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Water crises in a water-rich country: case studies from rural watersheds of Nepal's mid-hills

Anup Gurung[a,*], Sanot Adhikari[a], Raju Chauhan[a], Sudeep Thakuri[a,b], Selina Nakarmi[a], Sarita Ghale[a], Bhawani S. Dongol[c] and Deepak Rijal[c]

[a]*Youth Alliance for Environment, Gairidhara, Kathmandu, Nepal*
**Corresponding author. E-mail: anuptamu@gmail.com*
[b]*Central Department of Environmental Science, Tribhuvan University, Kirtipur 44618, Nepal*
[c]*Program for Aquatic Natural Resources Improvement, USAID, Kathmandu, Nepal*

Abstract

The main objective of this paper is to assess the water crisis in Nepal by conducting a series of case studies in rural watersheds in the mid-hills. This was achieved through the applied qualitative method, especially combinations of desk study/structured searches, consultation, and field observation. The ground survey revealed that most of the rural communities in the mid-hills have an unreliable water supply. According to the local stakeholders, 20–25% of water resources have dried up as compared to 20 years ago. Drying up of water resources disproportionately affects women and girls in rural areas as women are responsible for household chores, including fetching drinking water. The findings also revealed that low-income households bear a disproportionate coping burden as compared to elite groups, as they often engage in coping strategies such as collecting water from distant water sources, which is labor- and time-intensive, and also yields smaller quantities of water. Assuming that unreliable water supplies will continue to exist in rural areas of the mid-hills for the foreseeable future, there is a critical need to consider which, if any, coping strategies will be most effective in ensuring that poor households will have access to safe and sufficient water supply.

Keywords: Climate change; Drinking water; Drying; Nepal; Scarcity; Springs

Introduction

Water is the single most important natural resource that is widely distributed in the natural environment (Plessis, 2017; Singh *et al.*, 2019). Water is crucial for various aspects of human health,

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development and well-being (Guppy & Anderson, 2017; Plessis, 2017). Realizing the importance of water for human health and economic activity, the United Nations Sustainable Development Goal 6 targets access to water and sanitation for all people in the next 15 years (WHO, 2017). However, for developing countries it is more challenging to achieve this goal given their weak financial capabilities, poor infrastructures, and high population growth (Guppy & Anderson, 2017). Still, more than 40% of the total global population does not have access to sufficient clean water and the majority of these populations live in developing countries (UN, 2018; WHO, 2018). Widespread decreased availability of usable water poses a major threat to several sectors, including sustainable development (GLAAS, 2017). Furthermore, the condition of water scarcity is exacerbated by climate change that could cost some regions up to 6% of their gross domestic product (WBG, 2016).

In other words, although the total water globally has not decreased, the distribution and the demand for water are increasing to meet the demands of an increasing population and sectoral development. Freshwater resources are unevenly distributed across the Earth's surface, and thus, low-income countries like Nepal will be most affected by continuously decreasing availability of usable water. In terms of water resources, Nepal is one of the richest countries in the world, accounting for more than 2.27% of the world's water resources (HEMS, 2015). Despite being among the most water-rich countries, Nepal is ranked in the world's top five countries with a poorly developed drinking water system (McPhillips, 2017). Although water scarcity and lack of sanitation affect the entire population, impacts are differential and significant in inaccessible remote areas of the country. Thus, water scarcity is becoming an emerging national issue related to water pollution, food and energy insecurity, impeding the gross domestic product (Panthi *et al.*, 2018).

Nepal is divided into five major physiographic regions, namely, Terai plain, Siwalik hills, mid-hills, lesser Himalaya, and higher and trans Himalaya (Figure 1). Terai plain consists of flat areas with

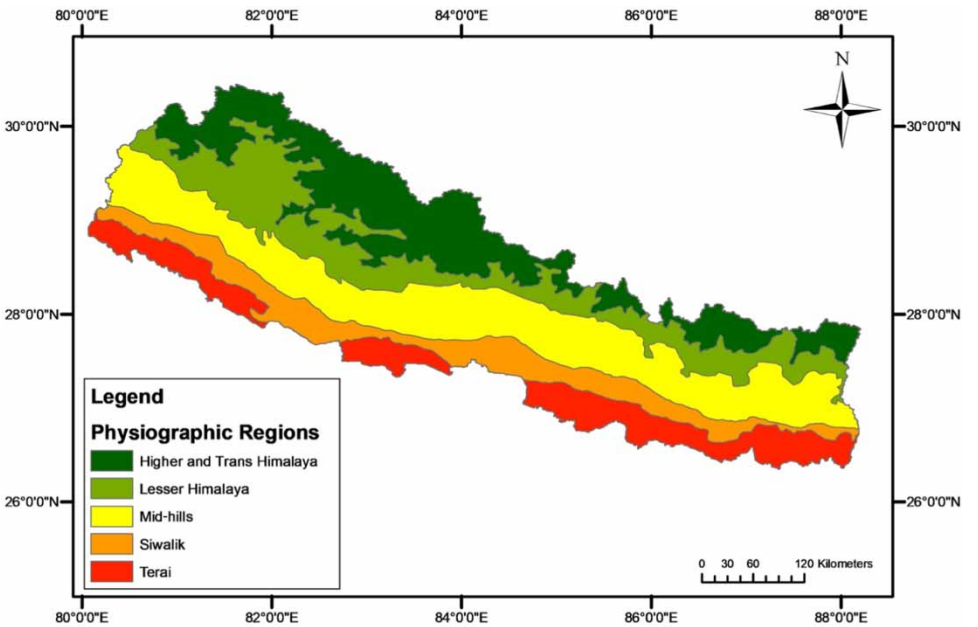

Fig. 1. The five major physiographic regions of Nepal.

elevation ranging from 60 to 200 masl. The Siwalik hills are commonly known as Churia hills and cover nearly 13% of the total area of the country. The elevation of the Churia ranges from 200 to 1,500 masl and is characterized by low terraces and alluvial flats with steep topography. The mid-hills are also known as the Mahabharata range. Elevation of the mid-hills ranges from 1,000 to 2,500 masl and extends throughout the entire length of the country. In many places the mid-hills ranges are intersected by major antecedent rivers, including the Koshi, the Gandaki, the Karnali, and the Mahakali. These rivers are the major source of water, originating from north of this range and drain to the south. The lesser Himalaya extends further north of the mid-hills and elevation ranges from 2,200 to 4,000 masl. The higher and trans Himalayas or the mountains range from 4,000 to 8,848 masl.

