DOI:

Forestry: Journal of Institute of Forestry, Nepal

journal homepage: www.nepjol.info/index.php/forestry

Status of springs in the mid-hills of Khotang district Nepal, (A case study from Diktel Rupakot Majhuwagadhi and Halesi Tuwachung Municipality)

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KEYWORDS

Climate change
Springs
Watersheds
Discharge

ABSTRACT

The study was conducted in Buipa (ward no.14) of Diktel Rupakot Majhuwagadhi municipality and Durchim (ward no.5) of Halesi Tuwachung municipality in Khotang district, Nepal. A total of 45 springs were mapped. The study showed 62.2% of the springs to be open springs, and the rest were modified into concrete structures. Seventy-seven percent of the springs were found to be drying up. The study showed 20% of the springs had dried up already and 17.7% were on the verge of drying. Most of the springs found were depression springs. At Durchim of Halesi Tuwachung, 16 out of 18 springs had discharge rates less than 0.05 l/s. Twelve of these had dried already. Thirty-seven per cent of the springs were located farther than 1km, of which 6.67% were also in a drying condition and more than 51% were farther than 500m. People used springs on various occasions and local festivals. Forty per cent of springs were drying due to landslides and road construction. In the Koshi basin, 78% of annual rainfall occurred during the monsoon and only 2.8% during the dry period. Springs are fully monsoon-dependent and slight fluctuation in the rainfall patterns could greatly affect the discharge in the springs

Introduction

A spring is a place where water moving underground finds an opening to the land surface and emerges, sometimes as just a trickle, sometimes only after rain, and in some cases in a continuous flow (USGS, 2019). Springs are typically found in groundwater discharge zones in areas with large differences in hydraulic conductivity and are classified as: fracture, depression, sinkhole, fault, and contact (Kløve, 2011).

Springs generally formed where impermeable and sloping ground intersects with the ground water table to yield water during both rainy and non-rainy seasons according to rainfall patterns and the recharge area characteristics (Negi, 2004). In many villages of the region, water shortage has been a

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Received 09/13/2022 Accepted 01/09/2023

growing barrier to local livelihoods and poverty alleviation. Activities like discharging domestic sewage and sludge without treatment, agricultural chemicals and solid waste, and encroachment upon riverbanks for illegal extraction of riverbed materials have polluted the existing surface water (Gurung, 2019). The occurrence of groundwater is greatly influenced by the interaction of the climatic, geological, hydrological, physiographical, and ecological characteristics (Andermann, 2012). For example, the alteration of physical characteristics of freshwater systems through infrastructure development, eg road network, deforestation, over-extraction of river resources, greatly influences land use, wetland, hydrology, and geomorphology (du Plessis, 2017). People in rural communities depend on spring water sources for drinking water, livestock, irrigation as well as other daily activities, but the threat of disappearing of springs and degrading water quality are the main problems in the mid-hill region of Nepal (Chapagain, 2019). While biological studies of large rivers, streams and lakes are commonly studied in Nepal, research on the biological and sociological importance of springs is lacking (Poudel and Duex, 2017). Freshwater resources are unevenly distributed on Earth (Placeholder 1) and contribute only 2.5% of the Earth's total water volume (cA, 1999). Fresh water is unevenly distributed in Nepal. The complex geography has been one of the factors hindering the supply of water services in rural area (Gurung, 2019).

In Nepal, research on groundwater is very limited and hence little known, in both the Terai plains and hilly mountain areas.In the mid-hills of Nepal, people still have to fetch water from other distant sources such as springs (15%) and rivers (4%), which are also diminishing compared to past years. The study by Gurung (2019) also showed that, in spite of tap water being the main source of drinking water to 72% of the households in the hilly region, the people had to depend on natural springs. Furthermore, Tien Bui (2019) found that, during dry periods spring water reduces villagers' reliance on stream water to meet their demands.

Nepal has low per capita water availability (Sharma, 2011). Although Nepal is rich in terms of water resources, it has been facing water scarcity. More than 70% of the total population still live in rural areas and do not have a proper drinking water supply system (CBS, 2011).

