Research Article

Drinking Water Sources in Bumthang Dzongkhag: Preliminary Assessment and Community Perceptions

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Abstract

This assessment documents the location and status of community drinking water sources in Bumthang Dzongkhag (district). There is a need for such baseline information to assess future trends of drinking water sources in the Dzongkhag in relation to factors associated for its production such as forest degradation in the watersheds and climate change. A total of 220 water sources, supporting 2379 households were identified through field visits and community consultations. The Study indicated that 61% of water sources are located in blue pine forest, 30% in mixed conifer forest, 7% in land without woody vegetation, and 2% in fir forest. One hundred and ninety households have their water sources in degraded forest. The reasons for forest degradation within 100m of the water sources was ascribed by communities mainly to tree harvesting (42%), non-wood forest product collection (43%), and open grazing (15%).

However, it was not clear whether forest degradation had resulted in a reduction in water quality.

The communities in the areas assessed reported inadequate quantity of drinking water, especially from November to January, associated with drying of water sources.

The research attempts to identify the root causes of the degradation of water sources through social methods, which will require

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conformity through ecological research. The extension of the study to other *dzongkhags*, in order to enhance planning of drinking water safety and security while maintaining the health of the watersheds, is discussed. The information generated from this Study will contribute to the formulation of relevant watershed management interventions and inform policymakers in decisions related to water resource planning and management.

Key Words: Water Sources; Spring Water; Local Communities; Drinking Water; Forest Degradation; Climate Change; Bumthang.

Introduction

Mountains are the source of fresh water for a large proportion of the world's population (Viviroli & Weingartner 2004; cited in Merz et al. 2003; Vivorali 2011). The ecologically fragile watersheds in the Himalayas play an important role in ensuring food, water, and energy security within the region and for the users of the downstream river basins (Rasul 2014). Water from the mountains forms the basis of hydropower generation, agriculture practices, and other livelihood activities to downstream communities. It is, therefore, critical to conserve and manage the Himalayan regions for a sustainable flow of ecosystem services and to strike a balance between conservation and livelihood activities including building resilience in the face of changing climate.

Freshwater sources for local use in the region are drawn from lakes and ponds (Sharma et al. 2005) as well as streams and springs. However, water scarcity and limited access to high-quality water for communities caused by either decreased discharge or complete drying of water sources is widely reported across the Himalayan regions of Sikkim, Kumaon, and the hill towns of Darjeeling and Shillong (GoM 2005, Merz nd). Tiwari and Joshi (2014) also reported that the springs have either dried or have become seasonal in Upper Kosi Catchment in Kumaon Himalaya, India. The reasons for the drying of water sources are postulated as being due to changes in land use patterns attributed to deforestation and forest degradation or climate change. It is argued that deforestation and accelerated surface erosion have disturbed the hydrological regimes, which results in drying springs, reduced discharge of rivers as has been observed in the Gaula river watershed of the Kumaun Himalaya (Valdiya & Bartarya 1989). Bhutan consists of a mosaic of watersheds because of its physiographic positions (WMD 2010, 2011). The water resources in the country include glaciers, wetlands, rivers, and groundwater reservoirs. Glaciers and freshwater lakes form major natural reservoirs and freshwater sources (RGoB 2016). The high forest cover of the country allows the recharge of groundwater which ensures sustainability and discharge of fresh water sources in the form of springs and streams. In Bhutan, springs and streams are widely used for drinking, household consumption, and irrigation (RGoB 2016), while groundwater is not being exploited directly. Various lessons and experiences from watershed management planning in Bhutan and globally indicated that identification of drivers of environmental degradation that lead to the diminished provision of watershed services are important to formulate relevant interventions (FAO 2017). The various drivers of environmental degradation for Lower Choekhor watershed management plan (of which the area falls within the study area) are forest degradation, soil, and water pollution (Wangchuk et al. 2017). Agriculture cropping trends indicate increases in the cultivation of paddy, horticulture, and other commercial vegetables, most of which depend on irrigation (Wangchuk et al. 2017). The cases of drying or decreased discharge of water sources are also raised as an issue of concern during the process of watershed management planning and as well as have been reported in different media across the country. A similar report was received by the Dzongkhag Forestry Sector, Bumthang. However, neither the Dzongkhag nor any of the *gewogs* (blocks) in Bumthang have firsthand information on the status of water sources in Bumthang.

An assessment of water resources in the Dzongkhag is of value because of changing agricultural practices and increases in urban and rural populations. This Study is limited to survey and mapping of water sources and assessing the condition of the water sources. It is intended to create a baseline of number and location of existing water sources (both in use and potential for future use) by the communities. Therefore, the Study was carried out with the objectives to:

- Identify and map different types of drinking water sources and establish the degree of community dependence on water sources
- Document and explore reasons for the degradation of different forest ecosystems around the water sources.
- Assess the condition and safety (water quality) of water sources with the consideration of different proxy indicators
- Identify the community's perception on the seasonal variation in the water discharge of different types of water sources.

