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An Integrated Study of Natural Springs to sustain water security: Case Study of three villages from a Himalayan State of India

Un estudio integrado de manantiales naturales para mantener la seguridad hídrica: estudio de caso de tres pueblos de un estado del Himalaya de la India

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ABSTRACT

Equitable access to water, whether it is quantity or quality, is one of the fundamental rights. It facilitates economic development, gender equality and good human health. But in the last few decades, lack of potable water has caused illness and resulting millions of deaths. In Himalayan Region, springs are the basic water source which fulfills the needs of rural population. The point at which the groundwater emerges over the earth surface and flows naturally is called spring. Drying up of these springs, due to climate change and biophysical landscape change, is not only causing problem to human health, impeding gender equality but also causing nearby bio diversity to lose resilience. Therefore, a basic understanding of springs is required for its further studies and to maintain water security. This present work is focused on the initial steps of Spring Sanctuary development. The present outline emphasized on the spring mapping and has prepared a social database of springs of three villages of Saurakhaal nyay panchayat of jakholi block, Rudraprayag, Uttarakhand. The status of the springs has been assessed by monitoring their discharge data for eight months (Nov, 2020-June, 2021). Also, the endangered and vulnerable springs of the study area has been identified by scoring them on the basis of critical issues.

Key Words: Springs, Climate Change, Bio-Physical landscape, Spring Sanctuary, endangered and vulnerable springs.

RESUMEN

El acceso equitativo al agua, ya sea en cantidad o en calidad, es uno de los derechos fundamentales. Facilita el desarrollo económico, la igualdad de género y la buena salud humana. Pero en las últimas décadas, la falta de agua potable ha causado enfermedades y millones de muertes. En la región del Himalaya, los manantiales son la fuente de agua básica que satisface las necesidades de la población rural. El punto en el que el agua subterránea emerge sobre la superficie de la tierra y fluye naturalmente se llama manantial. El secado de estos manantiales, debido al cambio climático y al cambio del paisaje biofísico, no solo está causando problemas para la salud humana, impidiendo la igualdad de género, sino también causando que la biodiversidad cercana pierda resiliencia. Por lo tanto, se requiere una comprensión básica de los manantiales para sus estudios posteriores y para mantener la seguridad del agua. El presente trabajo se centra en los pasos iniciales del desarrollo de Spring Sanctuary. El esquema actual enfatiza el mapeo de manantiales y ha preparado una base de datos social de manantiales de tres aldeas de Saurakhaal nyay panchayat del bloque jakholi, Rudraprayag, Uttarakhand. El estado de los manantiales se ha evaluado mediante el seguimiento de sus datos de descarga durante ocho meses (noviembre de 2020-junio de 2021). Además, los manantiales vulnerables y en peligro de extinción del área de estudio se han identificado puntuándolos sobre la base de problemas críticos.

Palabras clave: manantiales, cambio climático, paisaje biofísico, santuario de manantiales, manantiales amenazados y vulnerables.

INTRODUCTION

Springs, locally termed as *dhara*, assumes great relevance to the natives of Indian Himalayan Region – socially, culturally, religiously, ecologically and economically. They are considered sacred and venerated as devithans (Tambe, Kharel, & Kulkarni, 2020). Being the common source of a common resource, springs are considered as the lifeline of Himalayan inhibiters. Approximately 5 million springs are estimated in India, 3 million out of these are located in Indian Himalayan Region only (Gupta & Kulkarni, NITI Aayog, 2018; Tambe et al., 2011, 2012; Negi and Joshi, 1996, 2002, 2004 ; Chapagain, Ghimire and Shrestha, 2017). For many Himalayan states, the only source of water is spring (Negi and Joshi, 2002; Valdiya and Bartarya,1991). 80% of Sikkim's rural population relies on springs for their water security (Tambe, Kharel, & Kulkarni, 2020). Uttarakhand houses many springs and 90 % of potable water supply here is spring based (Gupta & Kulkarni, NITI Aayog, 2018). Uttarakhand Jal Sansthan (UJS) has also deliberated that mountain springs are an important supply of drinking water as well as water required for domestic chores in rural Uttarakhand. This natural source provide water to over a million people in the entire Himalayan region and serve as a safe and reliable supply of water (ICIMOD, 2015).

