Journal of
Water, Sanitation & Hygiene for Development

 Journal of Water, Sanitation and Hygiene for Development Vol 11 No 6, 859 doi: 10.2166/washdev.2021.045

Review Paper

Drinking water status in Nepal: an overview in the context of climate change

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ABSTRACT

Although Nepal has made remarkable progress in the drinking water only sector from past few decades, the status of drinking water, in terms of climate change, is poorly documented and thus less known. This review aims to sum up drinking water status in climate change perspectives by reviewing available secondary data from published and gray literature. Climate change, and its impact on the drinking water sector, is undeniable. Though many policies and laws are enforced to address climate change issues, very few policies and laws have incorporated climate change-resilient WASH as a priority. It is of current need to carry out action-based research followed by eco-region wise interventions for adaptation and mitigation of impacts on WASH sector due to climate change.

Key words: climate change, Nepal, WASH, water

HIGHLIGHTS

- This review provides the water, sanitation, and hygiene (WASH) status in Nepal.
- Clear evidence on the climate change impact on drinking water and adaptation is provided via review.

1. INTRODUCTION

The climate in Nepal is greatly affected by the Himalayan mountain range and South Asian monsoon (NCVST 2009). An annual maximum temperature increase of 0.056 °C (DHM 2017) has been experienced; likewise, a 1.8 °C increase in temperature was reported in Nepal between 1975 and 2006 (Karki 2004; Synnott 2012). This rate is higher than the global average which ranged from 0.8 to 1.2 °C (IPCC 2018). About 80% of the precipitation in Nepal pours down in the form of summer monsoon from June to September (DHM 2015). Trend analysis from 1971 to 2014 shows that the pre-monsoon rainfall in the high Himalayan areas has reduced significantly, by 0.74 mm per year (DHM 2017). The South Asian monsoon-dependent water sources of Nepal are strongly influenced by the change in temperature and precipitation with a range of effects such as Glacier melt, snowmelt, rain-fed downstream spring, and groundwater recharge (NCVST 2009). The changing monsoon pattern and the decreasing amount of rainfall have also been evident widely in Nepal (Ahmad *et al.* 2018). There are wide variation of climate within a north-south distance of 200 km in Nepal (Shankar & Shrestha 1985; Chalise 1994; UNEP 2001).

Generally in Nepal, variation in the effect of climate change is considered mainly due to its ecological diversity, which can be distinguished as mountains, hills, and southern plains (known as *Terai*). Assessing impacts of climate change based on eco-region shall be a wise approach. The increasing trend of temperature rate is higher in the mountains compared to other regions. Table 1 demonstrates the status of temperature and precipitation description in different eco-regions. No clear trend is projected for either increase or decrease in mean annual precipitation in Nepal. In terms of spatial distribution, increasing monsoon rainfall trends in eastern and central Nepal were evidenced (DHM 2017). Moreover, the projection indicates an increase in monsoon and post-monsoon rainfall as well as an increase in the intensity of rainfall and a decrease in winter precipitation. Climate change concerns in the Himalayan region are multifaceted – encompassing natural disasters like landslides, floods, and droughts (Barnett *et al.* 2005). Rising temperature and change in precipitation patterns in many parts of

Table 1 | Climatic description of Nepal's eco-regions

Eco-region	Temperature trend	Precipitation trend	Highest total precipitation	Lowest total precipitation
Terai	Increasing Highest 24.35 °C (1999) Lowest 23.03 °C (2011)	Increasing	40,377 mm/year (2007)	19,657 mm/year (2013)
Hills	Increasing Highest 20.79 °C (1999) Lowest 18.58 °C (1986)	Decreasing	59,346 mm/year (2003)	36,012 mm/year (1993)
Mountain	Increasing Highest 16.41 °C (2001) Lowest 12.32 °C (1986)	Decreasing	10,197 mm/year (2007)	5,612 mm/year (2013)

(*Source*: DHM 1984–2013).

the country resulting from climate change are predicted to have an influence on water resource availability in future (Dahal *et al.* 2020). In Nepal, this issue has not been adequately considered in the design of the water system and the focus is more on the supply and coverage side. It is obvious that there are some climate-related challenges meeting the sustainable development goal (SDG) by 2030. Thus, in this context, this review will provide an overview of the trend in the drinking water status of Nepal with climate change perspectives to emphasize safe, sustainable, and climate-resilient water, sanitation, and hygiene (WASH) services.