Acute water shortage is being felt in several parts of the country, especially in the mid-hills and high-hills. Assuming that water scarcity or unreliable water supplies will continue to exist in the mid-hills of Nepal for the foreseeable future, there is a dire need to consider which, if any, coping strategies will be most effective in ensuring that rural communities will have better access to clean and sufficient water for their domestic use. Demand for water is continuously increasing, but the availability of the water remains the same. The increasing water demand will put more pressure on the existing water sources, which could further deplete the supply in the regions of the country experiencing water shortage.

Freshwater resources are distributed unevenly in Nepal. In addition, the varied geographical setting has made the expansion or distribution of services and facilities unrealistic in isolated and rural areas. Most of the settlements are located far above the streams and rivers, which lie at the bottom of deep gullies and valleys far below, and the construction of water tanks could be most expensive or prohibitive in such settlements (Sharma *et al.*, 2016). The main objective of this paper is to attain efficient and sustainable water resources management in the western mid-hills watersheds of Nepal. A road map of the research paper is summarized in Table 1.

Table 1. Road map of the current research paper.

Road map of the research paper	
Objective	• Attaining efficient and sustainable water resources management in the mid-hills through sensitization in politics and water resources planners of Nepal
Definition and scope	• Problems in water resources management in Nepal • Context in which the problems and solutions need to take place in the mid-hills, Nepal
Strategic focus areas	• Water resources of Nepal • Water consumption trend in Nepal • Water scarcity in Kathmandu, Nepal • Water scarcity in the mid-hills, Nepal • Case studies in the mid-hills, Nepal
Outcomes	• Nepal is rich in water resources, however the poor and unsustainable management practices have resulted in water scarcity • The water sources in the mid-hills are very fragile, but can be maintained through the proper management practices. The traditional knowledge/practices may support water sources conservation • Support for the planners to take the effective action on water sources management • Restoration of water sources is mandatory to make the mid-hills livable

Materials and methods

The Paani Program, funded by the United States Agency for International Development (USAID), aims to reduce threats to freshwater biodiversity and increase the ability of targeted human and ecological communities in the Karnali, Mahakali and Rapti River basins to adapt to the adverse impacts of climate change through improved water management. The main objective of the Paani Program is to protect critical water resources by working with local and national counterparts to conserve freshwater biodiversity and implement sustainable water management practices. The Paani team works to raise the profile of freshwater issues through policy engagement, academic research, curriculum development, and sponsorship of international forums. The Paani project emphasizes user-centered design to analyze how various stakeholders, including fishermen, government officials, and hydropower developers, use water resources to better incentivize their engagement in water conservation and management activities.

A 1-year action research project was undertaken by the Youth Alliance for Environment (YAE) funded by the Paani Program for mapping of spring sources in five respective watersheds, namely, Middle Karnali, Rangun, Thuligad, Bogtan-Lagam Karnali, and Jhimruk. The grant was received for mapping spring sources and assessing point and non-point water pollution in mid-west and far-west watersheds. Apart from this grant, YAE has been working in this region in the sector of climate change and vulnerability assessment. The YAE teams visit the fields frequently, and hence these activities enrich the knowledge of the teams in gathering information about the shortage of water in different parts of the mid-hills regions.

The main objective of this research is to assess the current scenario of water resources in the mid-hills regions of Nepal. This study presents a number of case studies documented from the mid-hills areas of Nepal to identify gaps and areas for improved community access to water resources and sanitation that inform local governments and local partners, and ultimately contribute to achieving the sustainable development goal. This paper presents the outcomes of the survey conducted by a team of experts from YAE, that include the major findings and important insights gained from both scientific investigation and interaction with the local community. Some policy implications are discussed and recommendations made for future research or actions needed to enhance the revival of springs that have dried up.

To our knowledge, this is the first attempt to present Nepal as a water-rich country where water is a scarce resource among international communities. A systematic review of the literature was done using Google Scholar and Google search engines, ScienceDirect, Scopus, PubMed, and Medline. In addition, the authors also documented true stories from different communities among the mid-hills communities on site observations of the issues.

Results and discussion

Nepal's landscape

Nepal is one of the low income countries of the world. It covers an area of 147,181 km^2 with a current population of over 28 million people. Despite occupying only 0.03% and 0.3% of the total land area of the world and Asia, respectively, it has a very diverse topography and climate. Geographically, it has been categorized into three ecological zones consisting of mountains (43%), hills (30%), and plain

Terai (27%) (Bastola, 1994). The Nepalese economy is based on agriculture, which contributes about 33% to its national GDP (MOF, 2017).

