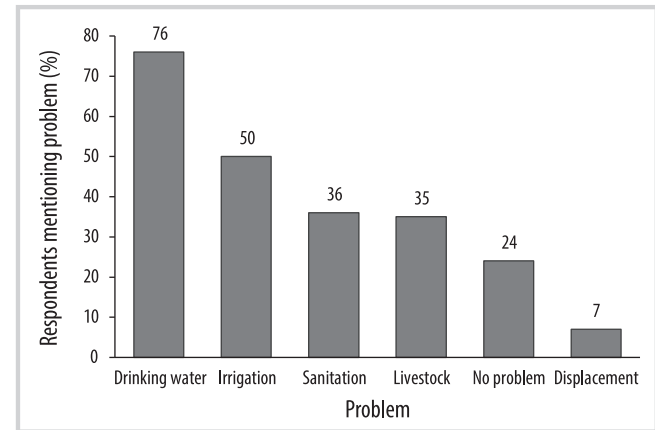


Chauhan, Thakuri, Nakarmi, Ghale, et al 2019; Shrestha et al 2019; Thapa et al 2020; Adhikari et al 2021). Sharma et al (2016) also report decreased water discharges from many springs, permanent springs turning seasonal, and seasonal springs drying up completely, attributing this to changes in land use and anthropogenic activities. This has also reduced river discharge in the Lesser Himalayan region, which has affected local livelihoods (Chinnasamy and Prathapar 2016). This is a common issue documented in other HKH countries, such as India (Tambe et al 2012; Vijhani et al 2022), Pakistan (DAWN 2022), Bangladesh (Eva 2016; Sultana 2016), and Bhutan (Jambay and Uden 2022). Most key informants from local governments observed that some previously dry springs had started to carry water again, possibly because of above-average rainfall in 2020. For instance, in Kailali District's Raskot Municipality, springs that had dried up 15 years ago had been revitalized.

Roads and other infrastructure works were identified as significant contributors to the drying up of spring sources, followed by earthquakes and climate change (Figure 2), a finding consistent with previous studies (Chapagain et al 2017; Gurung, Adhikari, Chauhan, Thakuri, Nakarmi, Rijal, et al 2019). Since the formation of 3 tiers of government in 2015 based on Nepal's new constitution, the responsibility for development and management lies with local governments. Rural roads have been constructed without considering their impact on water and other natural resources. Such rampant rural road development directly affects springs and springshed areas, destroys existing drinking water pipe networks, and causes waterspouts to malfunction. For instance, respondents from Sinja Rural Municipality of Jumla considered that the construction of roads had affected 40 springs in their area. Melamchi residents have also reported decreased spring water volumes following the construction of roads in the villages (Chapagain et al 2017). Earthquakes are responsible for the drying or displacement of water sources by disturbing the underground geology, something that was especially pronounced after the 2015 earthquake in Nepal (Chapagain et al 2017; Dhakal et al 2022).

The survey identified other factors not directly shown in Figure 2 but included in the others category, such as

FIGURE 3 Distribution of responses from the key informants regarding the main problems caused by the drying of springs in the municipalities of Nepal ($n = 300$).



population growth, forest fires, hydropower tunneling, cemented irrigation canals and spring enclosures, conversion of ancient ponds and lakes into other lands, and reduction in the number of small ponds in recent years. In addition, "one house, one tap" has become the motto of every municipality, leading to increased dependence on tap water, where water flows to the tap through either lifting or boring technology, leading to the neglect of spring sources by local people. This increases the likelihood of springs drying up with increased siltation and transpiration by bushes and plants (Thapa et al 2020).

Problems caused by springs drying up and adaptive measures to address them

People residing in hilly and mountainous regions rely entirely on spring water for various purposes (Chapagain et al 2017; Poudel and Duex 2017; Gurung, Adhikari, Chauhan, Thakuri, Nakarmi, Ghale, et al 2019). Although some springs serve a single purpose, others have multiple uses (Adhikari et al 2021; Thapa et al 2020). As a result, changes in spring water availability and quality directly affect the livelihoods of these communities. Our survey revealed that the drying up of spring sources had severe repercussions on drinking water, irrigation, sanitation, and livestock (Figure 3). In certain settlements, this caused outmigration; displacement related to water scarcity was recorded in 7% of local government units (Appendix S2, *Supplemental material*, <https://doi.org/10.1659/mrd.2023.00007.S1>).