2. METHODS

2.1. Search criteria

This paper was prepared by reviewing both published articles and gray literature. We reviewed published data on water, sanitation, hygiene, and climate change over the period 1980–2020. Electronic database-based searches were done: Google Scholar, Web of Science, PubMed, and HINARI. The databases were searched using key words: drinking water, sanitation, hygiene, climate change, temperature, precipitation, and Nepal. The searches for published data were confined to literature that was published with abstracts in English. Based on the inclusion criteria for the title and abstract, the full text of the relevant studies was reviewed and analyzed.

Published or unpublished documents, policy briefs, reports, power-point presentations, web content, and primary data from the Government of Nepal (GoN)'s relevant departments like Department of Water Supply and Sewerage Management, Sector Efficiency Improvement Unit, Ministry of Water Supply, and Department of Hydrology and Meteorology were considered as gray literature. Most of the gray literature was in the Nepali language, with a few in English – all kind of literature relevant to our objective was considered for review and, where possible, only the gist of Nepali literature was translated.

2.2. Inclusion and exclusion criteria

Documents were included if: (i) the study was carried out in Nepal, (ii) the sample size was more than 50, (iii) they were policy documents, sectoral reports, status report, and web-based information from authorized GoN's institutions, and (iv) the study provided information on WASH and the climate change scenario of Nepal. In addition, for analyzing meteorological parameters, we purchased meteorological data from the year 1983 to 2013 from the Department of Hydrology and Meteorology. We excluded those studies that primarily focused on engineering aspects of WASH and those climate change-related studies that exclusively focused on climatological parameters (e.g., glaciology and GHGs).

3. RESULTS

3.1. Water supply status in Nepal

Recent data from the Department of Water Supply and Sewerage Management (DWSSM) in 2019 reported, merely 51.69% of the population have piped water coverage and the remaining 48.31% are relying on un-piped locally and privately managed systems like private tubewells (Figure 1). Even if Nepal achieved the water supply related MDG goals, when analyzed by facility type, non-piped coverage has increased from 36% in 2000 to 44% in 2017 (JMP 2019). Similarly when analyzed by the service level, during these 20 years, safely managed improved water supply sources have just decreased from from 24% to only 18% (JMP 2021).

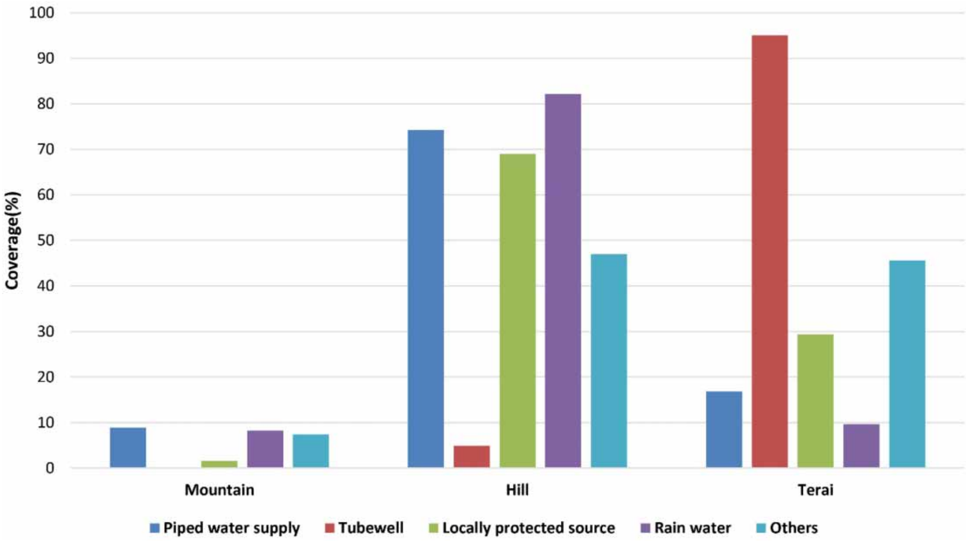

Figure 1 | Water supply type on the basis of eco-regions. (Source: DWSSM 2019).