Snow cover and glacier. Nepal is among the richest countries in the world in terms of water resources (WECS, 1994). Nepal is fortunate to have an abundance of water resources in different forms, including glaciers, rivers, rainfall, lakes, ponds, springs, and groundwater (WECS, 2005, 2011). Nepal is a small, beautiful landlocked country, located entirely in the Ganges basin, bordering with India in the east, west, and south, and China in the north. The northern border region of Nepal contains 200 peaks of more than 6,000 m and 13 peaks of more than 8,000 m high, including Mount Everest (Shrestha & Aryal, 2011; Shrestha *et al*., 2013). The Nepal Himalaya covers approximately 35% of the total area and contains a large number of glaciers and glacial lakes that provide huge natural storage of freshwater in the form of ice (WECS, 2011; Shrestha *et al*., 2013). Nepal is also known as the Land of Everest and contains approximately 3,252 glaciers with a total coverage of 5,323 km^2 and 481 km^3 of estimated ice reserves (Mool *et al*., 2001; Bajracharya & Shrestha, 2011; WECS, 2011). In addition, 2,323 glacial lakes in the high mountains region (>3,500 masl) covering an area of 75 km^2 are reported (WECS, 2011). Nearly 3.6% of Nepal's total area is covered by glaciers, and these glaciers are the source of major rivers of Nepal that provide vital ecosystem services (Mool *et al*., 2001).

River basins. Nepal is bestowed with water resources, where approximately 6,000 rivers and rivulets flow with a total drainage area of 194,471 km^2 (74% of which lies in Nepal alone) (WECS, 2011). There are 33 rivers whose drainage areas exceed 1,000 km^2, and these can be classified into three types depending on their origins and discharge (MOWR, 1985; Bastola, 1994; Upreti, 2006): (i) First Grade River, (ii) Second Grade River, and (iii) Third Grade River.

Precipitation occurs in two periods in Nepal: (i) June to September when the south-west monsoon causes about 80% of the total precipitation and (ii) 20% during the dry season (Upreti, 2006). The catchment areas from Nepal alone make up about 45% of the long-term average annual flow of the Ganges basin and contribute over 70% of the Ganges flow during the driest periods (Shumsher & Rana, 1996). The river discharge and the total catchment area of each river basin lying in Nepal are shown in Table 2.

Lentic environments. Nepal is rich in enclosed water resources as there are numerous enclosed water bodies in the form of lakes, ponds, dams, and other small wetlands. DOAD (1992) reported around

Table 2. River discharge flowing through Nepal's catchment (WECS, 2005, 2011).

River basin	Estimated catchment area in Nepal (km^2)[a]	Annual discharge (km^3/year)	Average discharge (m^3/s)
High mountains rivers			
Koshi	27,863	45.00	1,409
Gandaki	31,464	50.00	1,600
Karnali	41,058	44.00	1,397
Mahakali	5,188	18.00	573
Mahabharat rivers	17,000	14.50	461
Siwalik rivers	23,150	53.00	1,682
Total	**145,723**	**224.50**	**7,122**

[a]Total catchment area of each river basin is larger than shown in the table.

5,000 natural lakes, 1,380 reservoirs, and 5,183 traditionally built ponds. According to the National Lake Conservation Development Committee (NLCDC), there is a total of 5,358 lakes in Nepal distributed in different ecological regions (including 2,323 glacial lakes) (NLCDC, 2018). Among them, over 2,700 (51%) are distributed below 500 m, 2,227 (42%) above 3,000 m, and only 419 (<8%) in the altitudinal range between 500 and 2,999 m (Bhuju *et al*., 2010). Most of the lakes studied in Nepal seem to be confined within the Middle Mountain areas of Phewa, Begnas, Rupa, Khaptad, Tilicho, Phoksundo, Dudh Pokhari, Panch, and Pokhari. IUCN inventory (1996) reveals that there are 163 wetlands in Terai, and 79 in the hills and mountains. Nepal has declared 10 wetlands as Ramsar sites that have a distributed elevation between 90 and 5,000 m stretched over a total area of 60,561 ha (NLCDC, 2018).

Groundwater. Nepal is also rich in groundwater resources. The country has an estimated renewable groundwater potential of about 12 km^3 (WEPA, 2018), of which, 5.8–11.5 km^3 can be extracted annually without any adverse impacts (WECS, 2005). Groundwater plays a pivotal role in fulfilling domestic water demand all over the country, especially in Terai region and Kathmandu valley.

Uses of water resources in Nepal

Nepal's total annual surface runoff has been estimated to be about 225 billion m^3 (BCM), of which only 15 BCM is in use, and that has been estimated to be entering into the border rivers between Nepal and India from the tributaries located on the Indian side (WECS, 2011). Table 3 shows the total water availability and use by different sectors in 1995 and 2001 in Nepal (WECS, 2005; UNEP, 2001). The agriculture sector is the largest sector, consuming almost 96% of the available annual renewable water. The domestic sector accounts for approximately 4%, whereas the share of the industrial sector is insignificant. The fraction of water demand for irrigation and domestic purposes can be supplied from groundwater sources. The annual withdrawal of groundwater for irrigation and domestic purposes is 0.756 km^3 and 0.297 km^3, respectively (UNEP, 2001; WECS, 2005).

River water is used for generating hydropower in Nepal. Since Nepal does not have a reserve of fossil fuels, it is heavily reliant on hydropower to meet its energy demands. Table 4 shows the basin-wise hydropower potential of Nepal's river system. Theoretically, it is estimated that Nepal's rivers have the potential of generating about 83 gigawatts (GW) of hydroelectricity, of which 42 GW is technically and economically viable (WECS, 1994; Pokharel, 2001). At present, total electricity generation is around 2,305 MW (NEA, 2017).

Table 3. Status of water availability and use by different sectors, Nepal in 1995 and 2001 (UNEP, 2001; WECS, 2005).