Local governments reported various practices they had adopted to tackle water scarcity problems. Of these, 31% relied on water transportation from distant sources, 29% used lift water supply systems, 12% had opted for boring, and 11% had implemented rainwater harvesting systems. However, 42% of the local governments had not adopted any measures. Although some local governments are implementing short-term coping strategies, such as boring and lift systems, these solutions are unsustainable in the long run and may worsen water scarcity issues in the future (Prakash and Molden 2020). Hence, it is crucial to embrace more sustainable options for water conservation to achieve Sustainable Development Goal 6, ie 100% coverage of

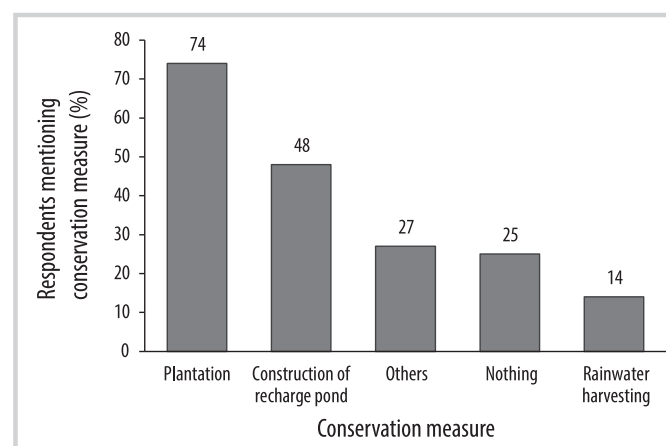
water, sanitation, and hygiene. Failure to do so would render the scarce fiscal resources invested in such short-term strategies useless. In addition, transporting water from distant sources can lead to conflicts among wards, local government units, and districts. For instance, in Jaljala Rural Municipality, Parbat, water is brought in from other wards because of the drying up of springs in Ward No. 8. Women and children responsible for domestic tasks and collecting water are particularly affected by the issue, because it takes more time to collect water from greater distances (Sharma et al 2016; Gurung, Adhikari, Chauhan, Thakuri, Nakarmi, Ghale, et al 2019). Studies have shown that 85% of women travel more than 4.5 km to fetch water (Shrestha et al 2019). In Suryodaya Municipality, Ilam, women have reported uterine problems resulting from carrying heavy buckets of water over long distances, even during pregnancy (DD Bhattarai, personal communication, 31 July 2020). This may be more severe in other rural parts of Nepal.

Conservation of springs and springsheds at various levels

Several local governments responded that they had constructed recharge ponds and established plantations and afforestation activities to conserve spring sources (Figure 4). Traditional practices were employed in the Melamchi area to sustain the water supply, including spring source cleaning for festivals and ceremonies, planting and fencing around the source, and using a plastic sheet and stone slab to conceal the source mouth. Constructing a concrete wall around the water source is a common practice in the villages (Shrestha et al 2019). Conservation techniques have gained significant attention in recent years, because they help to prevent the overexploitation of resources. For example, several households in the northeastern Himalayas have constructed rainwater collection systems supported by government initiatives (Singh et al 2020). Although unknown to many in other parts of the HKH, this approach is a viable option that local governments can replicate.

Some exemplary initiatives were reported by the key informants, including Chhabis Pathibhara Rural Municipality's success in conserving water sources while following traditional and religious practices. They had built a temple near the spring areas, and local people had started worshipping there, reducing deforestation and stopping cattle from grazing near the water sources, which helped to preserve the spring that was used for drinking water (A Dhami, personal communication, 27 August 2020). Suryodaya Municipality of Ilam formulated plans and policies for water source protection and conservation to prevent the use of heavy equipment in construction works around the spring sources. Based on a study carried out at several springs, the municipality declared some areas where springs had dried up to be dry zones and introduced a "one ward, one pond" program. The municipality also implemented a scheme to support the construction of ponds, especially for fish farming, and a birthday plantation scheme that offered plant saplings as birthday gifts to encourage people to plant more trees in their locality. In addition, pesticide use and deforestation within 50 m of the spring were prohibited (DD Bhattarai, personal communication, 31 July 2020).

FIGURE 4 Different measures for the conservation and revival of spring sources in local government units of Nepal ($n = 300$).



In response to past experiences with drying springs, Chaurpati Rural Municipality of Achham developed an annual plan to revive springs by constructing ponds for water recharge and minimizing water shortages in the area. At the time of our survey, the municipality had successfully constructed around 2000 medium-sized and small ponds, which citizen scientists had found to be effective in sustaining the discharge of previously dried-up springs. The municipality also planned to afforest and establish water storage facilities in barren community forests and public lands to ensure that rainwater reaches the groundwater table. In addition, the municipality prioritized its spring revival policy (HB Saud, personal communication, 30 August 2020).