After achieving the basic water supply target of MDGs (NPC 2016), Nepal has now set its target for the SDGs. The specific SDG 6 targets for the year 2030 include basic water supply coverage to 99%, piped water supply to 90%, and improved sanitation to 95% of households (NPC 2017). Despite the fact that Nepal is trying its best to improve the accessibility and sustainability of water supply, there are disparities in the ecological division level. The water supply and sanitation coverage seem to be unequal though not so noteworthy (Figure 1).

'Poorly functioning systems result in unreliable, insufficient and unsafe water supply, which has direct impact on the proper use and cleanliness of toilets and hand washing' as well as hygiene behaviors (Budhathoki 2019). Nepal's functionality of the water supply schemes is not as expected as the met target of basic water supply. Only 28.13% of drinking water schemes are fully functional (DWSSM 2019). Even if there is a decreasing trend in water supply schemes requiring repairs, reconstruction, and rehabilitation (Figure 2), available data indicate that water supply systems are not in good condition to have a reliable water supply that is sustainable. This also raises concerns on affectivity and sustainability of sanitation and hygiene-related activities.

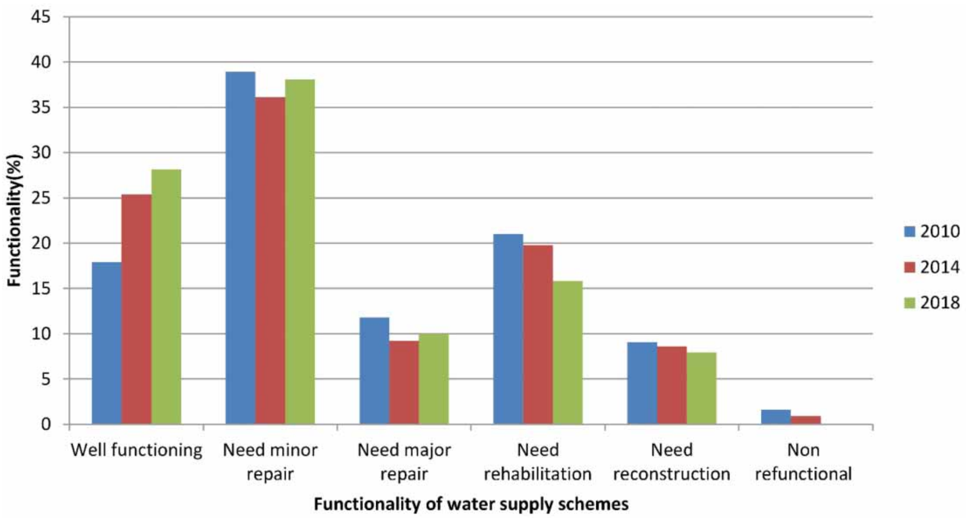

Figure 2 | Comparative status of the functionality of water supply schemes from 2010 to 2018 (*Sources*: NMIP 2010; NMIP 2014; DWSSM 2019).

3.2. Vulnerability of climate change in the water sector

Impacts of climate change are inevitable in almost every sector, nonetheless agriculture and food security, water resource and energy, forest and biodiversity, public health, climate-induced disaster, and urban settlements and infrastructures are directly recognized by the National Adaptation Program of Action (NAPA) for their vulnerability (NAPA 2010). Furthermore, climate change can create multiple impacts on water resources due to alteration of water flow on the rivers and streams (Mishra *et al.* 2018).