For the purpose of this Study, water sources emanating from a single source and tapped directly from that source were considered to be "spring" while running water with more than one source was considered to be a "stream".

Methods

Study area

The Study was conducted in the whole of Bumthang Dzongkhag, covering an area of 2667.76 sq. km and consisting of four *gewogs* (Choekhor, Chumey, Ura and Tang,). The elevation ranges from 2400 to 6000 masl. The Dzongkhag has a forest cover of 59.3% with the dominant species of blue pine, fir, spruce, and rhododendron (Figure. 1). The total population in the Dzongkhag is 18,965 (BD 2017) and the main sources of income are cash crops like potato, livestock, and tourism (NSB 2010, BD 2013).

Surveys

The water sources were the sampling units for collection of biophysical data; questionnaire surveys were used for the collection of demographic information. The water sources currently in use and earmarked for use in the near future were identified through community consultation meetings at *chewog* (sub-block) level with the respective head of the *chewogs* (*chewog tshokpas*) and community water caretakers. The *gewog* forestry extension agents were trained on the use of data collection procedures to avoid inconsistency in the data collection and use of GPS in the mapping of waters sources. The *gewog* forestry extension agents along with other key informants (local village heads and water caretakers) surveyed the water sources within their respective areas.

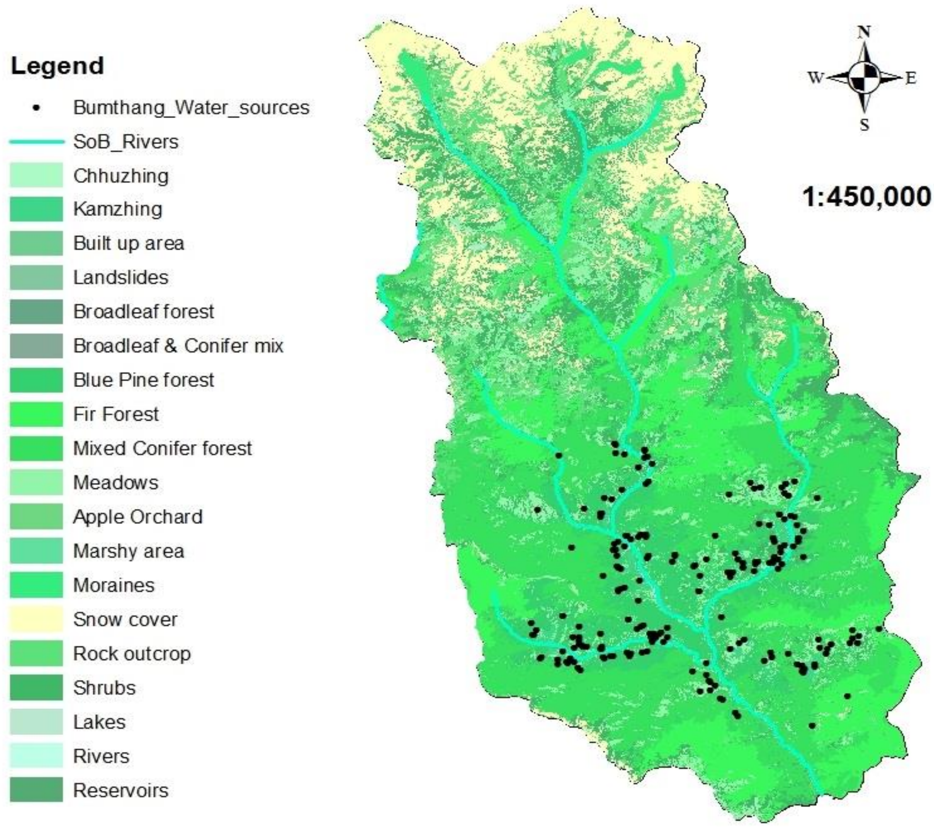

Figure 1: The distribution of water sources corresponding to different land use types. The water sources are mostly in blue pine forests and are confined to the lower part of drainage catchments

The GPS coordinates of the different types of water sources were recorded and mapped on the Dzongkhag map (Figure. 1). Information on the intensity of the users' dependency on a particular water source in terms of number of households and population was gathered through household surveys, community consultations, and confirmed through respective village heads or water caretakers.

The forest types within the periphery of 100m of the water sources were categorized as blue pine, fir, mixed conifer zone, and land without woody vegetation. The meadows, shrubs, agricultural fields, and other barren lands were considered under the category of land without woody vegetation. The information on the forest types and causes of forest degradation surrounding the water sources through physical observations at each water source was conducted by forestry technical team with support from the village heads.