Despite the indispensible role they play, this vital source has not been given adequate attention and care. As a result, they are in grave danger. The critical situation of the springs has manifested in form of its diminishing discharge, expeditious drying rate and increasing water scarcity. More than fifteen lakh of springs in IHR have either been dried up or became seasonal (Gupta & Kulkarni, NITI Aayog, 2018). As per last few decades, the health of springs is being debased in myriad ways. The unpremeditated development in the mountainous regions has resulted in considerable changes in land use and land cover, as well as reduction in the recharge areas of springs (Jeelani, Shah, & Deshpande, 2017). IPCC arrived at the conclusion that climate change will be evident in the form of increasing frequency of the natural calamities like intense storms, truant behavior of rainfall and drought in forthcoming years (Kusangaya et al., 2014). An erratic pattern of rainfall, its increasing intensity and decreasing frequency of distribution and ecological disturbance resulting from infrastructural development activities ought to be impacting the springs (Valdiya & Bartarya, 1989; Z. Xu et al.,2007; Ma et al.,2009). An outline recorded that 40% decrease in the spring discharge was attributed to the change in the vegetation and the LULC in the kumaun region (Valdiya & Bartarya, 1989). Another study demonstrated that drying up of springs causing many villages (approx 8,000) to face acute water scarcity in the Himalayan region (Mahamuni and Kulkarni, 2012). Although, aquifers have more refined influence, where the groundwater gets stored and discharges through these springs under the influence of varying geological formations (Patil, Barola, & Kulkarni, 2018).

Keeping in view the relevance of these springs, Of late, planning and management for their conservation has gained the momentum. Dhara Vikas Programme (2008, 2014) makes a splash by reviving and maintaining springs in the north eastern parts of Sikkim. The idea behind the programme was to increase the discharge of springs by recharging the groundwater and maintain water security. Spring sanctuary development has proved as decisive to sustain water security (Rawat, Jose, Rai, & Hakhoo, 2018). Revival of the springs was considered as an important thematic concern on the meeting convened on Sustainable development in mountains of Indian Himalaya region (Gupta & Kulkarni, NITI Aayog, 2018). ICIMOD &ACWADAM (2015) conduct Eight-step Methodology, which include, comprehensive mapping of springs and spring sheds; setting up data monitoring system; understanding social & governance aspects; hydro geological mapping; creating hydro geological layout of spring sheds; classifying spring types, identify aquifer & recharge area; developing spring shed management protocols; measuring the impact of spring revival to rejuvenate springs and improve spring sheds of mid Himalayas in Nepal. Arghyam (2007, 2008) flagged off its initiatives in spring based water security. The initiative use scientific methods to recharge springs, moderate flood peaks, enhance rainfall infiltration into ground, & also revive dysfunctional traditional system.

Deep spring studies were conducted in the western Himalaya, with an emphasis on features of spring discharge in relation to rainfall pattern (Singh and Rawat, 1985; Bisht and Srivastava, 1995). In these studies, spring discharge was found to be a consequence of both the rainfall pattern and the recharge area parameters (Rai et al., 1998; Negi and Joshi 1996; Valdiya & Bartarya, 1989; Rawat et al., 2017, 2018 ; Agarwal et al., 2012; vashisht and Sharma,2007). Although, the most constructive method of spring revival is spring sanctuary development which is usually carried out in six steps i.e., Spring mapping; Data Monitoring; Identification of Vulnerable Springs; Springshed mapping; the adaptive solution and training of para-hydrologist (Rawat, Jose, Rai, & Hakhoo, 2018).

The present work emphasized on the very first three steps of the spring sanctuary development method. This paper aims to explicate a social database of springs of the study area and to identify the endangered and vulnerable springs amongst them. Rainfall dependency of the springs has also been discussed in this outline. Other aspects as spring flow analysis, spring flow variability and water availability and requirement have been elucidated to comprehend the present status of the studied springs.

MATERIAL AND METHODS

Study area: The Uttarakhand state is divided into two divisions namely, Garhwal and Kumaon, having a total of thirteen districts. The Jakholi block of Rudraprayag district is located in garhwal division, between the coordinate 30° 37' to 30° 15'N and 79° 03' to 78° 50'E, cover an area of 497 km^2 .The block is bordered by Ukhimath block in north and east, Augustmuni block in south and Tehri garhwal district in west. Average rainfall of 1850-2000 mm is recorded in this block with temperature ranging from -5°C to 15° C in winters and 20°C to 35°C in summers (Singh, Nautiyal, Kunwar, & Bussmann, 2017). Besides Granite and phyllite, a large portion of Jakholi block has quartzite rock belong to the Jaunsar group embedded with partings of quartz veins (Rai, 2019). In this paper, an integrated study of natural springs of three villages namely, kharged, bansi and sera has been conducted.