Dried spring sources are evident in various parts of the country. For instance, In Tanahu district, depletion of stream, spring and point source water in 10 years (2004 to 2014) was observed by by 20, 34 and 50% retrospectively (RWSSP-WN 2016). Changing rainfall patterns and temperatures, and frequent occurrence of climate-induced disasters, has caused drying and depletion of spring water sources (Adhikari 2018). A spring assessment survey done in 2017 showed that 73.2% of the springs used as drinking water had a reduced flow and 12.2% had dried up over the decade in the watershed of Thulokhola, located in the *Nuwakot* district – Province 3 of Nepal (Poudel & Duex 2017). A similar study in *Melamchi* showed the volume of water in the springs has decreased by 30% in the last decade (Chapagain *et al.* 2017). There is no doubt that the climate change impact on water resources has led to a drinking water shortage in the hilly and mountain areas of Nepal (Gurung *et al.* 2019). It is already evident that because of climate change water shortages will be accelerated, mainly due to the gap between demand and supply. Poor and subsistence farmers will be the hardest hit (Chaulagain 2006), and a compelling reason for the community to opt for an alternate source of water (Gum *et al.* 2009). Here, the alternate source is undeniably an un-improved source with compromised water quality and quantity.

3.3. Climate-induced disasters in the water sector

Due to the varying topography of Nepal, 80% of the population is at risk from natural hazards including floods, landslides, windstorms, hailstorms, fires, earthquakes, and glacial lake outburst floods (GLOFs) (MOHA 2018). Climate change-induced hydro metrological disasters, like floods and droughts, are more likely to increase in future, causing loss of livelihood and property (UNDRR 2019). Increasing temperature due to climate change has caused glaciers to melt rapidly causing more critical floods in lowlands of the Terai, along with slow-onset disasters like heat and cold waves (NAPA 2010; ICIMOD 2013; Kaji *et al.* 2020). The Koshi flood in 2008, the Farwest flood in 2008, and the Terai flood in 2017 are some of the massive flood events that caused severe impact on lives and properties in the lowlands of the Terai (ICIMOD 2013; Chapagain *et al.* 2017). Meanwhile, in the mountains and Himalayan regions, different kinds of climate-induced disasters like GLOFs and landslides are evident. Studies have shown around 21 glacier lakes are at risk of bursting, including six critical GLOFS (NAPA 2010; ICIMOD 2011; Khadka *et al*. 2019). Along with casualties like life, properties, and livelihood loss, climate-induced disasters like floods and landslides have a major impact on WASH infrastructures like water supply pipes, intakes, reservoirs, and sanitation facilities (Oxfam 2008; Ahmad *et al.* 2018). The effect of this could be more devastating in developing countries like Nepal. As a result of such impact, the functionality of the WASH infrastructures is ultimately reduced, leading to compromised WASH behaviors and health issues relating to the same.

3.4. Climate-induced influences in the water sector and its impact on health

Direct and devastating effects of changing climate and its influence on the water sector raise a key concern for public health. Heavy rainfall accelerates flood frequency and intensity in the Terai, excessive runoff and landslides in the hills, and water quality degrades in the mountains. Similarly, with low rainfall, droughts are becoming common in the Terai and a water-scarce condition is created in the hills, as indicated by the drying of water sources. Low rain causes a shift in the snow line in the mountains. Temperature upsurge will also have an impact on water balance and reduce total water availability where subsistence farmers will be the hardest hit (Chaulagain 2006). Water-borne, water-washed, and vector-borne diseases are major issues of public health that come with rising temperature and fluctuating precipitation (Figure 3). The substantially high average temperature (Karki 2004; Dahal 2006; Synnott 2012) certainly makes a favorable environment for disease-causing vectors like *Anopheles* and *Aedes* mosquitos (Rogers & Randolph 2006). Disasters and natural calamities are not to be mistaken for population casualties, but the after effect of those calamities is always the bigger threat and challenge – where again the diseases are the major killers.