The condition of water sources was categorized by taking the signs of forest degradation as proxy indicators while information on the water quality was garnered through questionnaire surveys with the water user communities as shown in Table 1. (These included: open grazing, NWFP collection, tree harvesting, and water source protection (fencing & tanks). The water source condition was categorized as 'very good', 'good', or 'poor'.

Table 1: Methods applied to categorize the condition of water sources and water quality as 'very good", "good", and "poor". The physical observation of the proxy indicators (PI) for assessment of the condition of water sources were conducted within the periphery of 100ms

Parameters	Proxy indicators (PI)	Category of parameters		
		Very good	Good	Poor
The condition of water sources	i. NWFP collection ii. Tree harvesting iii. Open livestock grazing	All PIs absent	One PI present	Two or more PIs
Water quality	i. Turbidity ii. Incidences of water-borne diseases in the recent year	Both PIs absent	One PI present	Both PIs present

Water quality considered physical parameters (turbidity) of the water and any incidences of water-borne diseases being experienced by the communities. If the communities received muddy water any season, it was considered as turbid water.

Seasonal fluctuations in the water discharge of the water sources were assessed based on the perspective of the communities and heads of the respective *chewogs*. Water discharge information was not obtained from actual measurement because of time constraints as this would require multiple observations across all seasons.

Data processing and analysis

GPS data was processed using ArcMap 9.3.1. and water sources were mapped on the Bumthang Dzongkhag map. The information collected on water sources were computed in MS Excel spreadsheet and SPSS V.23 for statistical analysis purposes. The data was collated for each of the four *gewogs* and inferences were drawn within a particular *gewog* wherever possible. Most of the results are presented in graphical form to allow easy comparisons across different *gewogs* and within a *gewog*.

Results

Water source types and beneficiaries

A total of 220 drinking water sources were recorded, including springs and streams in use by the communities. For the Bumthang Dzongkhag alone, a total of 2,379 households depend on those 220 sources for drinking, irrigation, and other domestic purposes, with 78% dependence on spring water and 22% dependence on streams. Individual water sources support between one and 244 households. The average dependence on water sources across Bumthang Dzongkhag was around 11 households per single water source.

In Choekhor, although the *gewog* had many springs, 65% of the households depended on streams for their water needs. Chumey Gewog had the maximum number of stream water sources with a dependency of almost similar proportions on streams (45%) and springs (55%). In Tang Gewog, most households depend on springs. In Ura Gewog, where there are almost equal numbers of springs and streams, there was a similar level of dependency on each water source types (45% on springs & 55% on streams) (Figure. 2).

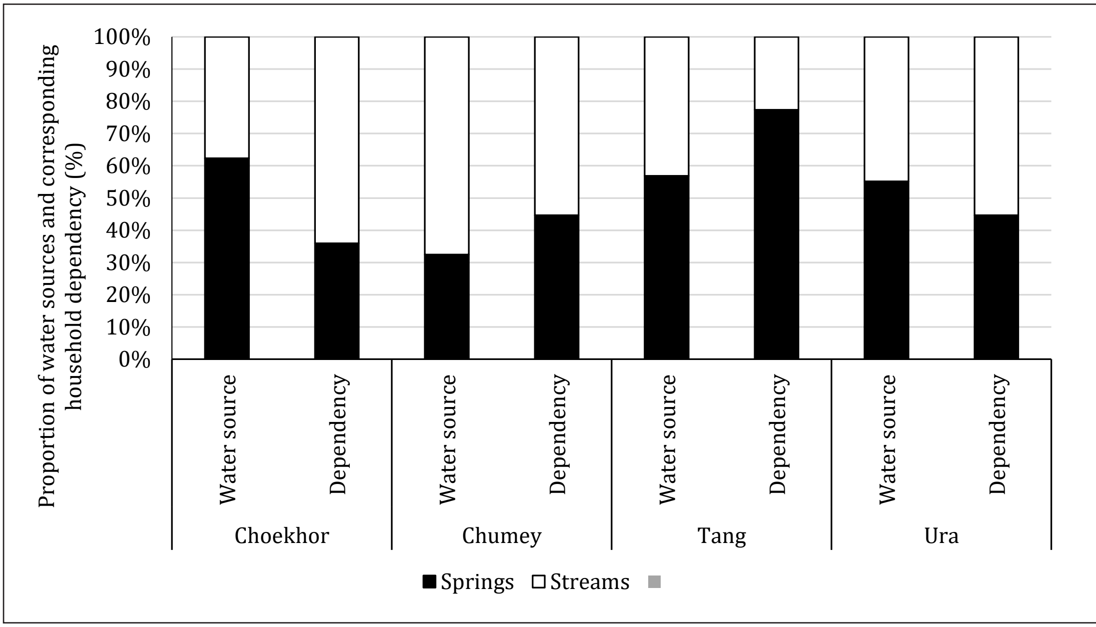

Figure 2: The proportions of springs and stream water sources and their corresponding dependency by households (Physical observation at the site and household survey)

Chi-squared test (α = 0.05) indicated that the occurrence of the water sources across different *gewogs* are significantly different from each other ($\chi 2 = 11.56$; p=.009). Chumey Gewog has the maximum numbers (69) of water sources, while Ura is the *gewog* with a minimum number (28) of water sources being observed. In terms of dependence, the Chi-squared test (α = 0.05) indicated that dependence on water sources across different *gewogs* did not differ significantly from each other ($\chi 2 = 107.43$; p=.0078).