In the past, springs provided sufficient water to meet the requirements of villages. Since the early 1980s, people have been facing increasing shortages of water. There are many factors involved, including growing population, land use changes, infrastructure development, and now climate change. The flow from many springs has lessened, permanent springs have become seasonal and seasonal springs have dried up completely. Natural springs in the mid-hills of Nepal are found at many places surrounding the hill slope. The ultimate source of the springs is rainwater, which infiltrates the soil and seeps through cracks and fissures in the rocks before accumulating underground above impervious rock layers. Springs can be relatively short-lived, providing water for a certain period after the monsoon when the groundwater levels are high, or perennial when they are fed from a level below the dry season water table. They can start with high discharge and quickly reduce to very low discharge during the dry season; they can have relatively high discharge or relatively low discharge that is more or less constant throughout the year; or they can dry up completely during the dry season (Poudel and Duex, 2017).

If the charge rate is below the extraction rate, the spring will eventually dry up. Annual rainfall is highly seasonal; about 80% of the total falls within around 100 days between June and October—the monsoon season, and this is when the main recharge of groundwater takes place. Precipitation in the dry season is often negligible and, in some years, completely absent. However, while there is little rainfall in the dry season, it can be more effective in recharging the groundwater because temperature, and thus evaporation, is lower and the ground is more absorbent (Talchbhadel, 2018). In the villages perched high in the mid-hills of Nepal, springs are a lifeline to the villagers, providing water to sustain the needs of households, their farms, and their livestock. Many villages sit far above the streams and rivers, which lie at the bottom of deep gullies and valleys far below, and the cost of carrying or pumping water to hill settlements from rivers can be prohibitive. In contrast, springs emerge all around the hill slopes close to the villages. These springs are poorly understood and insufficiently mapped, and responsibility for them is unclear, lying in a grey area between administration and conservation (Sharma, et al., 2016).

The general objective of the study is to generate knowledge on the condition and distribution of groundwater spring sources. A particular objective of the research is to map out the distribution of the springs in the study area, including listing themso as to assess the social and religious importance of springs in the area. Many of the springs in the mid-hills of Nepal are yet to be explored. The study provides a detailed inventory of springs in the landscape of the mid hills of Khotang, including seasonal variability,with the purpose of informing improved water supply and water security for poor and marginalized people living in the scattered settlements of Khotang.

Materials and methods

Study area

The study was conducted in two wards of two municipalities in the Khotang district in the spring season (April–May). The Khotang district covers an area of 1,591 km square (614 sq mi) and has a population of 206,312 in 2011. Khotang is a hilly district in Eastern Nepal. The Sunkoshi River and Dudh Koshi River mark the borders in the north, west, and south, and a series of hills and small rivers mark the eastern border that separates it from Bhojpur District.

The study mainly focused on Diktel Rupakot Majhuwagadhi municipality, ward no.14, Buipa and Halesi Tuwachung municipality, ward no.5, Durchim.

Diktel was renamed Diktel Rupakot Majhuwagadhi on March 10,2017 after it was merged with neighbouring VDCs. The municipality is divided into 15 wards. The area of the municipality is 246.51 km2. The Halesi Tuwachung municipality is named after the famous Halesi Mahadev Temple. The municipality is divided into 11 wards, and the total area of the municipality is 280.17 km^2 (2011 census).

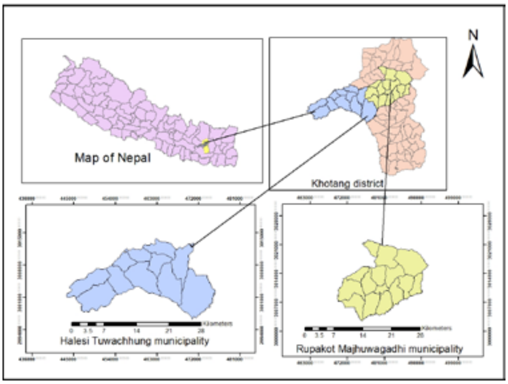

Figure 1: Study area

DataCollection:

A reconnaissance survey was conducted in both municipalities. The survey was done for exploring the conditions of the site and availability of infrastructure in the study area. All existing routes and hindrances to the sites were checked. The springs were enumerated. The type of springpresent (depression, fracture, contact, fault or sinkhole) was categorized, and the current condition (flowing, drying or dried) was identified visually. Questionnaire was conducted for a total of 45 springs of the Diktel Rupakot Majhuwagadhi municipality, Buipa and Halesi Tuwachung municipality, Durchim. The people residing near the spring area were targeted for the questionnaire survey. The questionnaire included quantitative data such as the distance from the hamlet to the spring and the number of people benefitting from the springs. The survey also incorporated villager's perceptions of sanitation requirements as well as any existence of social or religious importance of the spring.

