

P-ISSN: 2706-7483
E-ISSN: 2706-7491
NAAS Rating (2026): 4.5
IJGGE 2026; 8(6): 109-116
www.geojournal.net
Received: 08-03-2026
Accepted: 12-03-2026

Manisha

Department of Geography,
School of Earth Science,
H.N.B. Garhwal University,
Srinagar, Uttarakhand, India

Vandana Goswami

Department of Geography,
School of Earth Science,
H.N.B. Garhwal University,
Srinagar, Uttarakhand, India

Mahabir Singh Negi

Department of Geography,
School of Earth Science,
H.N.B. Garhwal University,
Srinagar, Uttarakhand, India

Corresponding Author:

Manisha

Department of Geography,
School of Earth Science,
H.N.B. Garhwal University,
Srinagar, Uttarakhand, India

Spatial analysis of spring water resources and village water security in Devalgarh Nyaya Panchayat of Khirsu Block, Pauri Garhwal, Uttarakhand

Manisha, Vandana Goswami and Mahabir Singh Negi

DOI: <https://doi.org/10.22271/27067483.2026.v8.i6b.791>

Abstract

Springs are the primary source of drinking water and domestic water supply for Himalayan Mountain communities, yet many are declining due to climate variability, land-use change, and reduced recharge. This study presents a comprehensive spring inventory and water budget assessment for 25 villages in Devalgarh Nyaya Panchayat, Khirsu block, Pauri Garhwal district, Uttarakhand. Field surveys were conducted during the pre-monsoon season. Village-level water demand was estimated using Jal Jeevan Mission standards and compared with measured spring discharge to evaluate water availability. Results revealed significant spatial variation. GIS-based mapping highlighted the uneven distribution of spring resources and the dependence of several villages on external piped supply, which remains unreliable during lean seasons. Household surveys further underscored the socio-economic burden of water scarcity, particularly on women and elderly members. The findings provide baseline data for local water security planning and sustainable management of spring-fed systems. The methodology offers a replicable framework for decentralised water resource assessment in other Himalayan regions.

Keywords: Spring inventory, water security, Devalgarh, water demand, water budget

1. Introduction

Springs are the naturally occurring primary water source for drinking, domestic, and agricultural use for the mountain communities. They are groundwater discharge points where the stratified zone of the aquifer intersects the surface and water seeps from rock pores, fissures, fractures, or depressions (Akhtar, N., Syakir, M. I., Anees, M. T., Qadir, A., & Yusuff, M. S. 2020) ^[1]. Mountain springs are the primary source of water for rural households in the Himalayan region. For many communities, springs are the sole source of drinking water, irrigation, and livestock needs. Early in the 60% of residents in the Himalayas depend on spring water, yet surveys show that half of the perennial springs have already dried up or become seasonal, leading to acute water shortages across thousands of villages (Bishwadeep Ghose, Arghyam Shri Vinod Kothari, Tata Trusts *et al.*, 2018) ^[2]. These springs are at risk of drying up or diminishing during the lean season due to climate variability, climate change, and land-use changes across the catchment (Singh Thapa Chitra, 2023) ^[3]. The historical origins of springs are familiar to local inhabitants. They refer to them as Khals, Chal, Gharats, and Naulas. According to Srivastava *et al.* (2025) ^[4], in Indian Himalayan communities, between 60% and 70% of the population depends directly on springs for domestic and livelihood needs. Additionally, springs are highly valued in these communities for cultural and religious reasons. The quantitative assessment of spring discharge is fundamental for characterising water availability in rural settlements and for formulating sustainable water resources management strategies (Daniel *et al.*, 2021) ^[5]. Systematic spring inventory investigations yield critical information on the spatial distribution, discharge dynamics, utilisation, and socio-economic relevance of springs. These data are indispensable for determining the extent to which existing spring-fed water resources can meet local communities' domestic water demands. Water budgeting is an important tool for assessing the balance between water availability and water demand within a settlement. By comparing spring discharge with the prescribed domestic water requirement, potential water surplus or deficit conditions can be identified. The integration of spring discharge measurements with village population data, therefore, provides a scientific

basis for evaluating water security and planning future interventions (Kim *et al.*, 2021) [6]. Basically, this study provides details on the pre-monsoon season, which is the most critical period for springs because groundwater recharge from the monsoon has diminished. Thus, discharge measurements during this time provide a realistic estimate of water availability under stressed conditions. The Indian Meteorological Department classifies the pre-monsoon season as the period from March to May, characterised by increased temperature and reduced water availability in the May Himalayan regions. This study aims to

- 1) Prepare a spring inventory of selected villages,
- 2) Measure spring discharge during the pre-monsoon period, and
- 3) Assess village-level water budget by comparing available spring discharge with domestic water demand.

The findings are expected to contribute to sustainable water resource planning and spring conservation in the study area.