Particulars	1995	2001
Total annual renewable water resource (km^3/year)	225	225
Per capita renewable water resource (000 m^3/year)	11	9.6
Total annual withdrawal (km^3/year)	14	18.5
Per capita annual withdrawal (000 m^3/year)	0.69	0.8
Withdrawal percentage		
Agriculture	95.9	96.1
Domestic	3.8	3.6
Industry	0.3	0.3

Table 4. Basin-wise potential hydropower development in Nepal (WECS, 1994; Pokharel, 2001).

River basin	Capacity on small river courses (GW)	Capacity on large river courses (GW)	Gross total (GW)	Economic potential (GW)
Sapta Koshi	3.60	18.75	22.35	10.86
Sapta Gandaki	2.70	17.95	20.65	5.27
Karnali and Mahakali	3.50	32.68	36.18	25.10
Southern rivers	1.04	3.07	4.11	0.88
Total	**10.84**	**72.45**	**83.29**	**42.14**

Current scenario of water supply situation in the capital city Kathmandu, Nepal

In recent years, the unplanned urbanization and increasing population inflow to city areas have exerted further pressures on water resources (Thakur *et al*., 2017). Competition for access to water resources increases when the renewable water availability decreases, and the poor household/community cannot afford to pay for water resources (Guppy & Anderson, 2017). Kathmandu, the capital city of Nepal, has been experiencing a dire situation regarding water, both availability and quality, for more than 30 years (Shrestha *et al*., 2013). The Kathmandu valley is the most urbanized and populated area and the daily water demand is more than 360 million liters per day (MLD) (Udmale *et al*., 2016; Raina, 2017). However, Kathmandu Upatyaka Khanepani Limited (KUKL) is able to supply 140 MLD in the wet season, and 90 MLD in the dry season (Manandhar, 2016). The key reason for this trend is that KUKL does not have enough financial and technical capacity to expand the pipe network and to control pipe leakages (nearly 35% of KUKL's total supplies go to waste through leakages) (Gurung *et al*., 2017).

Despite the lack of an assured water supply, 90% of households in Kathmandu are connected to the government piped water system, but only 70% use water from the system as the water supply is not adequate and reliable (Raina, 2017). Households diversify their sources of water by using bottled or jar water for drinking purposes, and tanker water from private tanker water vendors for cleaning, washing, and bathing purposes. Some households have private well water at their homes and this is used for washing and cleaning. Nevertheless, water poverty is becoming an emerging issue for the local government as the water provided by private water vendors is not safe to drink.

In a nutshell, the capital city is characterized by an acute water shortage and degraded water quality, and has the worst water supply system in the country (Udmale *et al*., 2016). The increasing population and rapid urbanization has resulted in the generation of solid waste that causes deterioration of the water quality (Thakur *et al*., 2017). KUKL, a public–private partnership company, is responsible for the operation and management of the water supply in the valley. In order to overcome the water shortages as well as to provide a regular water supply to the valley, the government has begun the 'Melamchi Water Supply Project' which will transfer water from the Indrawati River basin to the Bagmati River basin via a 26 km long tunnel (GLAAS, 2015). About 170 MLD will be delivered to Kathmandu upon completion of the first phase of this national water supply project (Raina, 2017). However, the completion date has been delayed, although it was expected to be completed by December 2017. The water shortage problem will continue to exist in Nepal for the foreseeable future.

Current scenario of water supply situation in the mid-hills, Nepal

Nepal experiences both natural and human-induced disasters with great frequency and intensity due to its rugged and fragile geophysical structure. Thus, the harsh mountainous topography is another reason for prevailing water scarcity in the hills and mountain regions of the country (Schwartz *et al.*, 2001). Floods, landslides, droughts, storms, avalanches, hailstorms, epidemics, and ecological hazards are common natural disasters in the mountainous regions of Nepal. In the mid-hills and the high mountain regions of Nepal, rural households have little or no access to basic services and facilities as compared to urban areas (Thakur *et al.*, 2017). In addition, most of the rural populations engage in subsistence farming without having proper irrigation facilities (MOF, 2017). Furthermore, rural households do not have the financial capacity to pay for water resources, and hence, water scarcity is more persistent in rural mountain regions than anywhere else in Nepal (Palmer *et al.*, 2008).

Nationwide, an estimated 40,000 water supply schemes of various types, including gravity flow, pumping, and a combination of both, and of large, medium, and small scale are documented (GLAAS, 2015). The water supply in rural and semi-urban areas comprises the traditional water systems, such as dug wells, tanks and ponds, and stone spouts. However, in most scenarios, communal tanks are out of order, and also the water supply is affected by the exhaustion of traditional sources, including wells and seasonal rivers (POSTNOTE, 2002; Raina, 2017). Most rural water schemes are operated and managed by Water User Groups – a kind of community-based organization formed by the local people themselves (GLAAS, 2015). This type of management team may lack technical skill and knowledge, which leads to the failure of the water schemes or projects. For example, when there is a plentiful water supply, these groups are unaware of the mechanisms that contribute to saving water for future use.

Figure 2 shows the scenario of water scarcity in Dullu-4, Dailkeh District. In this region, households rely on community tap water provided by the government. However, villagers have to wait for a long time to fill a bucket of water, and also the flow of water in the tap is irregular. Water is usually available in the morning or evening and lasts for about 2 hours, and so if villagers are busy doing other tasks they cannot fetch water. Figure 3 shows the daily routine of villagers while collecting water in Bhumisthan-3,

Fig. 2. Water scarcity scenario in Dullu-4, Dailekh District.

Fig. 3. Villagers in a queue while collecting water at Bhumisthan-3, Arghakhanchi District.

Arghakhanchi District. Villagers in this area rely on a spring source for fulfilling their basic water requirements. They do not have access to tap water in this area and rely entirely on the spring source that is near to the roadside. Approximately 15 households collect water and constructed a concrete tank where the excess flow of water can be stored. However, during dry periods, especially in the months of Chaitra and Baisakh (April–May), the water volume decreases in the spring and villagers have approximately 30–40 minutes to fill a 20 L bucket or jar.