A GPS survey was undertaken to track the location of the springs across the study area. A handheld Garmin GPS with a pair of alkaline battery was taken for the site tracking of the springs. Data was also recorded for the location coordinates, altitude, and aspect regarding. Timed volume measurements of discharge from all springs were conducted. The discharge of the spring was measured by the bucket method, which is a simple way of measuring flow in very small streams. The entire flow is

Figure 2: Springs mapped in Durchim (Halesi-Tuwachung-5)

diverted into a bucket or a barrel, and the time for the container to fill is recorded. The flow rate is obtained simply by dividing the volume of the container by the filling time. In our case, we used a mineral water bottle of 1litre capacity and used a stopwatch and checked the time required to fill up the bottle. This technique was used for most of the springs, which were in flowing condition in the study area as it is a simple and effective method for measurement. Secondary data regarding springs was collected from several research papers, internet, library, project papers, thesis reports, etc for reference. Hydrological data, ie rainfall of the area was collected from the Department of Hydrology and Meteorology for trend analysis of rainfall. The location coordinates were collected using the handheld Garmin GPS. The location coordinates which were collected by the GPS were plotted in map by converting into GIS shape files in the form of point features with Arc GIS 10.4 for constructing a distribution map of springs. The data sets were analysed by MS EXCEL and MS WORD and several satellite imagerywere also used.

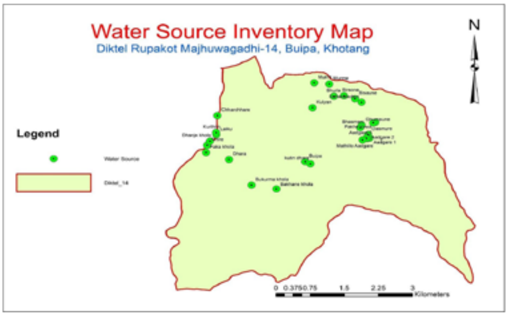

Figure 3: Springs mapped in Buipa (Diktel Rupakot Majhuwagadhi-14)

Result and Discussion

The study assessed existing water availability, uses and its impact on watershed hydrology in the Koshi basin. A total of 45 springs were spotted in two wards of Halesi Tuwachhungand Diktel Rupakot Majhuwagadhi municipality. The number of springs is tabulated below in table 1.

Springs experienced shortage during dry and low flow years. Some perennial springs have changed to seasonal springs while some seasonal springs have dried up completely. Twenty-seven springs were mapped in Buipa of Diktel Rupakot Majhuwagadhi municipality, and 18 springs were mapped in Durchim of Halesi Tuwachung municipality.

The springs were identified as increasing, decreasing or static. Two-thirds of springs were found to be decreasing in Buipa, of Diktel Rupakot Majhuwagadhi municipality, 18.5% were found to have increased and 14.51% were static. In Durchim of Halesi

Spring ID	Local name of spring	Latitude	Longitude	location
1	Bakhane Khola	86.717613˚	27.209833˚	Buipa
2	Bukurma Khola	86.712122˚	27.210796˚	Buipa
3	Faka Khola	86.702244˚	27.218325˚	Buipa
4	Tirtire	86.702509˚	27.219951˚	Buipa
5	Dhanje Khola	86.703170˚	27.220874˚	Buipa
6	Laiku	86.704604˚	27.222273˚	Buipa
7	Kurthim	86.704590˚	27.2227710˚	Buipa
8	Chharchhare	86.704954˚	27.226589˚	Buipa
9	Dhara	86.707278˚	27.216651˚	Buipa
10	Buipa	86.724145˚	27.215834˚	Buipa
11	Kutin Dhara	86.725281˚	27.215356˚	Buipa
12	Kulyan	86.726061˚	27.227932˚	Buipa
13	Bhurla	86.730869˚	27.230412˚	Buipa
14	Murme	86.729907˚	27.233201˚	Buipa
15	Murmi	86.726556˚	27.233529˚	Buipa
16	Birsone	86.733105˚	27.230490˚	Buipa
17	Bisaune	86.735525˚	27.22979˚	Buipa
18	Sahakaladevi	86.736930˚	27.228960˚	Buipa
19	Pakhekuwa	86.739895˚	27.224422˚	Buipa
20	Bijuwa Thane	86.739417˚	27.224286˚	Buipa
21	Ghumaune	86.736823˚	27.223815˚	Buipa
22	Bhasmeni	86.736520˚	27.223248˚	Buipa
23	Dasmure	86.738219˚	27.221670˚	Buipa
24	Aadgare 1	86.738496˚	27.220847˚	Buipa
25	Aadgare 2	86.738029˚	27.220785˚	Buipa
26	Aadgare 3	86.737833˚	27.220831˚	Buipa
27	Mathillo Aadgare	86.736949˚	27.220482˚	Buipa
28	Mul Padhera	86.5935044333˚	27.1864601596˚	Durchim
29	Mul Kuwa	86.5937556774˚	27.186777075˚	Durchim
30	Saharbate	86.5931283102˚	27.1871727303˚	Durchim
31	Saharbate	86.5928143954˚	27.1874336376˚	Durchim
32	Panitar Padhero	86.5872078621˚	27.1883561798˚	Durchim
33	Gaira Bari	86.5845860873˚	27.1875088133˚	Durchim
34	Juke Pani	86.5853325495˚	27.1849470089˚	Durchim
35	Juke Pani Kuwa	86.5855042047˚	27.1849384881˚	Durchim
36	Syal Padhera	86.5855041713˚	27.1849475163˚	Durchim
37	Mahuwa Pani Padhera	86.5979529849˚	27.1818419353˚	Durchim
38	Humla, Siwale	86.6043092006˚	27.1829163164˚	Durchim
39	Humla	86.6044390697˚	27.1833048968˚	Durchim
40	Dhobi	86.6044592284˚	27.1833139819˚	Durchim
41	Mayanku Kuwa	86.5575114829˚	27.189520533˚	Durchim
42	Mayanku Khola	86.5571537092˚	27.1906388994˚	Durchim
43	Doleni	86.5620684389˚	27.1730583602˚	Durchim
44	Odare	86.5592793025˚	27.1712710662˚	Durchim
45	Narunge	86.5567883729˚	27.1757863535˚	Durchim