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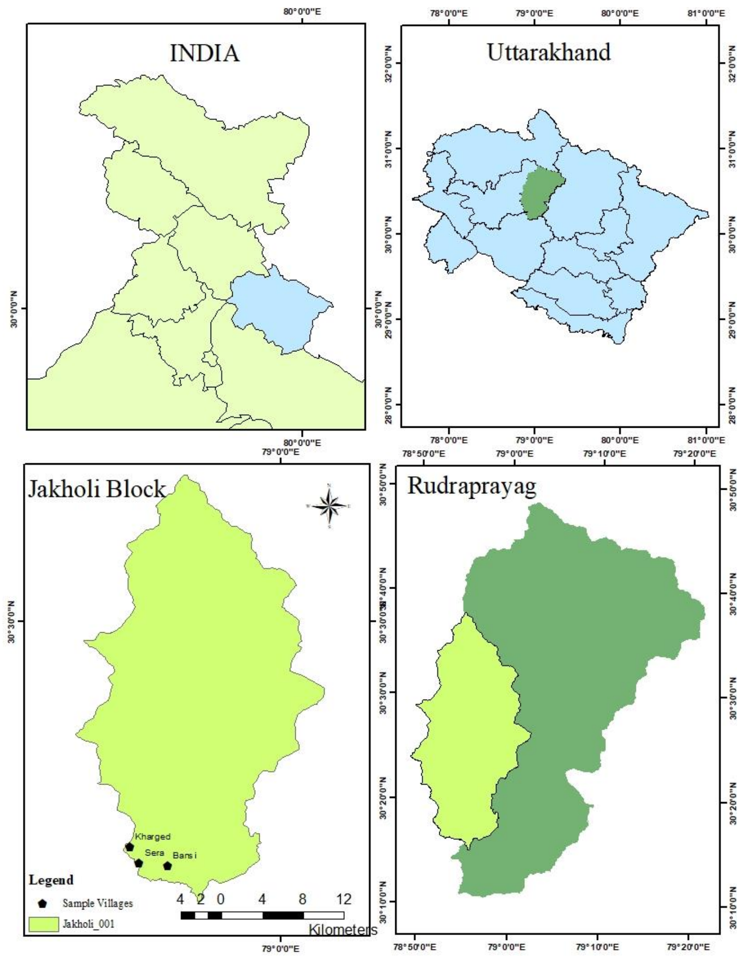

Fig. 1: Location Map of the study area

The study area was visited and the collected primary data was used to fulfill the objectives of the paper. Secondary data extracted from Indian Meteorological Department (IMD) and National Rural Drinking Water Programme (NRDWP) has been used in the present work. The springs were assessed through interviews conducted with the local people to gather information about the springs.

Database of springs:Transact walks were carried across the villages along with the local people to collect information about the springs. Global Positioning System (GPS) was used to record the locations of the springs and the general information about the spring was yielded by interacting with the local community. A questionnaire survey was used to compile a social data base of the springs. The respondents were local community and the representative of the population i.e. pradhan of the village. The springs are given specific IDs (Table 3) that are used in further studies.

Spring Flow Analysis: Hydrographs has been prepared to exhibit the link between spring discharge and the monthly rainfall. The bimonthly discharge of the discovered springs was recorded. The discharge data was monitored by the researcher with the help of the local people whereas; precipitation data for eight (November, 2020- June, 2021) months was collected from website of the Indian Meteorological Department.

Further, cumulative rainfall (mm) and cumulative spring flow (l/s) was extracted from the data to express the relationship between the spring flow and rainfall (Rathi et al., 2020). Moreover, the springs are classified on the basis of Meinzer's 1923 classification (Alfaro & Wallace, 1994):

Table 1. Meinzer's Classification of the springs

Magnitude	Mean discharge (gpm)	Mean Discharge
First	> 44,880	> 10 m^3/s
Second	4488-44,880	1-10 m^3/s
Third	448.8-4488	0.1 - 1 m^3/s
Fourth	100-448.8	10-100 l/s
Fifth	10-100	1-10 l/s
Sixth	1-10	0.1-1 l/s
Seventh	0.12 1	10-100 ml/s
Eighth	<0.12	< 10 ml/s

Source: Meinzer (1923b, p. 53)

The Discharge Variability and Index of variability has been calculated to appraise the reliability of the springs (Agarwal et al., 2012; Rawat, Jose, Rai, & Hakhoo, 2018).