Location of water sources in different forest ecosystem types

The forests types of Choekhor Gewog consists of mixed conifers (26.12%), fir forests (15.54%), blue pine (9.44%), and a negligible quantity of chir pine and broadleaved forests. Chumey Gewog consists of mixed conifers (26.31%), fir forests (15.65%), blue pine (9.50%), and very negligible quantity of broadleaved and chir pine. The Tang Gewog consists of only three forest types of which are mixed conifers (26.13%), fir (15.54%), and blue pine (9.44%). Ura Gewog consists of mixed conifers (26.42%), fir (15.72%), blue pine (9.51%), and insignificant quantity of broadleaved forests.

The forest types around the water sources were assessed. The majority of the water sources in Bumthang Dzongkhag are in blue pine forests (61%), followed by 30% in mixed conifer forest while only 2% are found in fir forests. The results also indicate that 7% of water sources are in land devoid of woody vegetation. Choekhor Gewog has the maximum number of water sources with the least diverse representation of forest types while Ura Gewog has the least number of water sources with most diverse forest types. In Chumey Gewog, none of the water sources are in land without woody vegetation. However, the water sources in degraded forests support 190 households.

Most water sources in Choekhor Gewog are in blue pine with the remainder in mixed conifer. There are no water sources in the fir zone or in land without vegetation. In Chumey, almost equal number of water sources are in the blue pine and mixed conifer zones, and few sources are in land without woody vegetation. Most water sources in Tang Gewog are in the blue pine zone, followed by barren land and mixed conifer. Ura Gewog has the fewest water sources of all *gewogs* with most of them (10 of 21) in mixed conifer, followed by fir and land deprived of woody vegetation. Unlike other *gewogs*, the fewest water sources in Ura are in the blue pine zone (Figure. 3).

A Chi-squared test (α = 0.05) indicated that the occurrence of the water sources is associated with different forest ecosystem types ($\chi 2$ = 21.18; $p \leq 0.001$). The maximum of 133 of the 220 water sources (of which 116 are springs and 17 streams) was observed in blue pine forests, while the minimum of 5 water sources occurred in fir forests. Water sources are more likely to occur in blue pine forests and mixed conifer than land without woody vegetation and fir forest.

Forest degradation around the water sources

Forest degradation was identified to have occurred around many of the water sources. This was attributed to the collection of NWFPs, harvesting of timber and open grazing of livestock in the periphery of the water sources. However, the extent of these degrading factors tends to differ from one water source to another. While grazing tends to be common, the signs of a collection of NWFPs and timber were also evident. Signs of NWFP collection and incidences of tree harvesting were observed for 43% and 42% of the water sources respectively (Figure. 4) while open grazing occurs only around 15% of the water sources.

Condition of water sources and quality of water

Figure 5 illustrates the water source condition and water quality for all four *gewogs*. The results revealed a similar pattern in the condition of water sources across all *gewogs*, with most water sources observed to be in