Tuwachung municipality 94.4% of the springs were decreasing, 5.5% remained static, and none were found to be in increasing condition. Between the two study areas, a total of 77.7% springs were decreasing, and 11.11% springs were increasing as well as static.

Twenty-three out of 27 springs mapped in Diktel Rupakot Majhuwagadhi municipality, Buipa, and 5 out of 18 springs mapped in Halesi Tuwachung municipality, Durchim, were found in flowing condition. Four springs in Diktel Rupakot Majhuwagadhi and 4 springs in Halesi Tuwachung were found in drying condition. Overall, 62.2% of the springs were found flowing, 17.7% have been drying, and 20% of springs were found to have dried up already. Trends in spring condition are shown in the following graph.

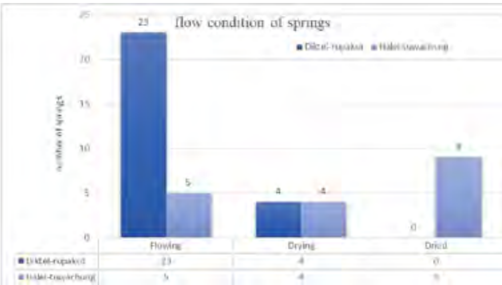

Figure 4: Flow Condition of springs

The springs were classified into whole year springs, 6-month springs, and 3-month springs. The 6-month and 3-month springs were only seasonal. Mostly the 3-month springs would arise during the monsoon and disappear soon after, whereas the 6-month springs would go dry after a period of drought. All of the springs in the Diktel Rupakot Majhuwagadhi municipality were whole-year springs, whereas 11 out of 18 were found to be whole-year springs in Halesi Tuwachung. Three whole-year springs were reduced to 6-month springs and 4 springs were reduced to 3-month springs in both municipalities.

Geographical classification of fetter was used to classify the springs geographically into