Discharge variability of these springs was calculated using the following equation:

$$\text{Variability (\%)} = \frac{Qmax - Qmin}{Qave} \times 100 \quad (1)$$

Index of variability (I_v) is calculated as:

$$I_v = \frac{Qmax}{Qmin} \quad (2)$$

Q_{max}= maximum discharge of recorded eight months (L/s); Q_{min}= minimum discharge of recorded eight months (L/s); Q_{ave}= average discharge of recorded eight months (L/s)

Water availability and Requirement: As per interview held with the pradnhans of the respective villages, it is concluded that the inhabitants have an external water supply through pipelines to fulfill their other domestic chores. However, they prefer to queue up for spring water to meet their drinking purpose. So, an average demand-supply module (Fig. 6) of the spring water is prepared using the data from Census of India (2011), District Census handbook of Rudraprayag and the questionnaire survey. The surplus or deficit spring water flow was calculated on the basis of the Domestic Consumption, which has been decided as 55LPCD in rural areas (NRDWP, 2018)

Identification of the endangered and vulnerable springs: The increasing intensity and reducing temporal distribution of rainfall is causing a marked decline in the discharge of our natural springs (Tambe, Kharel, & Kulkarni, 2020). The impact of climate change along with other anthropogenic activities is making the natural springs endangered and vulnerable (Kaushik, 2017). So, it becomes necessary to recognize the critical springs. In this study, six indicators have taken into consideration regarding identification of the endangered and vulnerable springs (ICIMOD, 2016):

- Number of user households
- Reduced Discharge in last 15years
- Potabilty
- Proximity of other sources
- Water Availability (LPHD)
- No. of months water is sufficient

Table 2. Indicators for identification of critical springs

Indicators	No attention	Moderate attention	Immediate attention
No. of user households	0-5	5-20	More than 20
Reduced Discharge in last 15years	Less than half	Almost half	More than half
Potabilty	Potable Without treatment	potable with treatment	Undrinkable
Proximity of other sources	0-100m	100-200m	More than 200m
Water Availability (LPHD)	Above 150	55-150	0-55
No. of months water is sufficient	More than 9 months	4-9 months	Less than 4 months

Three different shades in Table 2 marked the indicators in three stratum of importance (No attention, Moderate Attention and Immediate Attention)

RESULTS AND DISCUSSION

Database of springs: In this study, seven springs have been discovered and mapped with the help of a GPS device. Table 3 provides a database of discovered springs. Springs can be identified in the Figure 2 with the help of spring's name that are mentioned in Table 3.

