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Water Sources Inventory, Annotated Checklist, and Distribution of Water Sources Under Gelephu, Samtenling, and Dekiling Gewog in Sarpang District, Bhutan

Jigme Tenzin[1], Yeshi Yangdon[1], Karma Wangchuk[1], Pema Rinchen[1], Tashi[1]
[1]Department of Forests and Park Services, Ministry of Agriculture and Forests, Bhutan
Corresponding Author: Jigme Tenzin; Email: Jigmetenzin2@moaf.gov.bt

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ABSTRACT

The Kingdom of Bhutan is endowed with abundant water resources. However, owing to rugged topography and associated climatic variations, accessibility remains a major challenge with communities facing seasonal and local scarcity of water. Generally, freshwater appears in the form of glaciers, lakes, wetlands, marshes, springs, and streams which support diverse life and livelihood. However, comprehensive inventories of water resources seem lacking in a water-rich country like Bhutan. Thus, water sources inventory was carried out using Focus Group Discussion and semi-structured questionnaires survey with 81 households (27 villages) from three highly populated gewog under Sarpang district in 2016 and collected the geo-coordinates (location) of each water source using Garmin GPS. The survey recorded a total of 104 perennial water sources from three gewogs under the district. Among the three gewogs, Samtenling and Dekiling have the highest water sources (n = 40) and Gelephu has the lowest (n = 24). While, in the case of source types, Samtenling gewog has the highest (n = 29), followed by Gelephu (n = 18) and Dekiling has the lowest (n = 14). Likewise, Dekiling has the highest number of streams (n = 24), followed by Samtenling (n = 9) and the lowest was Gelephu (n = 6). Therefore, periodic monitor of existing water sources, strengthening water governance, and adaptation of an integrated watershed management plan backed with detailed hydro-geological assessment covering entire watersheds are suggested for ensuring sustainable management of water sources, but also mitigates the climate change effects of these regions in the future.

INTRODUCTION

Freshwaters appear in the forms of glaciers, lakes, wetlands, marshes, spring, and streams which constitute only 0.3% of the earth (UWICER, 2018) that supports diverse life and livelihood including the aquatic biodiversity. Among them, springs are the main water sources for the rural communities of the Hindu Kush Himalayan region (Poudel & Duex, 2017). Studies have shown that nearly 80% of the 13 million mountain people of Nepal completely depend on springs as their main water sources (CBS, 2012; Tambe *et al.,* 2012; Sharma *et al.,* 2016). Nonetheless, Negi and Joshi (2002) also reported that hill communities of the Pauri-Garhwal district in the central Himalayan region of India survived on 45% of its total water needs. While in the case of Bhutan, water uses in the agriculture sector-top with 94.08%, followed by domestic consumption (5.03%) and industrial purposes (0.89%) with 99.5% of households been access to improved drinking waters through the springs (FAO, 2011; NSB, 2017).

However, rapid population growth and urbanization have led to rampant rises in the demand of freshwater across the globe (FAO, 2011; WWAP, 2015; Poudel and Duex, 2017). This has resulted in substantial threats to sustainable management of freshwater due to widespread depletion of groundwater, surface water pollution, and climate change impacts (IPCC, 2007; Gleeson *et al*., 2012; WWAP, 2012). Such widespread water scarcity has adversely affected the public, ecological health, agricultural production, and livestock populations in the entire Himalayan region (ICIMOD, 2015; Poudel and Duex, 2017). Likewise, in the case of Bhutan, although it has the highest annual per capita availability of freshwater (94,508 m^3/person) in the world, still experiences water scarcity due to drying water sources in different parts of the country (MoHWS, 2020). Similarly, Nepal also experienced similar issues of water scarcity due to the rampant dying up of springs despite having abundant water resources (Chaulagain, 2009; WECS, 2011).

The Government of Meghalaya (2005) and Wangchuk *et al.* (2018) also reported that communities experience water scarcity and limited access to quality water due to drying water sources across Sikkim, Kumaon, Darjeeling, and Shillong in India. However, studies have identified that population growth, agricultural intensification, land-use changes, deforestation, economic development, and climate change impacts are the key drivers of water scarcity in the above regions (Negi and Joshi 2002; Merz *et al*., 2003; Nellemann and Kaltenborn, 2009; Vaidya, 2009). Furthermore, studies by Poudel and Duex (2017) have also predicted that the global water crisis is likely to exacerbate if proper water management and measures are not adopted. Thus, solving water scarcity for rural communities will become a critical policy challenge as per the studies of Poudel and Duex (2017).