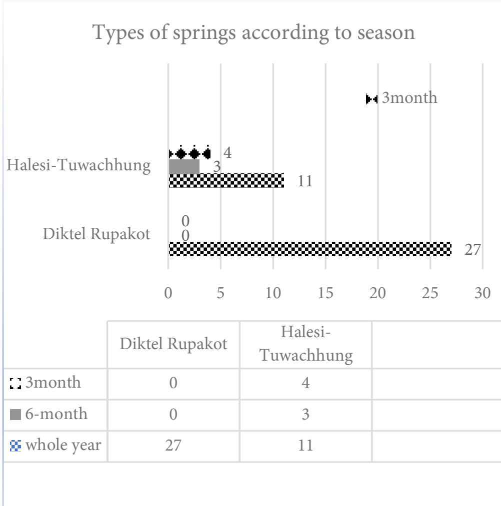

Figure 5: Type of spring according to season

depression, contact, fault, fracture or sinkhole springs. The earth seemed co-incident with the water table or seemed to intersect the water table in most of the springs, which were then classified as depression springs. Some springs seemed to be deflected to land surface and were classified as contact springs. Some springs, especially in the Halesi Tuwachung municipality, were classified as fault springs as they arose indifficult places such as faults formed in a rocky surface due to the hydraulic conductivity of rocks. As the topography seemed fracture-free and there was no presence of limestone, fracture and sinkhole springs were not identified during the observation. Fourteen out of 18 springs were found to be depression springs in Halesi Tuwachung and 19 out of 27 were depression springs in Buipa of Diktel Rupakot Majhuwagadhi municipality. An overall of 73.33% were depression springs, 6.67% were fault springs and 20% were contact springs in both the municipalities.

The discharge in the springs was measured by the bucket method. The flow rate was obtained by dividing the volume of container by the filling time of the container. In this case, a 1-litre water bottle was helpful, and the time taken to fill up the bottle was used and calculated using the stopwatch. Most of the springs in Buipa of

Diktel Rupakot Majhuwagadhi were flowing in good condition and had quite a good amount of discharge. Only nine springs in Diktel Rupakot Majhuwagadhi had flow less than 0.05 l/s, five springs had discharge between 0.05 and 0.1 l/s, and 13 springs in Diktel Rupakot had discharge more than 0.1 l/s. However, in Durchim of Halesi Tuwachung municipality, most of the springs appeared to have dried, and some would arise only in monsoon so that there was no discharge measurement for most of the springs. Sixteen springs were less than 0.05 l/s and only one spring had discharge more than 0.1 l/s. Overall, 53.3% were less than 0.05 l/s, 15.5% were in between 0.05 and 0.1 l/s and 31.1%had more than 0.1 l/s. These measurements denote the flow in spring or dry season only. The six-month and three-month springs reported an improvement of flow in the monsoon period. While the study was only limited to the dry season, all of the springs limited to three or six months in Halesi Tuwachung were reported to have a flow more than 0.1 l/s in the monsoon by the respondents. The results are shown in Figure 6.

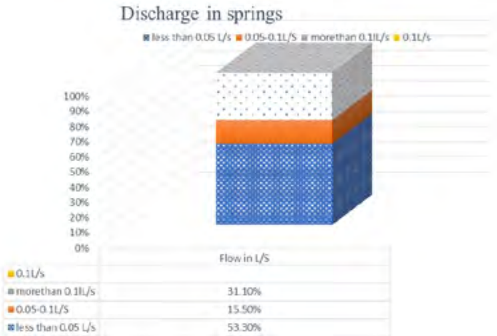

Figure 6: Discharge in springs

Diktel Rupakot Majhuwagadhi municipality liesina sub-tropical zone. All of the springs mapped in Buipaare found in the broad leaved sub-tropical vegetation. The springs had bamboo, kutmero *(Litsea polyantha),* utis *(Alnus nepalensis), chilaune (Schima wallichi),* chiuri *(Diploknema butyracea),* karam *(Nauclea parvifolia),* kafal *(Myrica esculenta),* and gogan *(Saurauia napaulensis)* as the major upstream as well as the downstream species of vegetation. However, Durchim lies in the tropical zone of the district, which also had broad-leaved vegetation. It included Gurans *(Rhododendron arboreum),* chiuri *(Diploknema butyracea),* maley bans, utis *(Alnus nepalensis),* salla *(Pinus roxburgii),* ritha *(Sapindus mukorossia),* khanyu *(Ficus cunia),* khirra *(Falconeria insignis),* simali *(Vitex negundo),* andmahuwa *(Madhuca longofolia)* as the major upstream as well as downstream species. An overall of 4.44% of the 45 springs mapped were found to be less than 1,000m altitude, 39 springs were in the 1,000-1,500m altitude (86.67%), and only 8.89% were more than 1,500m altitude (4 out of 45 springs).

In Buipa, most of the springs were located near the settlements, but in Durchim people were compelled to travel greater distances to fetch water. People were compelled to cross harsh topographies, such as steep rocky hills in Durchim and steep dense forest in Buipa, to fetch water. Of the total springs, 48.8% were less than 500m from the nearest settlement, 13.3% were located more than 500m but less than 1,000m from the spring, and 37.7%were found to be farther than 1km from the nearest hamlet.

Three of the 45 springs were found to be both further than 1km and also in drying or dried condition (6.67% of the total springs mapped) and represented the greatest suffering for villagers. The distance between the springs and the hamlets are shown in the graph below. A total of 51% springs were located more than 500m from the settlement.