Community-led initiatives focused on spring revival and protection are being implemented in various places in Nepal. For example, in Namobuddha Municipality, Kavre, a community group used a mapping exercise to locate springs that had dried up and those at risk of drying up. They found 40 dried-up springs; the remaining ones would dry up in 10 years if left unprotected. The group built a recharge pond (*pokhari*) to revive a dried-up spring (Figure 5). They engaged in conservation, disaster management, climate-change-related efforts, and local user capacity building (N Ghatane, personal communication, 11 October 2020).

In terms of policy and programs for spring conservation, 52% of local governments indicated that they had no policy in place. Of the 48% of local governments that recognized the need for a policy, some had implemented "one ward, one pond" or "one ward, multiple ponds" policies, especially for historical ponds. However, some local governments had policies in place that were not implemented effectively. Approximately 51% of local governments included spring conservation programs in their yearly plans and programs, either directly or as part of drinking water programs. This creates confusion and highlights the need for a clear conservation model. Spring conservation was prioritized in the annual plan and programs of 46% of local governments, with budget line items such as drinking water, spring conservation, pond construction, plantation, and contingency. Nevertheless, 53% of local governments did not allocate a budget for spring conservation.

FIGURE 5 Different types of ponds used by local governments and communities to revive dried springs. (A) Chhathar Jorpati Rural Municipality, Dhankuta; (B) Namobuddha Municipality, Kavrepalanchok; (C) Suryadaya Municipality, Illam; (D) rejuvenated spring after construction of the recharge pond in Namobuddha, Kavrepalanchok. (Photos by Bhumika Thapa)



A few local governments had taken action to conserve spring sources with campaigns to construct ponds. Moreover, a noteworthy proportion of local-level leaders were aware of the importance of spring revival and protection, and they intended to incorporate it into their annual plans and policies in the upcoming fiscal years. The involvement of organizations in spring conservation in Nepal's local government units remained limited, with 68% of local governments confirming that no organizations were involved in such efforts. This indicates a lack of nongovernmental efforts, presenting opportunities for organizations, institutions, and development partners to make a difference. However, some communities had taken it upon themselves to allocate funds from their annual plans and initiatives toward spring conservation. Conservation work had also been carried out in areas without the involvement of organizations. Some organizations coordinating with local governments on spring revival efforts are listed in Appendix S3 (*Supplemental material*, <https://doi.org/10.1659/mrd.2023.00007.S1>).

Conclusion

Springs play a crucial role in water and sanitation in the HKH region. However, millions of marginalized communities are vulnerable to water scarcity because springs are drying up or their discharge is decreasing. In Nepal, road and infrastructure development, the 2015 earthquake, climate change, deforestation, floods, and landslides are some factors leading to spring drying. As a result, thousands of communities are facing water scarcity,

including some communities being forced to relocate in search of water. However, our results are derived from phone interviews, and it is essential to validate these data through fieldwork conducted across Nepal, particularly in areas where drying is severe.

A spring conservation policy is crucial for the survival of springs. Decentralized governance and devolution of power to local bodies and institutions managing water are essential aspects of urban water management, particularly in rural areas. However, many local governments have yet to identify the issue and implement comprehensive policy instruments to address the growing problem. The drying up of springs is a multifaceted problem that requires a suitable policy solution to revive them. This solution must draw upon local and scientific hydrogeological knowledge to minimize negative impacts. Other local governments are aware of the importance of spring management and have started incorporating different spring revival mechanisms in their annual policies and programs. However, implementation is still lacking, and there is a need for community-level awareness-raising programs on spring conservation. A comprehensive approach to springshed conservation and local community participation, informed and supported by scientific, research-generated evidence, is necessary to mainstream spring revival in Nepal. Furthermore, although spring drying is a global problem, conservation is not given priority. In this instance, the sharing of cross-border knowledge and the creation of an international standard protocol to monitor spring sources may help to reduce the global water crisis and spring drying problems while assisting in the achievement of Sustainable Development Goals.

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Supplemental material

APPENDIX S1 List of local governments facing severe water scarcity and municipalities visited for field verification.

APPENDIX S2 List of local governments having displaced community because of water scarcity.

APPENDIX S3 Organizations working on spring conservation throughout Nepal.

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