Therefore, in line with the Water Act (2011) and Water Regulation (2014) of the country, the first pilot water sources inventory was carried out in Dekiling gewog under Sarpang district in 2015 with technical inputs from District Forestry Sector. Later, the National Environment Commission Secretariat (NEC) of Bhutan published the National Integrated Water Resources Management plan (2016) that had legally supported the initiatives and replicated the inventory across the two highly populated gewogs (Sub-district Administration) of Gelephu and Samtenling gewog in 2016 under Sarpang district. Later, Watershed Management Division (WMD) (2017-2018) in collaboration with National Parks and Wildlife Sanctuaries and Field divisions (Divisional Forest Offices) had jointly assessed 6555 trapped water sources that cover 194 geogs under 19 districts in Bhutan. According to this assessment, out of 6555 trapped water sources, 4048 are springs, 2191 streams, 176 lakes, 92 rivers, 29 ponds, and 19 marshes (WMD, 2021). Nevertheless, the report indicated that 35% (*n* = 2317) of the water sources are drying condition, 2% (n = 147) already dried and 63 % (*n* = 4091) are in perennial condition (WMD, 2021). Based on the survey of WMD (2017-2018), the Department of Forests & Park Services (DoFPS) had carried out a nationwide water source and utility survey in 2021 as per the Royal Audience receipt by the Secretary of the Ministry of Agriculture and Forests in September 2020 (Tenzin *et al*., 2021). Thus, this paper will basically generate the baseline checklist of existing water sources and the distribution of water sources which will serve as a technical basis for monitoring the status of water sources over the years to ensure sustainable management and utilization of existing water sources in that highly populated gewog in future.

MATERIALS AND METHODS

Study Area

Water sources inventory was carried in three highly populated gewog of Gelephu, Samtenling, and Dekiling under Sarpang district in Bhutan. It is located between 26°44'N to 26°50'N and 89°51' E to 90°19' E in a sub-tropical zone dominated by broadleaved forest (Tenzin *et al*., 2018). The elevation ranges from 164-3506 masl whereby it receives one of the highest annual mean precipitation of 3950 mm due to sub-tropical zones (Tenzin *et al*., 2018). More than 50% of the district landscapes is overlapped by the three ecologically-diverse protected areas of Bhutan Royal Manas National Park (RMNP) in the east, Phibsoo Wildlife Sanctuary (PWS) in the west, and Jigme Singye Wangchuck National Park (JSWNP) in the north connected each other by Biological Corridor No.03 (Tenzin and Dhendup, 2017; Tenzin and Wangyal, 2019; Tenzin *et al.,* 2021).

Among 12 gewogs, most of the regional development centers such as Municipality, regional head offices, and Army Welfare Project (AWP) in Gelephu, Centenary Grain Distillery, Sub-Tropical Agriculture Research Centre (STARC), and Monastic institutions at Samtenthang in Samtenling and Jigmeling Industry Estate, Patseling Monastic institute, Jigme Wangchuck Power Training Institute and Jigmeling GIS Sub-station, Bhutan Hydrower Service Limited in Jigmeling are located in Dekiling gewog**.** According to National Statistics Bureau (2018), Sarpang Dzongkhag has a total population of 46,004 people, out of which 25,096 individuals accounting for 54.55% of the total population were living in this gewogs. Thus, the demand for water needs is comparatively higher, due to the growing population and regional development centers. Therefore, an inventory of perennial water sources was conducted in that gewog to map out the existing water sources as well as to identify untapped potential water sources to address water crunches in these regions in the future.

Data Collection and Data Analysis

Generally, water sources are classified into three types: springs, streams, and rivers depending on the characteristics of the sources (Tambe *et al*., 2012; WMD, 2017; Shrestha *et al*., 2018). To survey those water sources, Focus Group Discussion (FGD) and short semi-structured questionnaires survey (Watershed Management Division, 2017; Wangchuk *et al*., 2018) was carried out with 5 key informants from 27 villages under three gewogs during December and March of 2016. Based on the FGD, the entire location of the water sources (geo-coordinates) was recorded using GPS and simultaneously, dully filled the data collection forms by the trained foresters (Sada and Pohlmann, 2002; Stevens *et al*., 2011; Department of Natural Resources, 2017; Wangchuk *et al*., 2018).