Most of the springs in Buipawere in natural

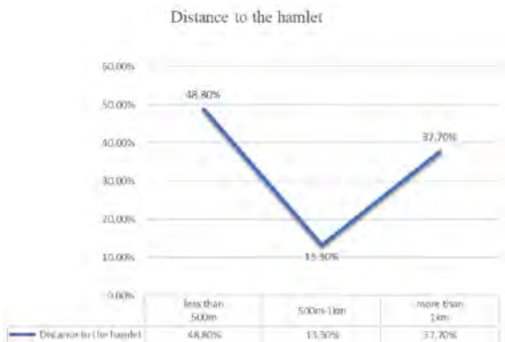

Figure 7: Distance to the springs

condition and did not require sanitation. Some of the springs near settlements were exploited by anthropogenic activities. A small number of springs in both places had quantities of garbage dumped in their vicinity. Water was found to be flowing in natural state and was drinkable. Twenty-five springs in Buipa Rupakot Majhuwagadhi and 16 in Durchim required only a little sanitation and were in natural condition. Two springs in Buipa and 2 springs in Durchim were found dumped with garbage. Overall, 91.1% of the springs required a little sanitation, but 8.89% were badly polluted and required urgent sanitation.

Most of the springs in Buipa as well as Durchim were owned by the public and only a few had private ownership. In some places, people used the spring as a public property despite it being a private property. Twenty-five out of 27 springs in Buipa and 12 out of 18 springs in Durchimwere owned by public, and the rest had private ownership. Combined, 82.2% of springs had public ownership and 17.7% had private ownership. Nevertheless, 17 out of 18 springs in Halesi Tuwachung were also used publicly and were not limited to private property (1 in Durchim and 2 in Buipa were found in such condition). So, overall, 93.3% were publicly used springs and 6.67% were privately managed.

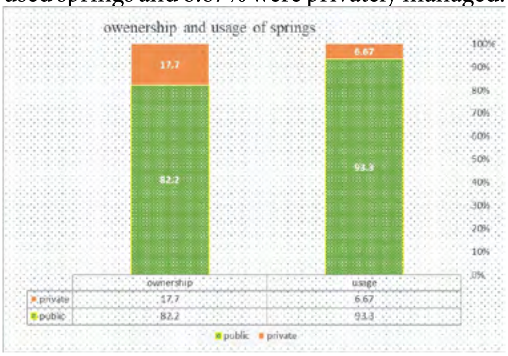

Figure 8: Usage and ownership

The springs were mainly used for irrigation and drinking. Most of them were multipurpose. Two-thirds of the springs in both municipalities were found to be used for both irrigation and drinking, 14 out of 45 were only used for drinking, 1 spring was found solely used for irrigation, and the rest were multipurpose. The spring being solely used for irrigation lied amidst terraces and was used to irrigate paddy fields.

Both municipalities were mostly inhabited by Rai and Limbu communities; so, all of the springs were used to the benefit of Janajatis. However, small numbers of other ethnic groups were also present. Seven out of 27 springs in Buipa and 9 out of 18 springs in Durchim were also used by Dalits. Three springs in Buipa and 13 springs in Durchim were also used by other ethnic groups (other than Dalit and Janajatis). Dalits used 35.5% of the springs and 35.5% were used by other than janajatis. Springs were haphazardly distributed in both areas. In the lower region of Buipa 9, springs were present in the vicinity of 15 households while, in the upper region, nearly 110 households had access to only one spring. There were around 30 Dalit households in Buipa among the 27 mapped spring sheds. However, in Durchim, nearly 105 Dalit households benefitted from 18 springs. Nearly 230 households other than those of Janajatis benefitted from 18 springs.

Forty-four percent of the springs in Durchimand 148% in Buipawere found to be religiously important. Overall, 12 out of 45 springs were religiously important, and the rest had only social importance. Most of the springs also possessed aesthetic importance. In Buipa, springs specifically were used in droughts. Some springs were used by wayfarers. The nearby villagers washed, worshipped and sacrificed their animals when crossing the water source. Some springs were used during the funerals of some ethnic groups. The people worshipped springs on Nagpuja, Chandipurnima, Udhauli, Ekadashi, etc.