Most rural households rely on small brooks running from the mountains and have to spend hours fetching water. The water collected from traditional sources has not always been safe. In most of the rural communities, the households use the water collected directly from springs or streams without any treatment. In such circumstances, the water supply source may be polluted. This is the main reason behind the outbreak of water-borne diseases in rural areas, mainly in the rainy season, that have taken the lives of many people, mainly children (WHO, 2017). In addition, access to water resources is worsened by a lack of financial capacity to invest to meet demand (POSTNOTE, 2002).

Water scarcity severely affects the rural economy as more than 80% of populations rely on agriculture for their livelihood (MOF, 2017). In most parts of the mid-hills, farmers rely on rain-fed agriculture, and thus, their cultivation is seasonal. There is no provision of proper irrigation facilities or mechanisms to save excess water in rural areas. Thus, cultivation is not even sufficient to sustain them for a six-month period. Most of the young and energetic family members go to India to get seasonal work to support their families. Severe water scarcity is already impacting communities, resulting in migration from their native villages.

Sources and quality of drinking water in the mid-hills

Human activity, health, and sanitation are greatly affected by the quantity and quality of water (Udmale *et al.*, 2016). Clean water refers to the suitability to sustain life or a livelihood that is free

Table 5. Estimated volumes of water needed for hydration (Howard & Bartram, 2003).

Particular	Volume (L/day)	
	Average condition	Manual labor in high temperature
Female adults	2.2	4.5
Male adults	2.9	4.5
Children	1.0	4.5

from detrimental microorganisms and pollutants. An adult female requires 4.8 L per day during pregnancy and 5.5 L per day during the lactation period (Howard & Bartram, 2003). Table 5 depicts the average water volumes required for maintaining hydration for human beings.

Tap water is the primary source of drinking water in hilly regions, providing drinking water to 72% of the households. Generally, tap water refers to water piped directly from a source as well as being centrally distributed and pretreated for sediments and microorganisms. The second most important source of drinking water in the mid-hills is spout water. The relative share of spout water is about 9.24%. In those areas where tap water is not available, households rely on wells for meeting their water demand. Table 6 shows the type of water resources used for households in the hill region of Nepal (CBS, 2011).

Figure 4 shows different forms of spring water in the villages. It has been observed that in the majority of settlements, water is consumed without any treatment. In most of the villages, natural spring water is diverted to a concrete tank and distributed among the villagers. However, there is no reservoir system and the water continues to flow even if it is not used. Spring water is often accessed without implementation of adequate protection measures or without having installed appropriate catchment systems.

Case studies from different rural watersheds of the mid-hills, Nepal

The authors visited several remote villages in mid and far western, and eastern rural areas of the mid-hills, and observed the conditions of water scarcity on site. Most of the visited villages do not have access to piped water for drinking purposes, although it is claimed that 72% of the total population has access to piped water in the hilly region. Even where piped water exists most of the taps were not functioning well and not delivering the expected services at full scale. In recent years, the local government authorities have invested a huge chunk of their budget in expanding the rural road network.

Table 6. Type of water sources used by households in the hill region of Nepal in 2011 (CBS, 2011).

Drinking water source	% of the total household in hill
Tap/piped water	72.04
Tube well	3.06
Covered well/kuwa	3.48
Uncovered well/kuwa	6.18
Spout water	9.24
River/stream	1.56
Others	3.91

Fig. 4. Different types of sources of spring water in mid-hills regions, Nepal.

While doing so, rural roads have been constructed without consideration of the environmental impacts upon water and other natural resources. Such unplanned rural road construction leads to the destruction of existing drinking water pipe networks along the roads (Figure 5) and disturbs water spouts. In some areas, spring sources had also dried up after expansion of the rural road network.

Figure 5 shows a dismantled drinking water pipe due to expansion of the road network in Bahine, Pyuthan District. The road section lies in Bahine-6, Nau Bahini Gaun Palika. Prior to expansion of

Fig. 5. Water pipe dismantled by road construction at Bahine, Pyuthan (15 June 2018).

this road, villagers used to collect drinking water from the pipe. After expansion of the road, the existing drinking water pipe was disrupted. In most of the villages, the settlement is scattered far above the streams and rivers, which lie at geographically inaccessible areas, so the construction of a water supply project may be too expensive or prohibitive in those areas. It was observed that springs are the primary source for rural households in meeting water demand for domestic purposes, including drinking, agriculture, and livestock. Both the quality and quantity of the springs are affected by anthropogenic activities, including land use changes, agricultural intensification, increases in population, and climate change. In many areas, villagers have noticed a significant change in the spring sources for the past few years. For example, the water discharge from many springs has decreased, permanent springs have turned into seasonal springs, and seasonal springs have dried up completely. Villagers believe that the key reason behind this change could be due to haphazard road construction and climate change. They also mentioned that after the Gorkha Earthquake in 2015, many spring sources had dried up.

In many villages, isolated drinking water projects have been implemented either by the government or by a non-government organization. However, there were no proper monitoring mechanisms once the project was handed over to the community by the donor. Populations who rely on streams or rivers have also been facing water shortages as the surface water quality has been degraded by sediments, suspended solids, bacteria, and organic substances. A lack of sanitation and an unreliable water supply are seen as among the biggest issues affecting the health of children across the mid and far western rural watersheds of the mid-hills, Nepal. Many villages were declared as open defecation free areas; however, many children are still denied the most basic rights to safe water and the simple practice of washing hands with soap. In many villages, it was found that although there are toilets in the schools they are not used due to lack of water.