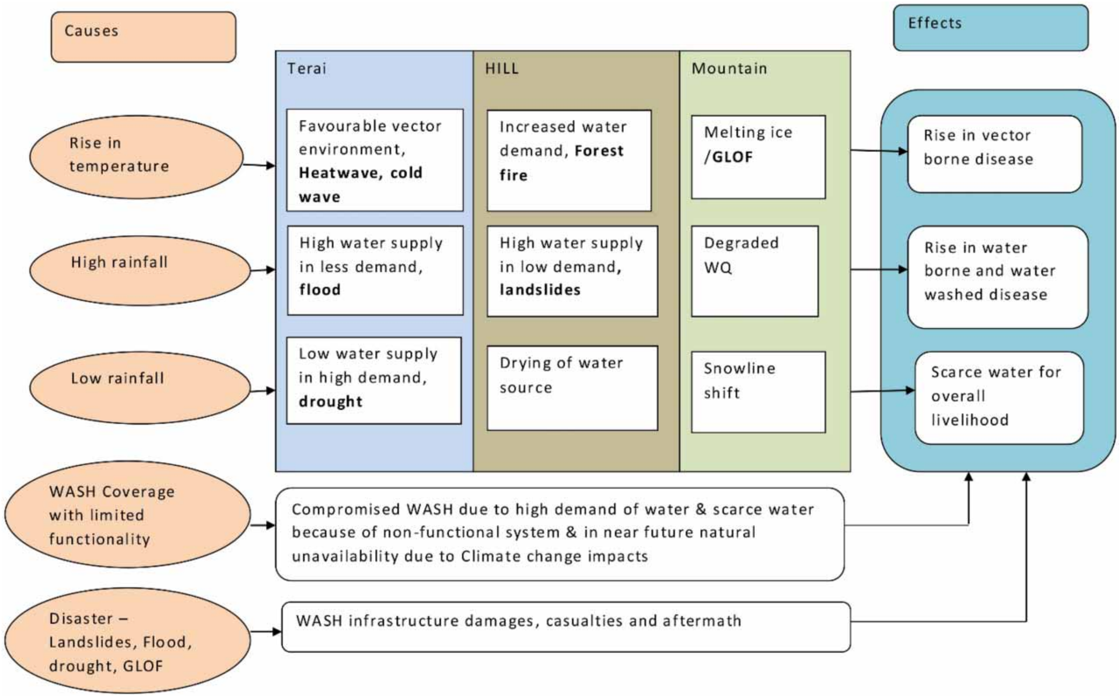

Figure 3 | Cause, effect and health impact of climate change in different eco-regions.

3.5. Adaptation practices in the water sector

In response to the decrease in precipitation and drying up of water sources like springs, local communities have limited adaptation measures and are largely depending on local initiatives such as water tank construction at the source itself, transporting water using pipes, water diversion from other sources, digging deeper wells, and traveling for activities like laundry and fetching drinking water (Poudel & Duex 2017). Besides this, the conservation of lakes and the promotion of rainwater harvesting are some other prevalent adaptation practices to reduce water stress (Patra & Terton 2017). Other local-level adaptation strategies to adapt to prevailing water stresses are water harvesting (small-scale structures), harvesting of rainwater, artificial groundwater recharge, conservation ponds, irrigation channels, and drip water irrigation (Jha 2011; Adhikari 2018). A potential study of rain water harvesting to combat climate change-induced water shortage in the *Arghakhachi* district has concluded that proper rainwater harvesting technology can compensate the immediate water uses such as domestic use, irrigation, and recharging groundwater and contribute to springs (WSSDO 2016). It is evident that the construction of conservation ponds by adapting rainwater harvesting methods has helped to revive dried-up wells and tube wells in Province 3 (Bista 2019). Conservation ponds themselves, being an indigenous practice but reintroduced as adaptive practice in Nepal, and proven as good strategy for storing water and replenishing groundwater reserves (FAO 2015).

Some indigenous practices to adapt hazards are not hazard resistant enough, mainly due to limited resource choices as well as usage, and also due to low economical conditions. Water-related interventions and development practices in Nepal did not consider climate and only focus on coverage in terms of access. A recent approach that seemed promising for reducing the climate change impact on water supply is the Water Safety Plan (WSP). WSP locally addresses disaster risk-reduction and climate change adaptation strategies, along with capacity building at the local level (Baidya *et al.* 2017). WSP is based on hazard analysis and critical point and the multiple barrier approach. The main principle behind this is, if one of the barriers fails, it can be compensated by effectively operating the other barriers, which will reduce the contamination passing through the entire system (DWSSM 2013). DWSS has initiated the implementation of WSPs in all districts since 2008. Even after the implementation of WSP in almost 2,000 water supply schemes, sustainable implementation of WSP itself is affected by factors like depletion of sources, increased disasters, and decreased water quality. Therefore, consideration for climate change was adapted in the same principle of WSP (MoWSS 2017). In Nepal climate resilient water safety plan (CRWSP) has been introduced in few water supply systems, where based on health based targets climate related existing and future hazardous events are also identified and managed accordingly (MoWSS 2017).