Meanwhile, entire survey questionnaires were punched, sorted, segregated, and analyzed using the Pivot table of Microsoft Excel 2016. Further, the geo-coordinates of entire water sources were consolidated and used for preparing the water sources distribution map of three gewogs using QGIS (Version 2.18.17). Data collection forms, pencil, eraser, plastic envelope, and DSLR camera were used for the above inventory.

RESULTS AND DISCUSSION

Annotated Checklist of Water Sources

Water sources were classified into three types: springs, streams, and rivers depending on the characteristics of the sources. The inventory had recorded a total of 104 (N) water sources which are spatially distributed across the three highly populated gewogs of Gelephu, Samtenling, and Dekiling under the Sarpang district (Table 1).

Table 1. Checklists of water sources of three highly populated gewogs under the Sarpang district

Sl.#	Name of water sources	Gewog	Longitude (N)	Latitude (E)	Types of sources	Status
1	Sadukholtsa	Gelephu	26.9101	90.4793	Spring	Perennial
2	Kerabari	Gelephu	26.9107	90.4775	Spring	Perennial
3	Gantay Kholsa	Gelephu	26.9126	90.4792	Spring	Perennial
4	Ap Penjor	Gelephu	26.9136	90.4928	Spring	Perennial
5	Ap Penjor1	Gelephu	26.9138	90.4936	Spring	Perennial
6	Ap Tashi	Gelephu	26.9146	90.4932	Spring	Perennial
7	Jogichu	Gelephu	26.9151	90.4895	Stream	Perennial
8	Dawlachu	Gelephu	26.9153	90.4795	Spring	Perennial
9	Aum Seldon	Gelephu	26.9169	90.4946	Spring	Perennial
10	Kamareykhola	Gelephu	26.9175	90.4827	Stream	Perennial
11	Army	Gelephu	26.9180	90.4936	Stream	Perennial
12	Tauraley1	Gelephu	26.9193	90.4656	Stream	Perennial
13	Tauraley 4	Gelephu	26.9197	90.4663	Spring	Perennial
14	Tauraley 2	Gelephu	26.9199	90.4655	Spring	Perennial
15	Tauraley 3	Gelephu	26.9208	90.4669	Spring	Perennial
16	Rejalpakha	Gelephu	26.9222	90.4910	Spring	Perennial
17	Pasangchu	Gelephu	26.9224	90.4944	Stream	Perennial
18	Devikhola	Gelephu	26.9226	90.4947	Stream	Perennial
19	Pujathan	Gelephu	26.9232	90.4943	Spring	Perennial
20	Pokhrel Chu	Gelephu	26.9279	90.4720	Spring	Perennial