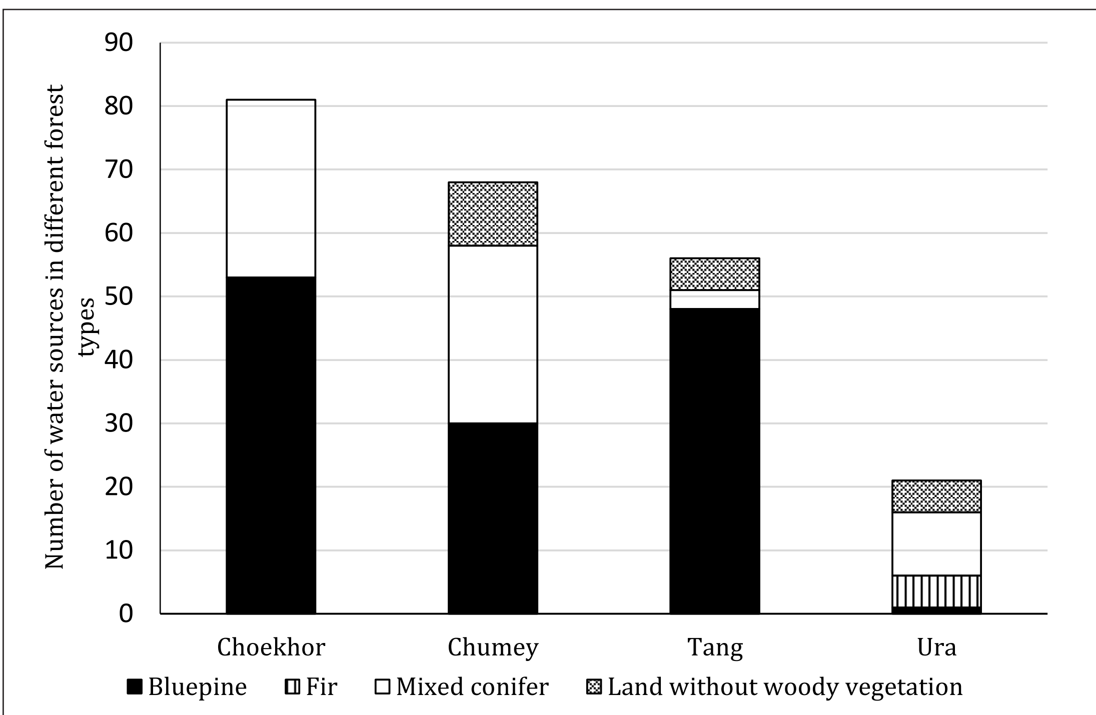

Figure 3: Location of water sources in different forest types (physical survey)

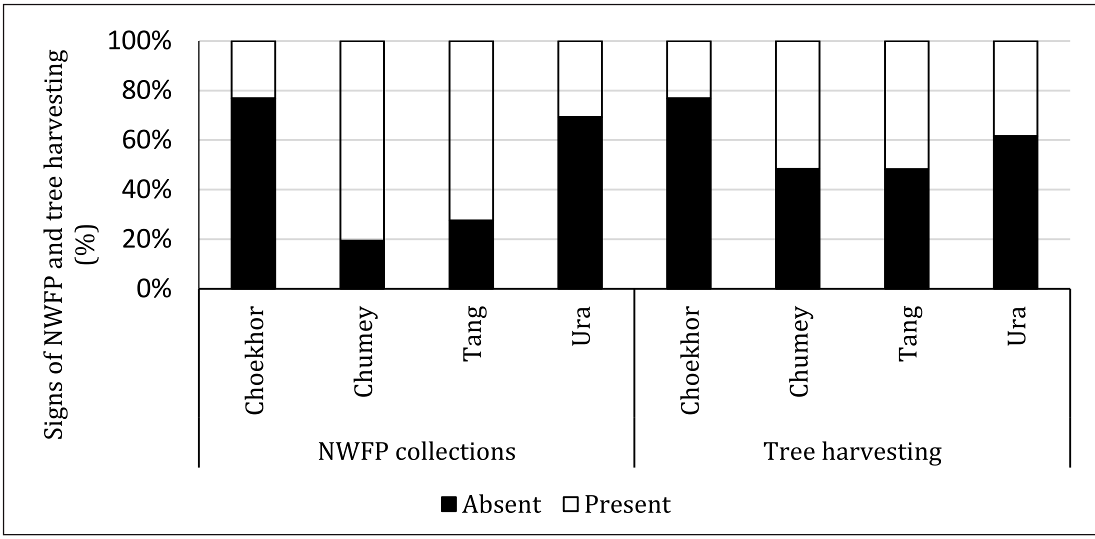

Figure 4: The signs of forest degradation (physical observation)

'good' (109), followed by 'very good' (83) and 'poor' (28) conditions respectively. Choekhor Gewog has almost equal numbers of water sources in 'good' (27) and 'very good' (26) conditions with few 'poor' (5) water sources. Chumey and Ura show similar patterns in the number of water source between 'good' to 'very good' and 'very good' to 'poor' conditions.

In terms of water quality, Choekhor (good=39, very good=18, poor=1), Chumey (goo=46, very good=15, poor=8), and Tang (good=41,