3.6. Adaptation practice in the health sector

Nepal recently developed the Health National Adaptation Plan (H-NAP) with a vision of developing climate-resilient health systems for protecting human health from the probable impacts of climate change. The plan aims to develop national frameworks and strategies on climate change and health along with a focus on the health sector and inter-sector collaborations, including research. Furthermore, it may be a milestone in mainstreaming health in the overall NAP and, in the following days, practical evidence of adaptation practices shall be documented.

4. DISCUSSION

Nepal is experiencing the impact of climate change in the early stages as a consequence of climate change directly hitting the Himalayas and freshwater reserves. The majority of national water supply systems are spring sources that are reliant on precipitation. Most of the glaciers are melting, causing increased risk of flooding, and thereby causing not only disaster situations but also affecting the functionality of the WASH-related infrastructures. The water supply coverage and its functional status do not match the water demand, e.g., annual 1.9% sanitation facility growth rate versus stagnant 28% functional water supply coverage. The functionality of WASH structures is largely questionable; the resilience to hold off the climate change impact and climate-induced disasters is yet a far distanced target for Nepal. The emerging climate scenario demands that the prerequisites such as drinking water supply and sanitation facilities be made climate resilient, identifying climate threats, and designing disaster risk-reduction measures.

Though Nepal surpassed the MDG to improve access to basic water supply, the disaggregated data clearly show the inequality of service coverage among eco-regions. Only basic water supply coverage increased, with no clear emphasis on quality and resilience. Hills – being most populous – are the most deprived region for basic water supply and are relying upon unprotected locally managed spring sources. Water supply is inadequate, unreliable, and low quality even in the capital city of Nepal (Katuwal & Bohara 2011). In a context where basic water supply is poor, compromised drinking water quality poses multiple risks to health where climate change plays synergetic effect on human health with a range of effects like water- and vector-borne diseases, climate-induced disasters, and infrastructural damage.

Very few policy documents justify eco-region-specific development plans, programs, and designs for adapting to the changing climate and to be resilient for future climatic conditions. In practice, the climate adaptive programs are only focused on a few sectors – mainly agricultures. The interlinkages between multi-sectors and the multidimensional synergetic effect of climate change on different sectors have not been well identified and addressed at the ground level in Nepal. Social networking and local indigenous adaptations with limited technical know-how within community are the only coping mechanisms against climate change hazards in community.

5. CONCLUSIONS

Climate change effects are evident in the water sector and will surely deteriorate current scenarios. Action-oriented studies on source improvement, rainwater harvesting, and groundwater recharging are essential to understand both qualitative and quantitative aspects of water usage. Given the diversity of Nepal, if climate sensitivity is to be considered, eco-region-based programs and interventions shall be more relevant and realistic. Efforts must be focused on adaptations and climate resilience.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the World Health Organisation (WHO), Nepal, Department of Water Supply, and Sewerage Management for technical support to develop this work.

AUTHOR CONTRIBUTIONS

S.S.M.B. and S.R.P. envisioned the concept of this review. Access to gray literature was facilitated by R.R.P.-S., M.B., and A.G. who designed the review and worked with P.P. and S.P.P. to develop the initial draft which was then reviewed and finalized by all aforementioned authors.

CONFLICT OF INTEREST

The authors' views expressed in this publication are personal and do not necessarily reflect the views and policies of the organizations they represent. The authors declare no conflict of interest.

FUNDING

This research received no external funding.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

Adhikari, S. 2018 Drought impact and adaptation strategies in the mid-hill farming system of western Nepal. *Environments* **5** (9), 101. https://doi.org/10.3390/environments5090101.

Ahmad, T., Shrestha, A. M., Das, S. K., Darnal, K., Neupane, R., Pote, B., Shrestha, R. & Paudel, D. 2018 *Impact of Climate Change on WASH Services: A Case from Nepal*.

Baidya, M., Sharma, S., Kayastha, R. & Poudel, P. 2017 Climate resilience and water, sanitation and hygiene (WASH WASH) interventions in Nepal. *International Journal of Environment Science* **6** (12), 14–22.