21	Naurakhola	Gelephu	26.9235	90.4768	Spring	Perennial
22	Jaruwa	Gelephu	26.9110	90.4716	Spring	Perennial
23	Drupchu	Gelephu	26.9389	90.4762	Spring	Perennial
24	Daraychu	Gelephu	26.9266	90.4736	Stream	Perennial
25	Charcharery 1	Samtenling	26.9444	90.4399	Spring	Perennial
26	Charcharery 2	Samtenling	26.9278	90.4409	Spring	Perennial
27	Aipoli 1	Samtenling	26.9341	90.4496	River	Perennial
28	Guman Singh sources	Samtenling	26.9167	90.4455	Stream	Perennial
29	Devithang	Samtenling	26.9179	90.4486	Stream	Perennial
30	Sasbotey(Salsoro)	Samtenling	26.9223	90.4489	Spring	Perennial
31	Sasbotey	Samtenling	26.9252	90.4482	Spring	Perennial
32	Talidratsang Orchard	Samtenling	26.9189	90.4454	Spring	Perennial
33	Paithachu (Jaijakhola)	Samtenling	26.9302	90.4177	Stream	Perennial
34	Devikhari	Samtenling	26.9215	90.4355	Spring	Perennial
35	Lampatey Gairi	Samtenling	26.9156	90.4354	Spring	Perennial
36	Paithashir	Samtenling	26.9190	90.4454	Spring	Perennial
37	Jarayokholsi	Samtenling	26.9367	90.4277	Spring	Perennial
38	Saskharka	Samtenling	26.9257	90.4447	Spring	Perennial
39	Thukneykharka	Samtenling	26.9393	90.4160	Spring	Perennial
40	Gararey 1	Samtenling	26.9393	90.4159	Spring	Perennial
41	Gararey 2	Samtenling	26.9393	90.4159	Spring	Perennial
42	Kundalekharka1	Samtenling	26.9420	90.4189	Spring	Perennial
43	Kundalekharka 2	Samtenling	26.9420	90.4189	Spring	Perennial
44	Bagan 1	Samtenling	26.9283	90.3991	Spring	Perennial
45	Bagan 2	Samtenling	26.9266	90.3999	Spring	Perennial
46	Bagan 3	Samtenling	26.9210	90.4018	Spring	Perennial
47	Kopcheykhola	Samtenling	26.9303	90.4177	Stream	Perennial
48	Kopcheykhola	Samtenling	26.9308	90.4181	Stream	Perennial
49	Harikholchi	Samtenling	26.9222	90.4192	Spring	Perennial
50	Daley(road)	Samtenling	26.9277	90.4199	Spring	Perennial
51	Devithan	Samtenling	26.9229	90.4213	Spring	Perennial
52	Balukhola	Samtenling	26.9506	90.4207	Stream	Perennial
53	GYT Kholchi	Samtenling	26.9474	90.4193	Stream	Perennial
54	Tashiling (Plantation)	Samtenling	26.9209	90.4197	Spring	Perennial
55	Tashiling(mining)	Samtenling	26.9266	90.4580	Spring	Perennial
56	Umchu	Samtenling	26.9257	90.4591	Spring	Perennial
57	Umchu (Barsiling)	Samtenling	26.9224	90.4617	Spring	Perennial
58	Tsho	Samtenling	26.9190	90.4566	Spring	Perennial
59	Barsiling	Samtenling	26.9211	90.4610	Spring	Perennial
60	Taurli top	Samtenling	26.9211	90.4610	Stream	Perennial
61	Taurli base	Samtenling	26.9338	90.4494	Spring	Perennial
62	Aipoli 2	Samtenling	26.9231	90.4520	River	Perennial
63	Sauntolabari	Samtenling	26.9243	90.4586	Spring	Perennial

64	Shatikhari	Samtenling	26.8944	90.3364	Stream	Perennial
65	Bijanbari	Dekiling	26.8949	90.3365	Spring	Perennial
66	Ultakhola	Dekiling	26.8992	90.3366	Stream	Perennial
67	Jorikholsi	Dekiling	26.8993	90.3365	Spring	Perennial
68	Laureykhola	Dekiling	26.8971	90.3299	Stream	Perennial
69	Panikuwa	Dekiling	26.8969	90.3296	Spring	Perennial
70	Dekiling School source	Dekiling	26.9017	90.3292	Stream	Perennial
71	Dongdongayjorykhola	Dekiling	26.9020	90.3285	Stream	Perennial
72	Dongdongay	Dekiling	26.9242	90.3544	Spring	Perennial
73	Devithan	Dekiling	26.9242	90.3543	Spring	Perennial
74	Jukaykholsi 1	Dekiling	26.9242	90.3544	Spring	Perennial
75	Jukaykholsi 2	Dekiling	26.9232	90.3518	Spring	Perennial
76	Janakeykholsi	Dekiling	26.9232	90.3518	Spring	Perennial
77	Lelabagan	Dekiling	26.9247	90.3492	Spring	Perennial
78	Dharaneykholsi	Dekiling	26.9275	90.3497	Spring	Perennial
79	Kaila source	Dekiling	26.9278	90.3446	Spring	Perennial
80	Premla Dangal	Dekiling	26.9278	90.3446	Spring	Perennial
81	Golay bagan	Dekiling	26.9310	90.3252	Spring	Perennial
82	Hillaykhola	Dekiling	26.9291	90.3443	Stream	Perennial
83	Aleydangra Pokhari	Dekiling	26.9348	90.3338	Stream	Perennial
84	Kubindayjarwa	Dekiling	26.9351	90.3323	Stream	Perennial
85	Sanu Pakhaykhola	Dekiling	26.9347	90.3318	Stream	Perennial
86	Main Pakhaykhola	Dekiling	26.9347	90.3318	Stream	Perennial
87	Guringkhola	Dekiling	26.8981	90.3448	Stream	Perennial
88	Dolkhola	Dekiling	26.9042	90.3458	Stream	Perennial
89	Panditeykhola	Dekiling	26.9089	90.3414	Stream	Perennial
90	Dolpani	Dekiling	26.9124	90.3362	Stream	Perennial
91	Neteykhola	Dekiling	26.9196	90.3293	Stream	Perennial
92	Bakaseykhola	Dekiling	26.9233	90.3224	Stream	Perennial
93	Dolkhola Mandir	Dekiling	26.8990	90.3095	Stream	Perennial
94	Dolkhola	Dekiling	26.8891	90.3377	Stream	Perennial
95	Leokhop	Dekiling	26.8792	90.3278	Stream	Perennial
96	Leokhola	Dekiling	26.8866	90.3280	Stream	Perennial
97	Dhundreykholsi	Dekiling	26.8823	90.3216	Spring	Perennial
98	Phungdeykholsi	Dekiling	26.9380	90.3925	Spring	Perennial
99	Bhimmayakholsi	Dekiling	26.8907	90.3063	Spring	Perennial
100	Balukhola	Dekiling	26.9434	90.3828	Stream	Perennial
101	Tenbadikhola	Dekiling	26.9441	90.3595	Stream	Perennial
102	Bhurkhola	Dekiling	26.9520	90.3453	River	Perennial
103	Rateykhola	Dekiling	26.9329	90.3562	River	Perennial
104	Bethkholsi	Dekiling	26.9273	90.3608	Stream	Perennial