The springs in Buipa were mostly undisturbed and managed using bamboo taps and making small reservoirs. Only a few have been managed with stone spouts and concrete tanks. Some springs in Buipa had irrigation canals built to supply water to the nearby fields. Most of the springs in Durchim were well managed with concrete tanks, wells and spouts even if the water availability was low. Twenty out of 27 springs in Diktel Rupakot Municipality and 8 out of 18 springs in Halesi Tuwachung were open springs. Two springs in Diktel Rupakot Majhuwagadhi and five in Halesi Tuwachung were stone spouts. The remainder of springs were modified with wells and concrete tanks. In total, 62.2% were open springs, 15.5% were stone spouts and 22.22% were modified wells and concrete tanks. This is shown in a pie chart

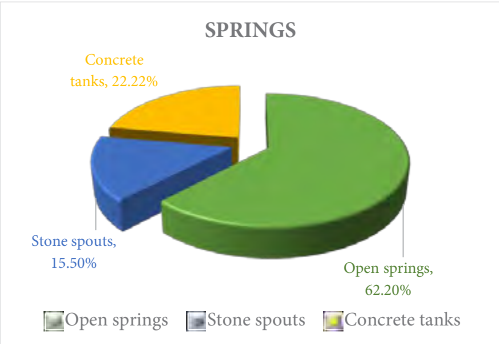

Figure 9: Types of springs

in Figure 9.

Various disrupting situations such as landslides, erosion, and earthquakes and road construction have had serious impacts on the condition of the springs. Eighteen of the 45 springs were impacted by landslide and soil erosion and other factors such as earthquake and anthropogenic activities, including road construction. But the remaining 26 springs (57.7%)were undisturbed. Villager argued that two springs in Buipa and 12 springs in Durchim(31.1% of total springs) had declined due to recent earthquakes. Surprisingly, one spring in Durchim arose after the earthquake.

Figure 10: Devastating situations in the spring

People in Buipa were aware of the important of conservation of springs. The situation seemed to be satisfactory but declining. Villagers mentioned a need for a suitable water project. The distribution of government drinking water system was not regarded as equitable. Villagers suggested making suitable laws and making people aware of the importance of the conservation of springs. Haphazard distribution and utilization was a foremost concern. People urged the need for spring infrastructure, to construct tanks, bordering, reconstruction and construction of intakes, metal taps, PVC pipes, etc in most of the springs.

People in Durchim were more concerned about conservation of springs as their condition was worsening and they were drying out. Participant sex pressed an opinion for establishing nurseries for trees with soil anchoring capacity. Some people even mentioned the need for scientific study of the area. People who were worried about the effects of landslides and erosion due to various causes suggested applying bio-engineering techniques for protection. However, some people were more concerned about the increasing corruption and formation of an efficient working capacity. Many villagers placed more focus on afforestation (35.5%), greater awareness among the locals (24%), and construction and repair of permanent

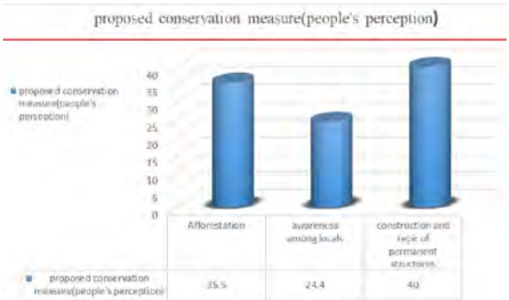

Figure 10: Proposed Conservation Measures

structures (40%) as their main focus.

In the study areas, activities carried out in the upstream have impacts on services derived in the downstream. To ensure continuous delivery of services and also, to keep the livelihood of upstream people intact. Loss of forest, loss of nutrient, loss of sediment issues for downstream inhabitants, and reduction in water recharge are categorized as indirect value.

The study revealed prevalence of grievances and poor collaboration between them. People have also argued that using excavators during road construction may be one of the causes of waters sources drying up. The study found out the water source to be declining. Stories of water sources drying up began fifteen–twenty years ago after the development of Sagarmatha Highway. In the mid-hills, mobilizing community around spring management can be challenging, energy intensive and arduous because of complex hydrology and scattered hamlets. Water resource conservation must take into account the underlying geology and understand the basic hydrology.

Occurrence of springs is greatly influenced by rainfall distribution, intensity and infiltration rate. Rainfall pattern across Nepal is dominated by monsoon and 80% of annual rainfall occurs during the four months of June to September. The shortage is greater during seasons other than monsoon. The distribution of rainfall from the central to the upper parts of the district is the lowest (-7.89–5.52 mm/year) and is the highest in the southern part (Rai, 2019). Annual average precipitation for the Koshi basin 2008/2009 was 1,729 mm, with mean dry season of 49mm during winter, 241mm during the pre-monsoon, 1,345 mm during the monsoon, and 84 mm in post-monsoon. Annual variability shows a significant fluctuation, which is reflected in variation in spring discharge rates. Low discharge in the springs directly corresponds to low annual rainfall of a place.