Barnett, T., Adam, J. & Lettenmaier, D. 2005 Potential impacts of a warming climate on water availability in snow-dominated regions. *Nature* **438**, 303–309. https://doi.org/10.1038/nature04141.

Bista, P. 2019 *Construction of Conservation Ponds in Province 3 Shows Positive Result*. *The Kathmandu Post*, 29 August 2019. Available from: https://kathmandupost.com/province-no-3/2019/08/29/construction-of-conservation-ponds-in-province-3-shows-positive-result (accessed 20 June 2020).

Budhathoki, C. B. 2019 Water supply, sanitation and hygiene situation in Nepal: a review. *Journal of Health Promotion* **7**, 65–76.

Chalise, S. R. 1994 Mountain environments and climate change in the Hindu Kush-Himalayas. In: *Mountain Environments in Changing Climate* (M. Beniston, ed.), Routledge, London, pp. 382–404.

Chapagain, S. P., Ghimire, M. & Shrestha, S. 2017 Status of natural springs in the Melamchi region of the Nepal Himalayas in the context of climate change. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-017-0036-4.

Chaulagain, N. P. 2006 *Impacts of Climate Change on Water Resources of Nepal the Physical and Socioeconomic Dimensions Gutachter*. University of Flensburg, Germany.

Dahal, P., Shrestha, M. L., Panthi, J. & Pradhananga, D. 2020 Modeling the future impacts of climate change on water availability in the Karnali River Basin of Nepal Himalaya. *Environmental Research* **185**, 109430.

DHM 2015 *Study of Climate and Climatic Variation over Nepal Submitted by: Nepal Hydrological and Meteorological*. Available from: http://www.dhm.gov.np/uploads/climatic/47171194Climate and Climatic variability of Nepal-2015.pdf.

DHM 2017 *Observed Climate Trend Analysis in the Districts and Physiographic Zones of Nepal*. Government of Nepal Ministry of Population and Environment, Kathmandu.

DWSSM 2013 *Water Safety Plan Hand Book Nepal*.

DWSSM 2019 *Drinking Water and Sanitation Status – 2075 B.S*. Government of Nepal.

FAO 2015 *Water Conservation Ponds in Nepal*. Available from: https://www.doc-developpement-durable.org/file/eau/retenuesbarrages/Water%20conservation%20ponds%20in%20Nepal_TECA.pdf.

Gum, W., Singh, P. M. & Emmett, B. 2009 *'Even the Himalayas Have Stopped Smiling': Climate Change, Poverty and Adaptation in Nepal*.

Gurung, A., Adhikari, S., Chauhan, R., Thakuri, S., Nakarmi, S., Ghale, S., Dangol, S. B. & Rijal, D. 2019 Water crises in a water-rich country: case studies from rural watersheds of Nepal's mid-hills. *Water Policy* **21** (4), 826–847.

ICIMOD 2011 *Glacial Lakes and Glacial Lake Outburst Floods*. Integrated Centre for International Mountain Development, Kathmandu, Nepal.

ICIMOD 2013 Flooding and inundation in Nepal Terai: issues and concerns. *Hydro Nepal* **12**, 59–65.

IPCC 2018 Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change. https://doi.org/10.1038/291285a0.

Jha, K. 2011 Climate change: impact, adaptation and vulnerability in the water supply of Kathmandu valley. *WIT Transactions on Ecology and the Environment* **155**, 563–574. https://doi.org/10.2495/SC120471.

JMP 2019 *Progress on Household Drinking Water, Sanitation and Hygiene I 2000-2017 with Special Focus on Inequalitie*. United Nations Children's Fund (UNICEF) and World Health Organization (WHO), New York.

JMP 2021 *Progress on Household Drinking Water, Sanitation and Hygiene 2000-2020: Five Years into the SDGs*. World Health Organization (WHO), Geneva and the United Nations Children's Fund (UNICEF).

Kaji, N., Paton, D., Lassa, A. J. & Zander, K. K. 2020 Assessing farmers' preparedness to cope with the impacts of multiple climate change-related hazards in the Terai lowlands of Nepal. *International Journal of Disaster Risk Reduction* **49**, 101656. https://doi.org/10.1016/j.ijdrr.2020.101656.