Out of 104 water sources, Samtenling and Dekiling have the highest (*n* = 40), while, Gelephu has the lowest (*n* = 24). The studies of Ellison *et al*. (2017) indicate that forest cover plays significant role in producing and regulating world temperature that determines the flow of fresh water. Not only that, but Shrestha *et al*. (2018) also verified that dense forest canopy coverages retained the optimum temperatures of underground aquifers and regulates the evapo-transpirations that ensure the perennial flow of the waters. Nevertheless, the ground reality has also shown that Samtenling and Dekiling gewogs have better forest covers in the watershed areas than the watershed of the Gelephu which contributes to the abundant availability of water sources above gewogs. While in cases of Gelephu, nearly 80% of 1980-1989 logging operations sites were fallen inside the watershed of Gelephu gewog that had degraded the watershed and resulted in extensive erosions which have not only diminished numerous water sources but also widened the courses of the Shetikhari and Dawlakhola below Raidara village that has now become a major flood source for Gelephu Municipality. Due to these reasons, Gelephu might have recorded lesser water sources than the other gewogs.

With regards to water source types, Samtenling gewog has the diverse types of water sources (n = 29), followed by Gelephu (n = 18) and Dekiling has the lowest (n = 14). This indicates that most of the diverse types of water sources (rivers, streams, and springs) are distributed across the Samtenling gewog. Burkhola river is the only perennial running river after the Sarpangkhola and Moukhola rivers that benefited countless humans and wildlife including the most Endangered Asiatic elephants during the dry winter in the Sarpang district. While in the case of streams, Dekiling has the highest (n = 24), followed by Samtenling (n = 9) and Gelephu has the lowest (n = 6). The more number of streams is attributed due to intact upstream watersheds and also due to different hydro-geological settings of gewog landscapes (Shrestha *et al*., 2018). However, the in-depth relationship between geological setting and spring abundances is inadequately known that requires separate studies in the future.

Distribution of Water Sources Inside Three Highly Populated Gewog

The distribution of water sources map for three highly populated gewog has been shown below (Figure 1). The figure shows that most of the water sources were randomly distributed across the three gewogs and most of the water sources are located inside the dense broadleaved forest which might have contributed to the sustainable flow of water downstream, while, very few are located within the proximity of the human settlements as shown in Figure 1.