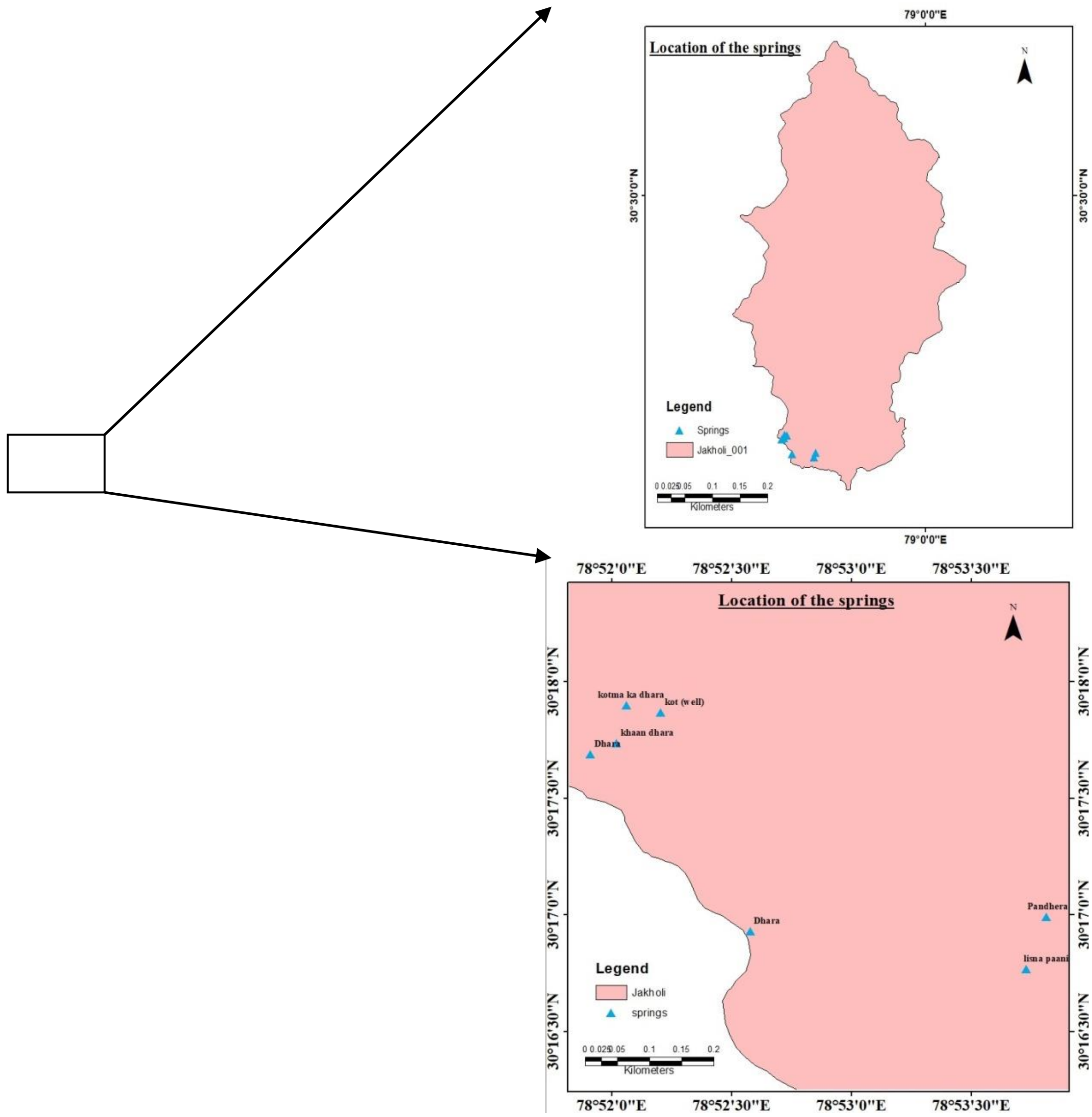

Fig 2: Map showing the location of the discovered springs

The springs that have been mapped were studied further to collect data on their discharge, people's perception, societal disputes and governance issues related to them. SpKh4 is not included in further studies because the discharge measurement for the respective well could not be maintained and visited considering the lockdown amid the covid pandemic.

Table 3. Database of springs

S.No.	Spring ID	Spring Name	Village	Latitude	Longitude	Elevation (ft)	Type(Spring/Well)
1.	SpBa1	Pandhera	Bansi	30°16.997' N	78°53.819'E	3324	Spring
2.	SpBa2	Lisna Paani	Bansi	30°16.771' N	78°53.734' E	3506	Spring
3.	SpKh1	Khaan Dhara	Kharged	30°17.736'N	78°52.021'E	2820	Spring
4.	SpKh2	Dhara	Kharged	30°17.693'N	78°51.912'E	3004	Spring
5.	SpKh3	Kotma Dhara	Kharged	30°17.902' N	78°52.065'E	3935	Spring
6.	SpKh4	Kot	Kharged	30°17.868'N	78°52.210'E	3800	Well
7.	SpSe1	Dhara	Sera	30°16.929'N	78°52.475'E	2843	Spring

Source: Primary Survey

Table 4 provides a social data base of the invented springs. It shows that all seven springs are possessing high dependency to fulfill drinking and domestic needs of the villagers.

Table 4. Social Database of the springs

Spring ID	Dependency (High, Medium , Low)	Use (Drinking, Domestic, Irrigation, others)	Decrease in the spring flow in last 15 years(Perception based)	Water conflicts	Seasonality of the spring	Spring managing
SpBa1	High	Drinking, Domestic, irrigation	Decrease	No	Perennial	Gram Panchayat
SpBa2	Medium	Domestic	Decrease	Yes	Perennial	Gram Panchayat
SpKh1	Medium	Drinking, Irrigation	Decrease	No	Perennial	Gram Panchayat
SpKh2	Medium	Domestic, Drinking	Decrease	No	Perennial	Gram Panchayat
SpKh3	Medium	Drinking, Irrigation	Decrease	No	Seasonal	Gram Panchayat
SpKh4	Medium	Drinking, Domestic, irrigation	Decrease	No	Perennial	Gram Panchayat
SpSe1	High	Drinking, Domestic	Decrease	No	Seasonal	Gram Panchayat

Source: Primary Survey

Spring flow analysis

Water Discharge Pattern: Hydrographs in Figure 3 illustrate a positive relationship between spring discharge and rainfall. SpSe1 records the highest discharge while SpBa2 witnessed the lowest discharge. The spring stimulation to rainfall can easily be correlated. This response diminishes for months that records low rainfall. Amongst the studied springs, the most instant response to the rainfall is depicted in SpBa1 and SpSe1 while the least response is observed in SpBa2.