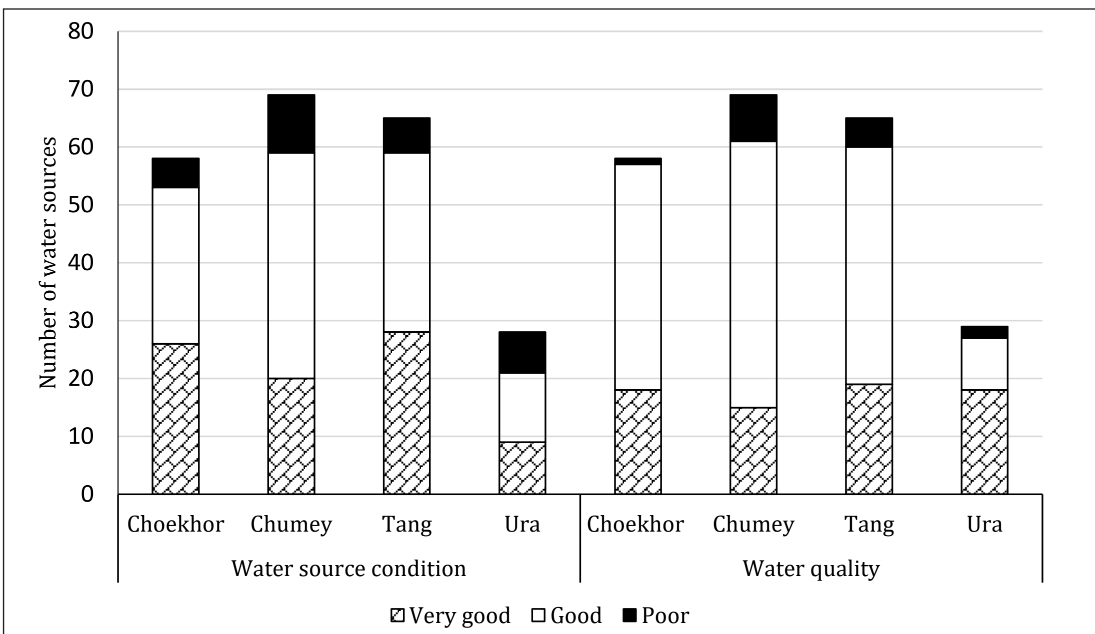

Figure 5: The condition of water sources (physical observation) and water quality (community questionnaire survey)

very good=19, poor=5) *gewogs* show a similar pattern with most sources rated as 'good' and 'very good' and few rated as 'poor'. However, most water sources in Ura Gewog are rated as 'very good' (19), and very few are rated as 'poor' (2).

Water discharge

Overall, 59% of the water sources in the Dzongkhag showed no seasonal change in water discharge, and for most of these, the water sources were springs. Most of the water sources which showed changes in seasonal discharge (41% of the total) were streams. By and large, springs in the Dzongkhag are less susceptible to seasonal variations in discharge than streams. However, Ura Gewog reported of considerable change in water discharge despite being the *gewog* with a maximum number of spring water sources. Similarly, most water sources in Choekhor Gewog show no change in water discharge across different seasons. For those water sources which showed a seasonal change in discharge (predominantly streams), the maximum discharge was reported in summer (associated with monsoon rains) while minimum discharge was reported in winter (Figure. 6 & details in Table 2).

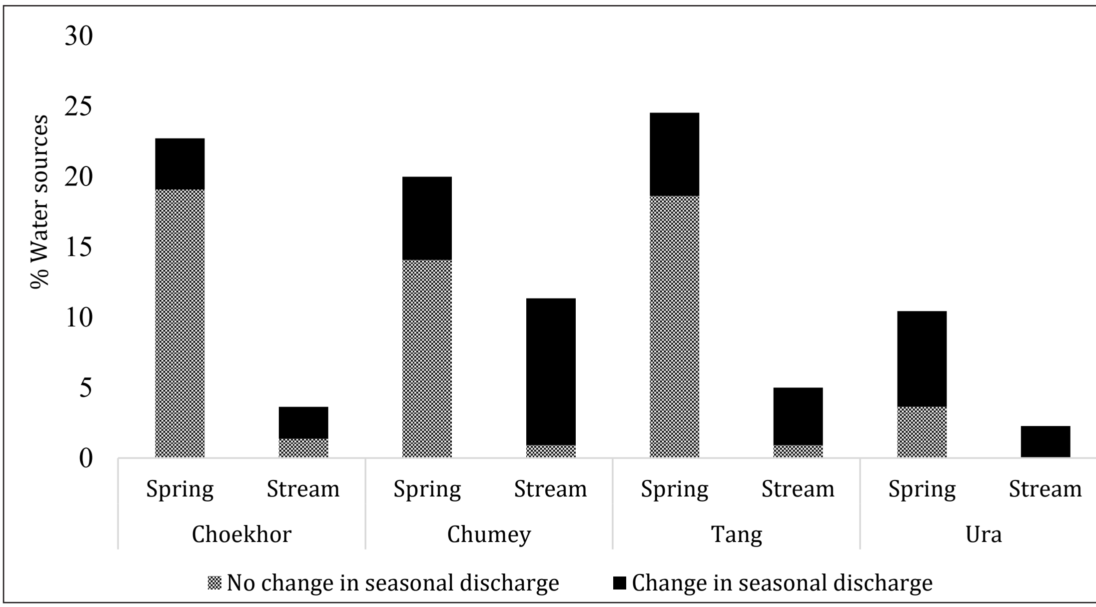

Figure 6: The status of water discharge (community perceptions)

Table 2: Discharge fluctuations of water sources in Bumthang dzongkhag (Community perceptions)