In the past, springs provided sufficient water for the basic requirement of local people and observed rainfall was higher thirty years ago. However, villagers are facing a cute shortage today. The causes of scarcity include population pressure, land use changes, infrastructure development and natural calamities. Permanent springs have transformed into seasonal springs. The acute water shortage compels villagers to migrate out, especially in Halesi Tuwachung municipality. Overall, declining condition in 77% of the springs is very significant. This is similar to the findings of Adhikari (2021) of a 70% decrease. Even though most of the springs were in flowing condition, the study shows 20% of the springs to have dried up already and another 17.7% on the verge of drying, which corresponds to the 20–25% figure in the study of Adhikari (2021). As this altered flow trend continues annual springs are becoming seasonal only (3 months and 6 months). Many spring snow appear only during the monsoon period and disappear as soon as the monsoon is over. In Durchim, 4 out of 18 springs have become monsoonal. Most of the springs found were depression springs linked to hilly topography of the Khotang district. Absence of limestone in the region limited the probability of presence of sinkhole springs.

Road construction and natural calamities are the main reason for decreasing conditions for springs. In the Buipa area, despite being full of water springs, distribution of suitable drinking water systems does not seem equitable. Villagers suggested solutions such as forming effective committee and implementing some strict rules. The prevalent springs were mostly open; so, a construction of intakes, wells, bordering, and fencing, pipes, taps, etc would be a boon for spring conservation. The springs of Durchim were more in trouble. People suggested scientific study, nursery establishment of trees with soil anchoring capacity, and also urged better coordination in government as in the finding of Lamichhane (2020). Study mentioned the establishment of Sagarmatha Highway led the spring to decline. In order to prevent their mass exodus from villages, especially in Durchhim, the current strategy must be reviewed at a higher level. Besides the variation of rainfall, tectonic movement etc also continued to cause rapid drying of the springs.

Conclusion

The documentation of water sources helps understand the overall scenario of their status, and hence such documentation is important in larger scale to manage water resources effectively at the basin level. Paradigm shift from conventional watershed management to water source management for therevival water sources is necessary for effective watershed resource management.

This study focuses on hydrology and hydrogeology. Hydrology is primarily concerned with the study and understanding of how water moves on the surface while interacting with underground water, whereas the science of hydrogeology deals mainly with water inside rocks and rock material, ie groundwater along with its chemical, physical and environmental characteristics. Moreover, associated sciences such as pedology or soil science and forestry are also important.

The spring has become sites for watershed measures such as forestation, soil and water conservation techniques like bunds, trenches and ponds. Improving the recharge regime through such measures leads to improvement in water source discharge and quality. However, conducting scientific tests and taking up appropriate engineering solutions to enhance recharge are not enough. At a local scale, this implies the involvement of the community, educating various stakeholders, especially the communities depending on water source as well as those located in the springs about resource protection, preventing contamination of the aquifer that supplies water to water sources and land use management and control. Hence, social, economic and ecological sciences must also complement hydrology and hydrogeology in the management of precious water sources in the mountains.

Water source management must be integrated with community management of groundwater resources. Involvement of the community in development and decision making is essential and also an achievable task, as there are cultural and religious beliefs that motivate people to protect water sources.

Development and ecological balance must go side by side, ignorance of one-part results negative impact on our lifestyle. Grassrootsscientific action research with its 'learning by doing' approach shall be coupled with advanced scientific methods.

Water source management includes various aspects of water management, ranging from hydrology to governance of natural resources. The methodology has been able to successfully integrate natural science with social sciences, hydrogeology with engineering and research with implementation. while also ensuring the common thread of community involvement and skill development.

Acknowledgement

This study is made possible by continuous support and guidance of many people. The authors express their sincere gratitude and appreciation to all those who directly or indirectly contributed to the completion of this study. They would like to acknowledge IOF and FRTC for providing them with the internship opportunity. Also they would like to express their sincere gratitude to Dr Shiv Kumar Manjan (Associate Professor, Tribhuvan University, Institute of Forestry, Hetauda) for his intensive guidance, continuous encouragement, constructive comments, and valuable suggestions during the entire research work. The research could not have been accomplished without the liberal support of the members of BMC, Koshi, which is also the internship venue.

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