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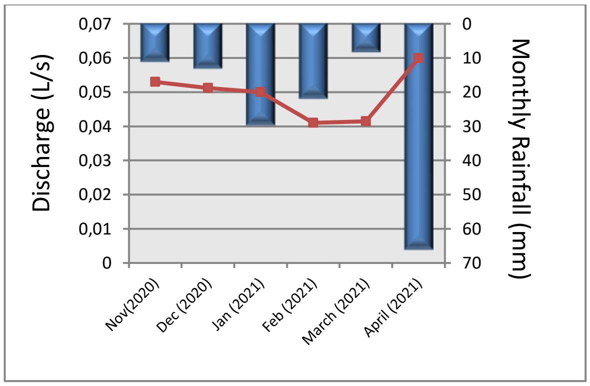
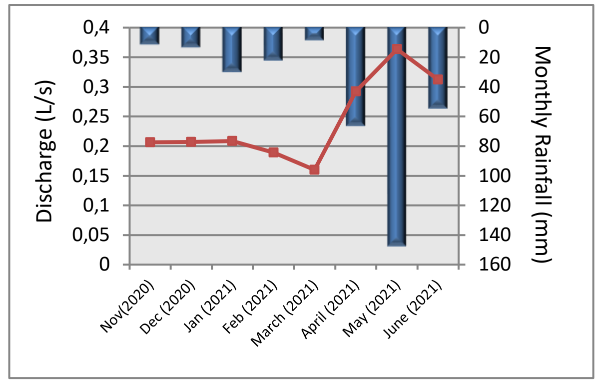
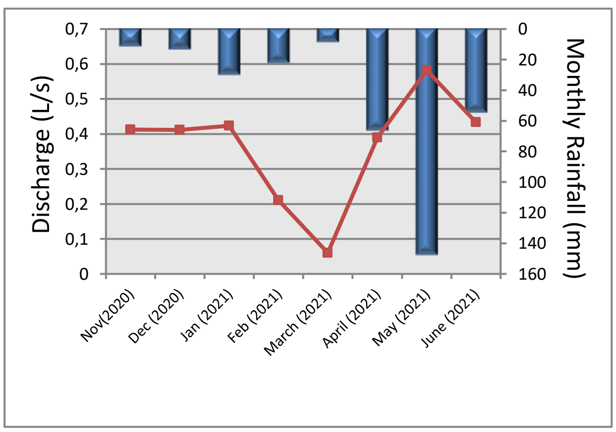
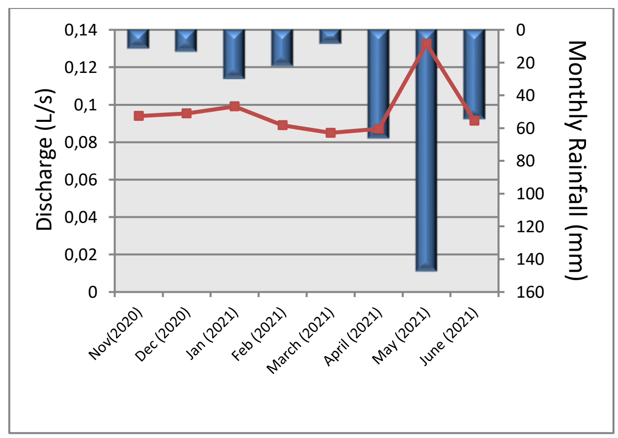


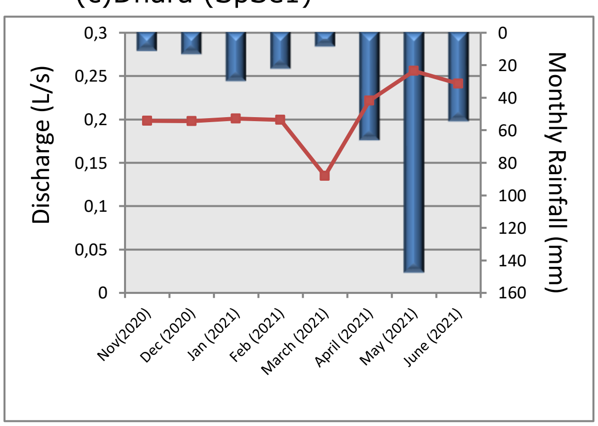


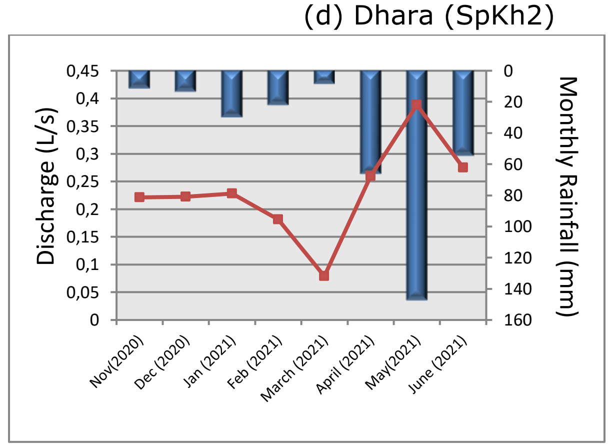
(a) Lisna Paani(SpBa2)* (b)
Pandhera (SpBa1)