Gewog	Discharge fluctuations of water sources (in terms of no. of water source)				
	Spring	**Summer**	**Winter**	**Remain same**	**Total**
Choekhor	0	16	0	42	58
Chumey	0	36	0	33	69
Tang	2	21	2	42	65
Ura	0	20	0	8	28
Total	2	93	2	125	220
% of the water sources	*0.90*	*42.27*	*0.90*	*56.81*	*100*

Discussion and conclusion

This Study documented the location and other details of 220 drinking water sources in Bumthang Dzongkhag, which will serve as the baseline data for future studies to authenticate any incidences of drying up water sources. A study documenting these surface water sources at a single point in time is difficult to ascertain if there are any incidences of drying up of water sources and if so the probable causes of drying up water sources. Therefore, a study on the causes of the drying of the springs needs to be conducted by identifying it as one prominent activity within a watershed management plan. On the other hand, similar surveys can be conducted after an interval of several years to find out if any sources have dried, and if there has been any change in dependence intensity of the communities or any new water source being accessed by communities.

The drying incidences of springs and water scarcity may worsen with the impacts of climate change which are increasingly felt in Bhutan (Choden & Norbu 2013). In the last 20 years (1996-2015), the temperature in Bumthang has increased by 0.087°Celcius (Figure. 7). The increasing trends of temperature may lead to disturbances in the different components of watersheds and affect the quality of watershed services. The Climate Change Vulnerability Assessment (WCNP & WWF 2011) in WCNP indicated that communities are already experiencing higher temperatures, more erratic rainfall patterns, less snowfall, and changes in the intensity of frost. Changes in climate in Chamkhar Valley are also being perceived by the communities such as warmer winters and reduced snowfall, which is correlated to hydro-meteorological data (Dorji 2014). In Punakha, the availability of water for irrigation is attributed to decrease in the quantity of monsoon rains as perceived by the communities and in conformity with rainfall data from the weather stations (Kusters & Wangdi 2013). The impacts of climate change on precipitation patterns coupled with other anthropogenic causes and the problem of dying springs is being increasingly felt across the Himalayan region (Tambe et al. 2011). However, various technical expertise from the field of hydrology and geology will be required to understand the causes and recommend measures to revive drying water sources. The study could also include any incidences of new evolvement of springs or other water sources in other parts of the region. In Nepal, springs have either dried up, new springs emerged, or the discharge of the existing springs changed considerably after the 7.6 magnitude earthquake (ICIMOD 2015). However, the causes may vary from other regions to Bhutan. In defining the future water resources in the mountains, research should consider the combined drivers of land use change, population growth, and economic development alongside climate change (Viviroli et al. 2011).

In the future, the dependence on the available water sources can increase with the rise in users and population growth. Global climate change will lead to the increase in such incidences, which may require adaptation plans and programs. The availability of the water sources will affect the livelihoods of the communities and their capacity to adapt to the impacts of climate change. Similar to other regions of Himalaya (Merz et al. 2003, Singh et al. 2014), spring is the main water source for the communities than streams for drinking and other domestic consumption. However, it is also likely that the settlements are also close to springs, similar to the location of villages in India driven by the availability of springs as per archaeological study (Spechler & Donna 1995). Spring water is likely to be least affected in terms of quality or less likely to be contaminated by anthropogenic activities as most of the springs are tapped at the source. The study on the water quality of five springs

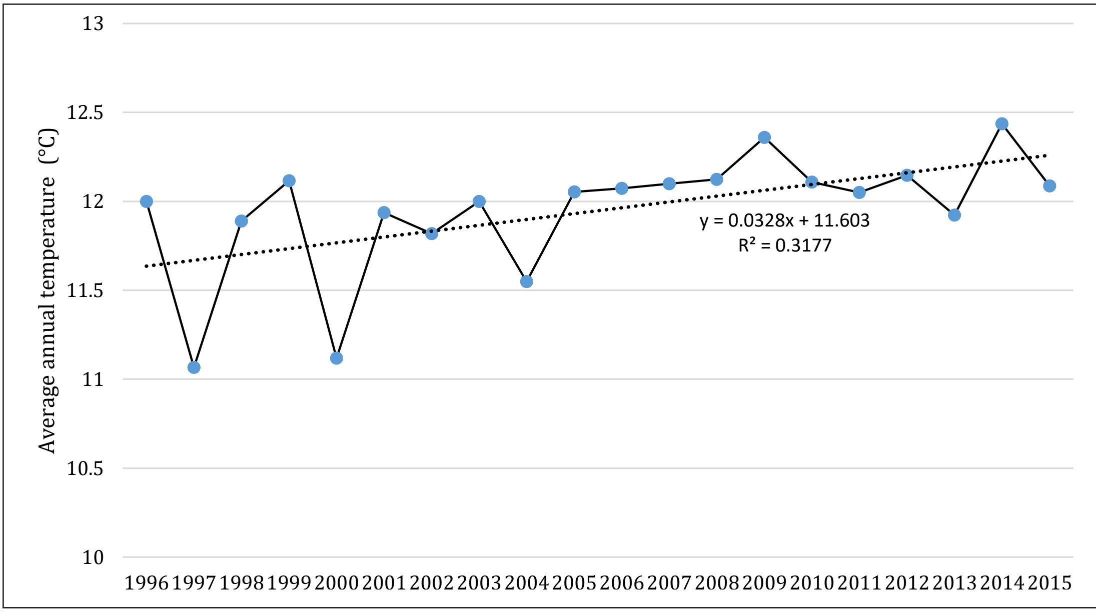

Figure 7: Temperature trends in Bumthang in the last 20 years (Department of Hydromet Services, MoEA)