The so-called 'racial discrimination' still persists in the villages, where the marginalized/disadvantaged groups are devoid of access to water resources. In some villages, disparities in access to water resources among different wealth groups are clear as Dalit or low caste people are compelled to use low quality water for drinking and other purposes. In many parts of the mid and far western region of the mid-hills, women (during their menstrual cycle) are not allowed to go to spring sources due to superstitious belief, and thus, water scarcity disproportionately affects women's health in the rural areas.

Case study 1

Water resources are becoming increasingly scarce in Dhanras-1, Chaukune Gaun Palika of Surkhet District. The shortage of drinking water during the dry months of the year is of particular concern in Dhanras. Most of the villages have an unreliable water supply system and rely entirely on spring sources to meet their water demands. During dry periods, when nearby spring sources are dried up, householders have to walk all the way down to the bottom of the hill, a drop of many meters in height, along many more meters of trail to fill their water canisters. Some households even consume water directly from the Karnali River to fulfill their water demands.

Households in Papighat area, Dhanras-1 of Chaukune Gaun Palika have been suffering from an unreliable water supply for generations. They have neither access to pipe water nor springs or wells. They have been consuming water from the Raji Khola Irrigation Canal or directly from the Karnali River (Figure 6) since they do not have any other option for a drinking water supply. The collected water is left for 2–3 hours to settle, and then used without further treatment. Previously, there used to be 16–20 households in the community; however, as the water scarcity continues, most of the households

Fig. 6. Households use water from Karnali River for drinking and cooking purposes in Papighat village (30 May 2018).

have migrated either to low land areas of Kailali District or elsewhere. Currently, only 5–7 households remain in the village, and they have requested their ward office to solve the water scarcity. If they do not get any support from their ward office, the remaining households are also considering migrating to Kailali District.

Case study 2

Most of the villages in Chaukune Gaun Palika, Surkhet District, do not have access to a reliable drinking water system. Although rice is the main crop they do not grow paddy due to lack of water for irrigation. They only grow wheat and barley as these crops do not need much water. They import rice from Surkhet. The shortage of water for agricultural and domestic purposes puts immense pressure on women and girls as they are the primary managers of household chores, including feeding their family, collecting fodder, firewood, and small-scale agriculture. Men often go out of the village for employment.

In Pag village, Dhanras-1, Chaukune Gaun Palika of Surkhet District, women and girls are responsible for fetching water from dug wells and springs. Collecting water from dug wells is always risky since the depth of the well is more than 20 m deep (Figure 7). As depicted in Figure 7, the wooden frames are almost rotten and can break at any time. Since there are only 7–8 households in the village immediate help is not available if anyone falls down the well while drawing water.

Sota village, Dhanras-1, Chaukune Gaun Palika, in Surkhet District is another village where villagers have long been suffering from a shortage of drinking water. They hardly have access to tap water and hence have to rely on spring sources. There is a spring source called 'Budokhola' in the vicinity of the village but it takes 45 minutes to reach the water source. However, women and girls are afraid to go to the 'Budokhola' alone to fetch water because villagers often encounter wildlife, such as tigers and bears at the spring source. Most of the time their husbands are away from

Fig. 7. Dug well that is about 30 m deep in Pag village, Dhanras-1, Chaukune Gaun Palika Surkhet District (30 June 2018).

the village seeking employment in the city center. Consequently, women and girls have to walk more than 3 hours to fill their canisters. Most of their day is spent fetching water for drinking and livestock. In the past, there were a couple of wallows in the village where livestock could drink water; however, in recent years, these ponds have also dried up and therefore villagers could not raise livestock as easily.

Case study 3

In some villages, villagers have to pay for using water resources. In the eastern mid-hills, villagers have to raise money to use water from the spring. For example, the villagers of Rajapani Halesituwachungmun Gaun Palika-11, Khotang District, collected the sum of NRs. 400,000 from the 48 households to buy a spring source of Simkhet (rice field) of Mr. Lal Bahadur Shrestha. The villagers formed Janasewa Simkhet Water Users Committee and the spring registration card was obtained from the local government in 2017. The villagers have no option other than to buy the source. During dry periods, all the spring sources near the locality they had used in the past have dried up, and they have no other option for sourcing water. In the same village, other similar cases were also noticed. In some parts of Bhojpur and Khotang District, the extent of water scarcity is so severe that it led to a mass exodus of villagers. Already 20–22 households from Bhojpur and Khotang have migrated to other, water-rich areas, especially Terai region, for better livelihood options. This type of migration is very common in the mid-hills due to the shortage of water resources.

Case study 4

Generally, farmers rely on nearby streams for irrigation and other farming activities since there are no proper irrigation facilities in the mid-hills. Rice is the main crop that is grown by the villagers in rural areas. However, in recent years, the drying up of the water resources or decline in water resources has become a major threat to farmers' livelihoods. One such case was obtained from Nuwakot district. For

the past 15 years, Nabaraj Adhikari and neighbors in Silame village, Shivapuri-5, Nuwakot District have been using water for irrigation in the dry season from the nearby irrigation canal. Water in the canal was brought from the Gaare Khola (river) which is about 4 km away from the village, and the water was used for cultivating mustard and wheat during the winter season. However, the scenario has now changed. For the past 10 years, the canal has remained functionless, mainly due to decreased water discharge. The water discharge in the river has decreased and the flow is not sufficient to divert to the canal. Consequently, the intake section is filled with gravel and other solid materials. These days, Mr. Adhikari has abandoned cultivation of wheat and mustard, rather leaving the land fallow. This is not only the case for Mr. Adhikari but also in many parts of the mid-hill areas. Water scarcity is becoming an emerging issue and challenge for the local government as villagers are facing hardships in following their livelihoods and are compelled to opt for other livelihood opportunities. Figure 8 shows the districts where the case studies were conducted.