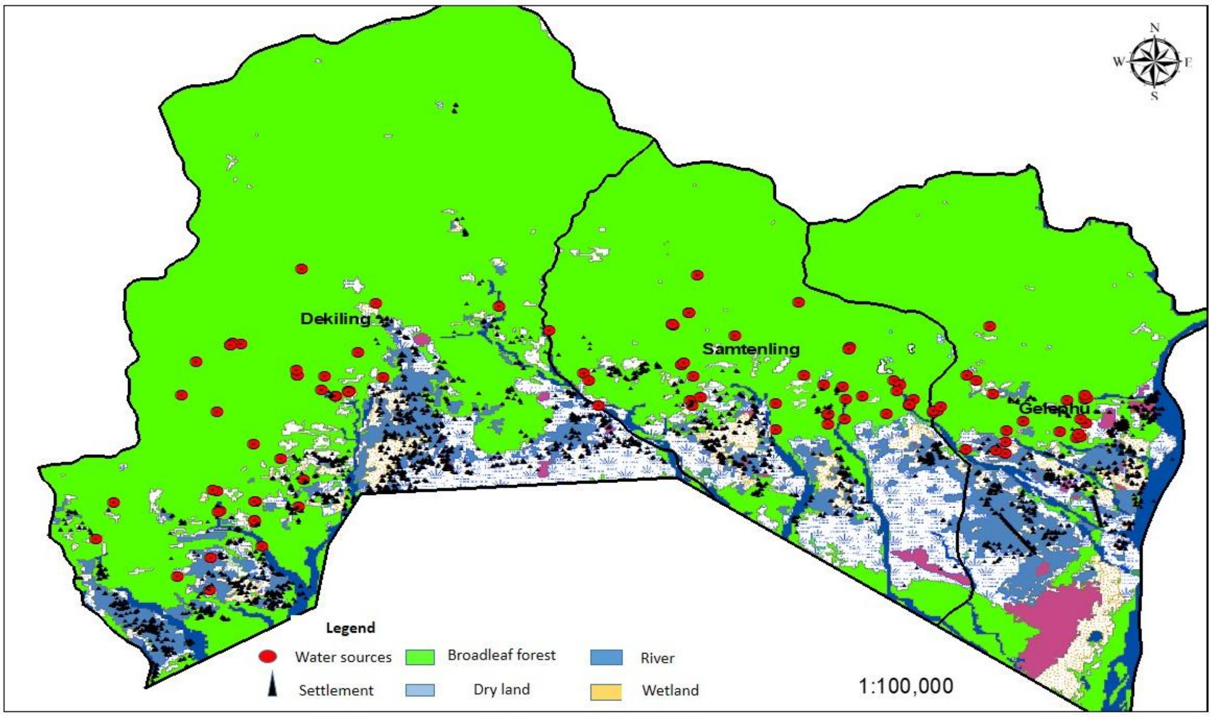

Figure 1. Distribution map showing entire water sources of three highly populated gewogs of Sarpang district.

Unlike other gewog, Gelephu gewog has water sources that are distributed in proximity to the human settlements which might have dried the water sources due to anthropogenic activities. While most of the water sources of Dekiling gewog are distributed far away from the human settlements which have lesser chances of degradation. However, most of the extensive cardamom plantation sites in the south were mostly located at the sideline of the watershed that had poses threats to the existing water sources which compromised the water quality downstream. The studies indicated that cardamom cultivation and management involve clearing of undergrowth, selective removal of canopy trees, and the regular slashing of undergrowth (Kumar *et al*., 1995; Anon, 2002; Buckhingham, 2004). Such activities can change the species richness and diversity of the tree community as per the studies of Connell (1979) and Sheil and Burslem (2003). Nevertheless, periodic maintenance of cardamom plantations includes the addition of fertilizers or weedicides which directly affects the water quality through eutrophication (Kumar *et al.,* 1995; Anon, 2002; Buckhingham, 2004). Thus, the aforementioned activities can impact biodiversity conservation (IUCN, 1994; Gunawardane, 2003). However, in Bhutan, none of the Bhutanese researchers had carried out the studies on the ecological impact of the cardamom plantation inside water sources and watersheds which must be required in this gewogs under Sarpang district to avoid unforeseen future ecological implications.

CONCLUSION

In summary, water sources inventory has become an important task on the eve of growing population and development activities. But on the other hand, climate change had already worsened the perenniality of existing water resources, especially in the Himalayan region. However, due to a lack of empirical evidence to gauge the drying water sources, nationwide comprehensive water inventory and adaptation of integrated water sources management had not been carried out in Bhutan owing to the water-riched country. Therefore, periodic monitoring of existing water sources, strengthening water governances (community-based water user association), and adapting an integrated watershed management plan, backed with detailed hydro-geological assessment is suggested not only for ensuring sustainable management of water resources, but also gradually mitigates the impacts of climate change effects of that gewog in the future.

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