(c)Dhara (SpSe1) (d) Dhara (SpKh2)





(e) Khaan Dhara(SpKh1) (f) Kotma Dhara (SpKh3)

Fig. 3: Monthly Discharge Hydrographs of studied springs

*The discharge data of Lisna Paani Dhara could not be recorded for months of May and June because the spring got enshrouded by falling debris.

Source: Primary Data and IMD

Discharge Characteristics of the Springs: The cumulative rainfall (mm) and the cumulative spring flow (l/s) are displayed in Fig 4. The cumulative rainfall and the cumulative spring flow for the months recording high rainfall shows a linear response which suggests that the recharge area of respective springs lies nearby ambit of the spring. The springs show non linear behavior for the months of low rainfall.

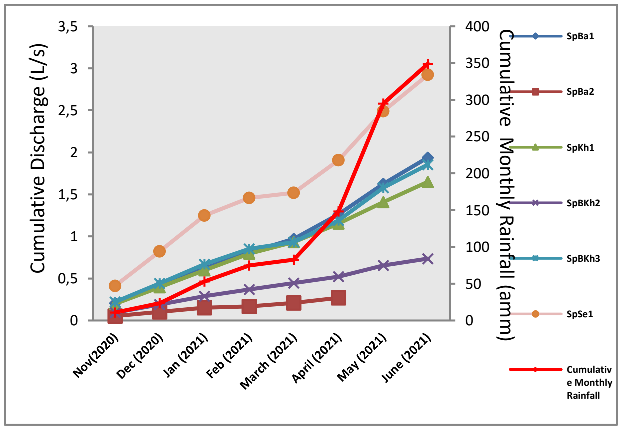


Fig. 4: Cumulative rainfall with the cumulative discharge rate

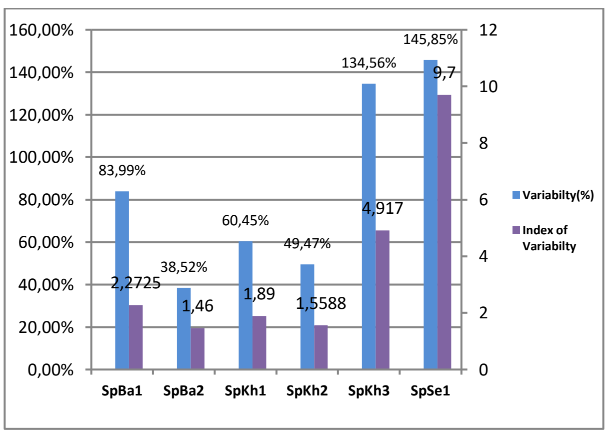


Fig. 5: Variability and the index of variation

The respective figure shows that the SpSe1, SpBa1, SpKh3 and SpKh1 are highly responding springs as they witness an increase in their discharge with the increasing rainfall whereas, a very least response to rainfall recorded in discharge rate of SpBa2 and SpKh2 shows that the respective aquifers posses less infiltration and low transmissivity.

The minimum, maximum and average spring flow information was calculated to estimate the variability of springs and to understand spring flow behavior. Only average discharge cannot be effectual to evaluate the potentiality of any spring. To evaluate the reliability of a spring, minimum discharge and the variability in the discharge is pertinent. The maximum Variation in the flow of SpSe1 and SpKh3 (145.85%, 134.56% respectively) and their minimum recorded flow (0.06 L/s, 0.079 L/s respectively) suggest that their reliability is susceptible whereas a low variation in the flow of SpBa2 (38.52%) and SpKh2 (49.47%) propounds them dependable.

Table 5. Discharge Characteristics of the springs

Spring Id	Max flow(l/s)	Min Flow(l/s)	Average(l/s)	Variabilty (%)	Spring Class
SpBa1	0.3636	0.16	0.2424375	83.99%	6th
SpBa2	0.0599	0.041	0.049433	38.52%	7th
SpKh1	0.2559	0.135	0.2063	60.45%	6th
SpKh2	0.1325	0.085	0.09668	49.47%	7th
SpKh3	0.3885	0.079	0.23195	134.56%	6th
SpSe1	0.582	0.06	0.365425	145.85%	6th

Source: Primary Survey

Using Meinzer's classification of the springs on the basis of their discharge, SpBa2 and SpKh2 is categorized as 7th magnitude while the remaining springs of the area falls under the 6th magnitude.