The presented case studies clearly demonstrate that springs are the principal source of domestic water supply for rural communities in the mid-hills of Nepal. In recent years, the process of drying springs in the mid-hills has become a major threat. At present, households collect water from a range of sources: (i) springs, (ii) community tube wells, (iii) privately dug swallow wells, water conveyed by pipe from a distant spring, (iv) streams, and (v) rainwater harvesting. Although tap water is the preferred source, the majority of the households or communities rarely have this type of supply. Even if the villagers have a tap water supply, it becomes unfunctional after a couple of years due to a lack of maintenance and awareness. Therefore, the most reliable source of water for villagers is the natural spring. During dry periods, when water in the springs reduces, or in times of scarcity, villagers rely on streams to meet their water demand (Singh *et al.*, 2019).

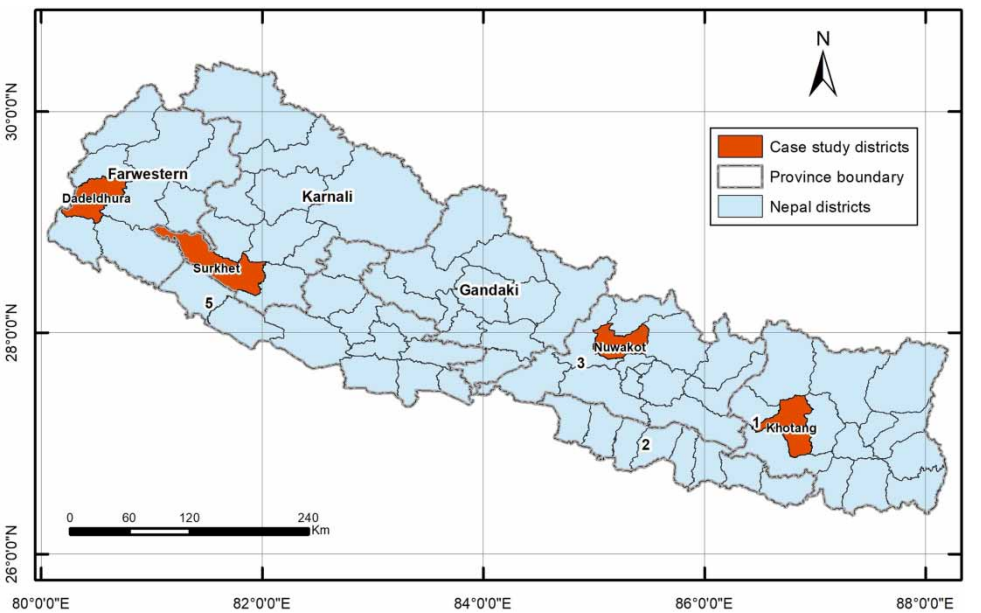

Fig. 8. Map showing the case study districts in Nepal's mid-hills.

Paddy is grown only once a year in the mid-hills. It is grown during the monsoon season (June), when water flow increases in the nearby streams. During the monsoon season, almost all households collect rainwater from their roofs in rainwater harvesting jars. The water collected in the jars can be used in times of water scarcity. Such water is especially used for washing dishes, irrigating vegetables, and feeding livestock. In recent years, with the aid of non-government organizations, local farmers have been collecting rainwater in ponds lined with plastic film, which is locally known as 'plastic pond'. Water harvested in a plastic pond can be used for irrigation of vegetables, fish farming, and livestock. However, rural settlements in the mid-hills would be unable to undertake fish farming or other commercial activities since they are not able to manage or cope with their daily drinking water. Highly educated and rich people often migrate from the rural and isolated areas of the mid-hills and only the illiterate and people with low economic status remain in the villages. Consequently, they are unable to afford to make water tanks on their own. Some households are deprived of using the community tap water as they could not contribute NRs. 2,000 to the water user group.

Households in the mid-hills adopt different technologies to store water to use for various purposes. As depicted in Figure 9, some houses in Chamunda Bindrasaini-4, Dailekh District have adopted a rainwater harvesting technology. Using this technology, households collect rainwater from the roofs of the houses and store it in a jar. The water collected in the jar is mainly used for washing dishes, irrigating vegetables, and feeding livestock. The rainwater harvesting jar was constructed with financial assistance from non-governmental organizations. However, most of the households complain that water stored in the jar is not so suitable for long-term use as the water attracts insects. In some villages, these jars are functionless. In some areas, households collect water in polythene jars if there are transportation facilities in the locality. Water collected in polythene tanks is used for drinking, cooking, washing, and other

Fig. 9. Different mediums for collecting water in the mid-hills, Nepal.

purposes. Nowadays, the polythene tank is commonly used for storing water in the villages as it is easy to carry compared to a cement jar.

In Kelabari, Dhanras-1, Chaukune Gaun Palika in Surkhet District, villagers have been facing water scarcity, especially during the dry periods. In this village there are very few natural springs, and villagers collect spring water in a concrete tank. When the water overflows from the tank, it spills out and is stored in the outer base part of the concrete tank and utilized by livestock, as shown in Figure 10. In some villages, excess water is collected by making a wallow and used by livestock and for irrigation.

In many rural areas, spring water is often accessed without having implemented adequate spring protection measures or having installed appropriate catchment systems. The consequences are that the spring becomes contaminated (by pathogens, chemicals, metals) and water quality thus does not meet the criteria for drinking water. As depicted in Figure 11, some villagers protect their water source by surrounding it with an iron fence. The barbed iron fence helps to protect the water source from livestock, children, and other damage. In some areas, wallows are also found to be maintained with the objective of water recharge. However, such practice is rarely seen in the settlements.