carried out in Srinagar valley in Uttarakhand, India, using six water quality parameters also indicated that springs are suitable for drinking and other household consumption for the people in the region (Singh et al. 2014). However, similar studies may need to be carried out even in Bhutan. Considering the community preferences, discharge fluctuations, and water quality factors, spring water tends to be the most reliable long-term water source for drinking and another household uses in Bumthang Dzongkhag.

Overall, most water sources are located in blue pine forests which do not necessarily indicate that blue pine favours infiltration of rainwater for recharging of groundwater. It could also be deduced that most settlements are within or adjacent to the blue pine zone. It can also be argued that the discharge outlets of the water sources are mostly in the blue pine zone because this zone is at a lower elevation than the fir zone and is more likely to be a site of discharge because of underlying hydrogeological and geomorphic characteristics of the watersheds. As is evident in Figure. 6, most water sources recorded in this Study are confined to the lower slopes of the watershed in the vicinity of settlements. However, the presence of water sources in the upper parts of the watershed was not determined as the area tends to be inaccessible. Further study on recharge area zonation and forest types may be required. Moreover, Ura Gewog lies in an alpine zone where fir is the dominant species.

Degradation around water sources can contribute to contamination and deterioration of the water quality which in turn can affect the health of user communities. Similarly, the degradation of forest around water sources can also affect discharge depending on the location of the recharge zone. The forest cover can influence the level of groundwater, wells, springs, and water quality (Hamilton 2005). Similarly, the total volumes of water yield (such as wells and springs) are determined by the type of vegetation cover such as taller vs shorter forms, fast-growing vs slow-growing species (Gilmour 2014). Although the findings show similar observations in dry tropics wherein moderate tree cover depicted increase groundwater recharge (Ilstedt et al. 2016), the situations may differ in temperate regions and on varying topography. The harvesting of trees and NWFPs around the water sources have resulted from easy access and their location being close to settlements. The effect of tree harvesting is minimal as compared with the collection of NWFPs, while open grazing is a common occurrence around water sources. The link between forest condition and the condition of water sources require further study.

The general condition of the water sources that were surveyed was rated as 'good' and 'very good', which is consistent with the results of the rapid assessment of the Chamkharchhu sub-basin. As part of the rapid assessment, 176 watersheds were assessed in Bumthang Dzongkhag, of which 54 were pristine, 122 normal, and none was assessed as degraded (Wangchuk et al. 2017). However, periodic monitoring of the watersheds is critical, as the condition of watersheds could alter with land use changes and other degrading influences. The deforestation and accelerated surface erosion have disturbed the hydrological regimes in Gaula river catchment of the Kumaun Himalaya, which is manifested in the forms of drying springs, reduced discharge of rivers (Valdiya & Bartarya 1989). As the principal source is groundwater, spring water is usually crystal clear with rich in dissolved nutrients and gases (Knight & Notestein nd). Although these are not the common water sources in Bhutan, the lakes and ponds may act as receptacles for all kinds of wastes as reported in Nepal (Sharma et al. 2015) as compared to springs which are fresh. However, site-specific monitoring and studies need to be conducted as situations can differ from one region to other widely.

Community perceptions were that most water sources (of which the majority are springs) do not fluctuate considerably in discharge with seasons. However, to validate the observations, long-term monitoring of discharge in a few selected sites may be necessary. There are still around 7.8% of total households in the Dzongkhag with inadequate water which could be aggravated by a seasonal change in water discharge, reduced discharge over the years, water source degradation, population growth, crop intensification, climate change, and other factors. In a few cases, the water sources, especially springs, are almost completely tapped or fenced for human consumption. Springs or their associated springs form unique aquatic ecosystems which provide habitat for diverse flora and fauna (Knight & Notestein nd). Additional data such as the number of years the water source has been in use and the occurrence of water-borne diseases could not be obtained. In addition, the Study could not clearly link observed variations to climate change as this would require long-term and more focused observations. It may be worth relating the study to climate change and finding ways to adapt and build resilience to the impacts of climate change.

The findings of this Study could enable watershed management planners and managers to identify and recommend relevant interventions for the watershed management in Bhutan. A study such as this is also expected to improve the formulation of better policies related to water resource planning and management across the country.

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