Potable Water Availability and Requirement: Figure 6 shows that, except SpBa2, all other springs meet the required potable water demand. Water availability from SpBa2 (31.63 LPCD) is less than the requirement from the respective spring (55LPCD).

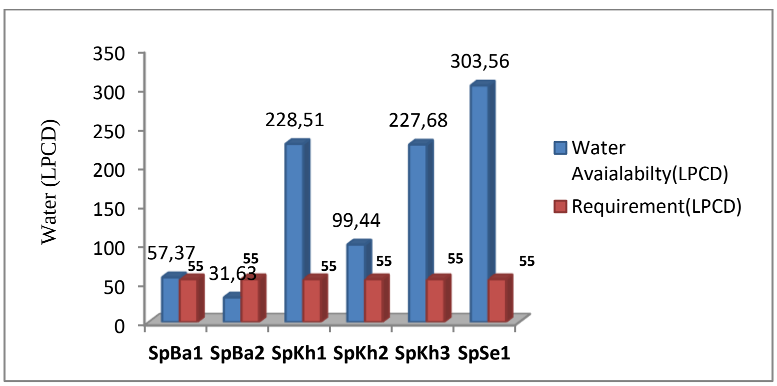


Fig. 6: Graph showing water availability and requirement

Source: Primary Survey and NRDWP

The endangered situation of SpBa2 puts high pressure on SpBa1. SpBa1 is located approximately 200m from SpBa2 and consequently imposes the pressure on the women of the village to fetch the water for their families. These situations is concerning, for it give rise to the problem of gender vulnerability.

Identification of endangered and vulnerable springs: According to pre-mediated indicators, three out of the studied springs are in a critical situation and an instant action is needed to rejuvenate these springs so the water security could be maintained for the local people.

Table 6. Hardship ranking of the springs

Spring Code	Spring Name	No. of user households	Reduced Discharge in last 15 years	Potabilty	Proximity of other sources	Water Availability (LPHD)	No. of months water is sufficient
SpBa1	Pandhera	80	Almost half	Without treating	200m	57.37	10
SpBa2	Lisna Paani	20	More than half	With treating	200m	31.63	3
SpKh1	Khaan Dhara	15	Less than half	Without treating	100m	228.51	10
SpKh2	Dhara	12	Almost half	Without treating	100m	99.44	6
SpKh3	Kotma dhara	15	Almost half	Without treating	150m	227.68	9
SpSe1	Dhara	32	Less than half	Without treating	100m	303.56	9

Source: Primary survey

Based on the Hardship Ranking System, SpBa2 is categorized as an endangered spring that requires immediate attention. While, SpBa1 and SpKh2 are considered as the vulnerable ones that could turn, sooner or later, into endangered if not taken care early. Since a large apportion of the population count on these springs to satisfy their drinking, irrigation and domestic needs, springshed management through the participation of the community is requisite.

As conclusion, the issue of water scarcity is highly suffusing in the rural parts of Himalayan states because the springs, prime natural source, are swiftly worsening due to its inappropriate utilization, assessment and management. Considering the pertinence of this traditional source, many organizations- *People Science Institute, Central Himalayan Rural Action Group (CHIRAG), Himalayan Seva Sangh (HSS), ACWADAM, ICIMOD, Arghyam, Himmotthan Society* are relentlessly working to develop spring sanctuary for rejuvenation of these springs.

Through this study, an attempt has been made to provide the database of discovered springs, which shows a high dependency on the spring for drinking purpose. An assessment of the discharge of springs and their reliance on rainfall shows different characteristics of the springs. High reliability of SpBa2 and SpKh2 exclaim their rejuvenation at the earliest. Also, high dependency and low water yield in the vulnerable and endangered springs (SpBa2 and SpKh2) makes their revival indispensable. The reliability of the springs can be enhanced by building minimum storage to fulfill the local water demand during the lean season (Feb- April). The deteriorating condition of SpBa2 is not only imposing excess population pressure on SpBa1, but also playing as a factor increasing gender vulnerability.

The concept of spring sanctuary development and its application is making splash by increasing the discharge of the springs within a water year. Spring sanctuary is, now, being looked up as an efficacious method to eradicate the problem of water insecurity. This method can be implemented in the studied area to restore the health of the critical springs and hence, perpetuate water security.

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