The potential reason behind drying water resources

Water resources are becoming increasingly scarce in Nepal's mid-hills and ultimately threaten the livelihood of rural populations. Shortage of water for agricultural production and domestic purposes during the dry months of the year is of particular concern in the mid-hills areas. Villagers believe that the amount of rainfall has decreased over the years and also the rainfall pattern is irregular, and that these are contributing to the drying up of springs in the area. Increasing population and modern lifestyles create more water requirements (Wang *et al*., 2018). For example, these days traditional toilets

Fig. 10. Multiple use of water resources in Kelabari, Dhanras-1, Surkhet District.

Fig. 11. Source protection methods applied in the mid-hills, Nepal.

are replaced with modern flush toilets, which consume more water. People are also conscious of their personal hygiene and wash their clothes frequently. Although no specific studies have been conducted to explore the reasons behind drying water sources, with the preliminary assessment and on-site observations we present the probable reasons behind the decreasing water supply:

- The infiltration rate is directly proportional to the groundwater recharge (Theis, 1940; Max, 1956). In the case of the mid-hills, due to rugged topography (sloped area), the infiltration rate is low, and when precipitation occurs it pours down the hill. Smooth and continuous precipitation helps to recharge the groundwater aquifers spontaneously. However, in sloped areas, heavy precipitation supports the surface runoff and decreases the infiltration rate, thus reducing the aquifer recharge rate (Jinquan & Renduo, 1994). In recent years, the pattern of precipitation is of short but high intensity rainfall that contributes to the surface runoff, and decreases the recharge rate of the aquifer (Don & Norum, 1967).
- In the past, villagers followed the conventional and traditional patterns of livelihood. For example, it was part of their culture to make wallows, ponds, wells in their surrounding environment for livestock, including buffalo, cow, pig, fish, etc. That not only provides water for livestock but also plays a pivotal role in recharging the groundwater and downstream sources. These days, villagers have abandoned their traditional customs and none of the households make wallows in their surroundings. This could be one reason for the drying up of water sources in the mid-hills.
- Local governments all over the Middle Mountain are investing most of their total budget in expanding the rural road network. However, the roads have been constructed without proper environmental impact assessment. Due to the varied geography, most of the rural roads have been constructed in a spiral way which cuts off and damages the water percolation route.

- The traditional approach of collecting water from a nearby spring source is laborious and time-consuming (Sharma *et al.*, 2016). The water collected in this way also limits the amount people use as a large volume of water cannot be collected at a single time. In the past, most of the spring sources flowed naturally and water was collected directly from the source. However, in modern times, the spring sources have been directly tapped and collected into concrete tanks. The households use PVC pipe to collect water from the spring sources. In doing this, the natural water flow is disrupted which prevents infiltration while flowing through their natural course.

Potential solutions to water scarcity in the rural areas of the mid-hills, Nepal

Water scarcity is becoming a widely perceived issue among the policy makers, politicians, and water scientists in Nepal. In order to restore spring sources in the highly impacted areas, the following activities should be carried out:

- There should be a mechanism to hold the monsoon runoff to increase the infiltration rate. Formation of numerous waterholes in the upstream catchment may support the water recharge in springs and streams.
- There is a need to formulate the water sources restoration strategy at local and national level.
- The management and quality of water resources should be improved, involving communities and including members from Dalits and other marginalized people.
- From the field visit/observation, it was observed that villagers do not have the technical knowledge to use water efficiently. In most of the locality excess water sources are wasted as villagers do not use them. However, if such excess water sources can be collected and stored in a constructed water tank or system then consistent availability of water can be maintained.

Conclusions

Despite being one of the water-rich countries of the world, Nepal has been suffering from water scarcity and a lack of sanitation for many years. In particular, remote and rural areas of the mid-hills do not have access to safe and sustainable drinking water and adequate sanitation and hygiene facilities. The majority of the villages do not have access to pipe water and have to rely on polluted ponds and rivers for cleaning, bathing, and drinking. Due to a lack of sufficient water, people merely use latrines and wash hands before taking food. Hand washing facilities in the home and at school are limited, and in some villages, people are used to taking a bath once a month due to the lack of sufficient water.

An unreliable water supply system has differential impacts in rural communities. In dry periods, women's drudgery increases as they have to walk a long distance to fill a water canister, and also have to face risking their life while fetching water from dug wells. The condition becomes even worse for the Dalits and other marginalized groups as racial discrimination still persists in the rural areas. As compared to elite groups, marginalized groups have fewer livelihoods options and cannot invest additional budget in managing water resources. Consequently, they are compelled to drink water from polluted ponds and rivers.

It can be concluded that the natural springs in the mid-hills of Nepal are a lifeline – providing water to meet the needs of domestic purposes, farms, and livestock. Most of the settlements are far from the rivers and streams, which lie at the bottom of the deep gullies and valleys below, and construction of

drinking water infrastructures could be too expensive or prohibitive in such settlements. In addition, most of the spring sources do not provide a sufficient amount of water as their discharge pattern has changed. For example, the discharge of many springs has lessened, perennial springs have become seasonal, and seasonal springs have dried up. This has resulted in an exodus of villagers, as most of the villages are now empty.

According to locals, the long spell of drought and acute water crisis have compelled them to leave their villages. Dozens of villages in the mid-hills are reeling under the acute shortage of drinking water after most of the local water sources have dried up. The majority of the locals are farmers and are reconsidering their reliance on agriculture, in part due to the lack of adequate water assurance. If freshwater resources are not adequately safeguarded, the livelihood of locals are under threat. Therefore, alternative mitigation options, such as planning land use for potential recharge, introducing micro-to-macro level rainwater harvesting structures, conjunctive use of surface and groundwater resources, and water demand-side management, would be helpful in enabling livelihoods in Nepal's mid-hills.

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Conflict of interest

The authors have not declared any conflict of interests.

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