Karki, M. B. 2004 Nepal's experience in climate change issues. In: *14th Asia Pacific Seminar on Climate Change*, Australia.

Katuwal, H. & Bohara, A. K. 2011 Coping with poor water supplies: empirical evidence from Kathmandu, Nepal. *Journal of Water and Health* **9** (1), 143–158.

Khadka, N., Zhang, G. & Chen, W. 2019 The state of six dangerous glacial lakes in the Nepalese Himalaya. *Terrestrial Atmospheric and Ocean Sciences* **30** (1), 63–72. https://doi.org/10.3319/TAO.2018.09.28.03.

Mishra, Y., Tai, N., Babel, M. S., Saeawut, N. & Ochi, S. 2018 Impact of climate change on water resources of the Bheri river basin, Nepal. *Water*, 1–21. https://doi.org/10.3390/w10020220.

MOHA 2018 *Nepal Disaster Report 2017: The Road to Sendai*. Ministry of Home Affairs, Government of Nepal, Kathmandu.

MoWSS 2017 *Climate Resilient Water Safety Plans Guideline Rural Water Supply System*. Government of Nepal, Ministry of Water Supply and Sanitation, Kathmandu. Available from: https://www.who.int/globalchange/resources/wash-toolkit/rural-water-supply-system.pdf.

NAPA 2010 *Climate Change Vulnerability Mapping for Nepal National Adaptation Programme of Action*. Government of Nepal, Ministry of Environment, Kathmandu.

NCVST 2009 *Vulnerability Through the Eyes of the Vulnerable Climate Change Induced Uncertainties and Nepal's Development Predicaments*. Institute of Social and Environment Transition – Nepal (ISET-N).

NMIP 2010 *Nationwide Coverage and Functionality Status of Water Supply and Sanitation in Nepal* Ministry of Urban Development, Kathmandu.

NMIP 2014 *Nationwide Coverage and Functionality Status of Water Supply and Sanitation in Nepal*. Ministry of Urban Development, Kathmandu.

NPC 2016 *Sustainable Development Goals Status and Roadmap 2016–2030*. National Planning Commission, Kathmandu

NPC 2017 *Nepal's Sustainable Development Goals Baseline Report*. National Planning Commission, Kathmandu.

Oxfam 2008 *Evaluation of River Basin Programme in Nepal*. GB, UK.

Patra, J. & Terton, A. 2017 Review of current and planned adaptation action in Nepal, pp. 1–92. Available from: www.idrc.ca/caria no.

Poudel, D. & Duex, W. T. 2017 Vanishing springs in Nepalese mountains: assessment of water sources, farmers' perceptions, and climate change adaptation. *Mountain Research and Development* **37** (1), 35. https://doi.org/10.1659/mrd-journal-d-16-00039.1.

Rogers, D. J. & Randolph, S. E. 2006 Climate change and vector-borne diseases. *Advances in Parasitology* **62**, 345–381.

RWSSP-WN 2016 Analysis and Mapping of Climate and Source Yield in Tanahun District. Research Brief. Vol. 3. Available from: www.rwsspwn.org.np.

Shankar, K. & Shrestha, B. P. 1985 Climate. In: *Nepal-Nature's Paradise: Insight Into Diverse Facets of Topography, Flora and Ecology* (Majupuria, T. C., ed.). White Lotus Co. Ltd, Bangkok, pp. 39–44.

Synnott, P. 2012 *Climate Change, Agriculture and Food Security in Nepal Developing Adaptation Strategies and Cultivating Resilience*.

UNDRR 2019 *Disaster Risk Reduction in Nepal – Status Report 2019*. United Nations Office for Disaster Risk Reduction (UNDRR), Thailand.

UNEP 2001 *Nepal: State of the Environment*. United Nations Environment Programme, Pathum Thani.

WSSDO 2016 *Study of Potentiality of Rainwater Harvesting System as a Climate Change Adaptation Option in Arghamaidan, Arghakhanchi District*. Government of Nepal, Ministry of Water Supply and Sanitation.

First received 8 March 2021; accepted in revised form 1 September 2021. Available online 21 September 2021