2. Study area

This study was conducted in Devalgarh Nyaya Panchayat, located at a longitude of 87.52°30'E to 78.49°30" E and a latitude of 30.10°30" N to 30.13°30" N within the Khirsu Community Development Block of Pauri Garhwal district, Uttarakhand, India. Pauri Garhwal is one of the hilly districts of the Garhwal Division of Uttarakhand, covering an area of 5,230 sq km, which is nearly 10.7% of the state's total geographical area. According to the 2011 population census, Devalgarh Nyaya Panchayat has a total population of 1,737 persons distributed across 25 villages. This region is characterised by a subtropical to temperate climate, with seasonal variation in rainfall and temperature influencing water availability.

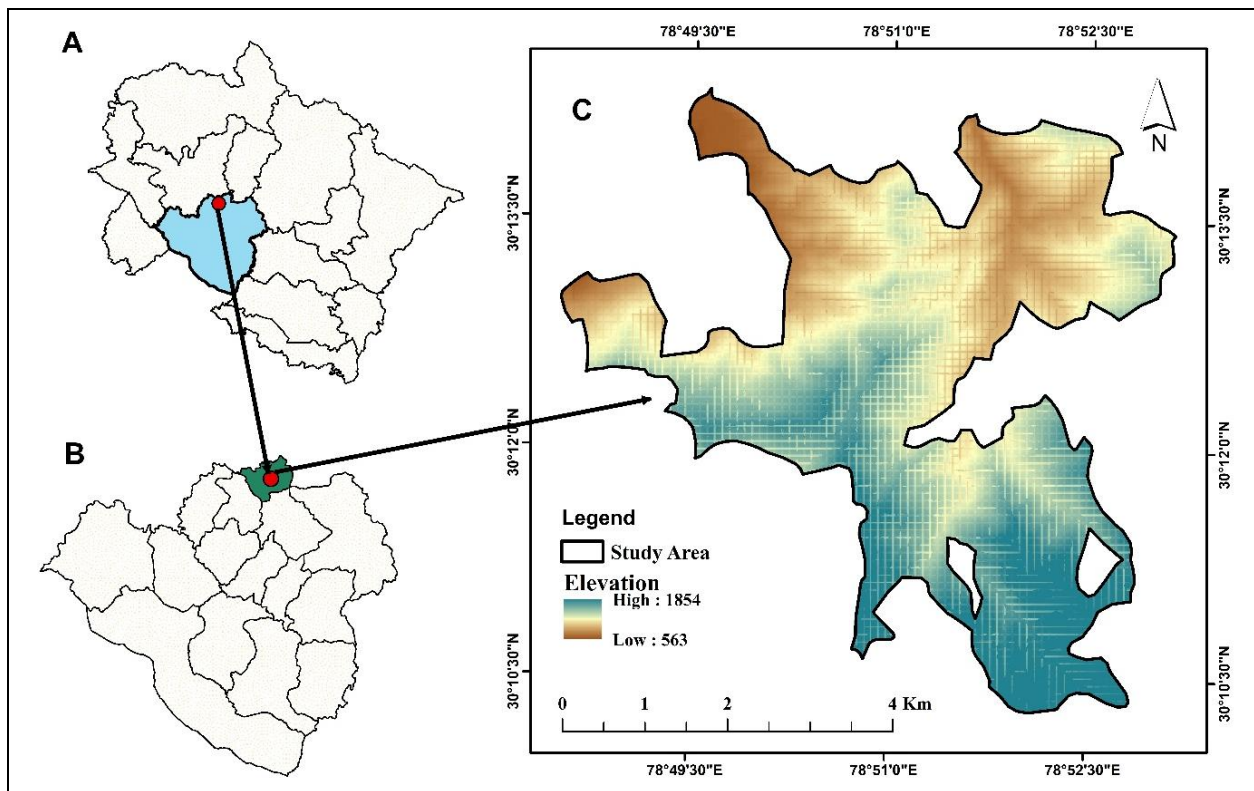


Fig 1: Study Area; (A) Pauri District in Uttarakhand, (B) Khirsu Block in Pauri, (C) Devalgarh Nyaya Panchayat

3. Methodology

3.1 Data collection and inventory

This study is based entirely on primary data collection. A field survey was conducted in the villages of Devalgarh Nyaya Panchayat, Khirsu block of Pauri district, during the pre-monsoon season. The geographic coordinates of each spring were recorded using a handheld mobile GPS application. Information regarding Spring type, location, water uses, Seasonality, etc., was also documented by observation and questioned by local residents. Detailed methodology is described in Fig 2.

3.2 Discharge measurement

Spring discharge was measured in March and April, which

represent the period of minimum water availability. The volumetric method was employed to estimate the discharge. A container volume of one litre was filled directly from the spring outlet, and the time required to fill the container was recorded using a stopwatch. Three observations were taken at each spring for the average time discharge calculation.

The discharge rate was calculated as:

$$Q = V/T,$$

where Q is the discharge rate in litres per second, V is the volume of the container in litres, and T is the time taken to fill the container.

The resulting discharge values were subsequently converted into litres per minute (L/min) and litres per day (L/Day).

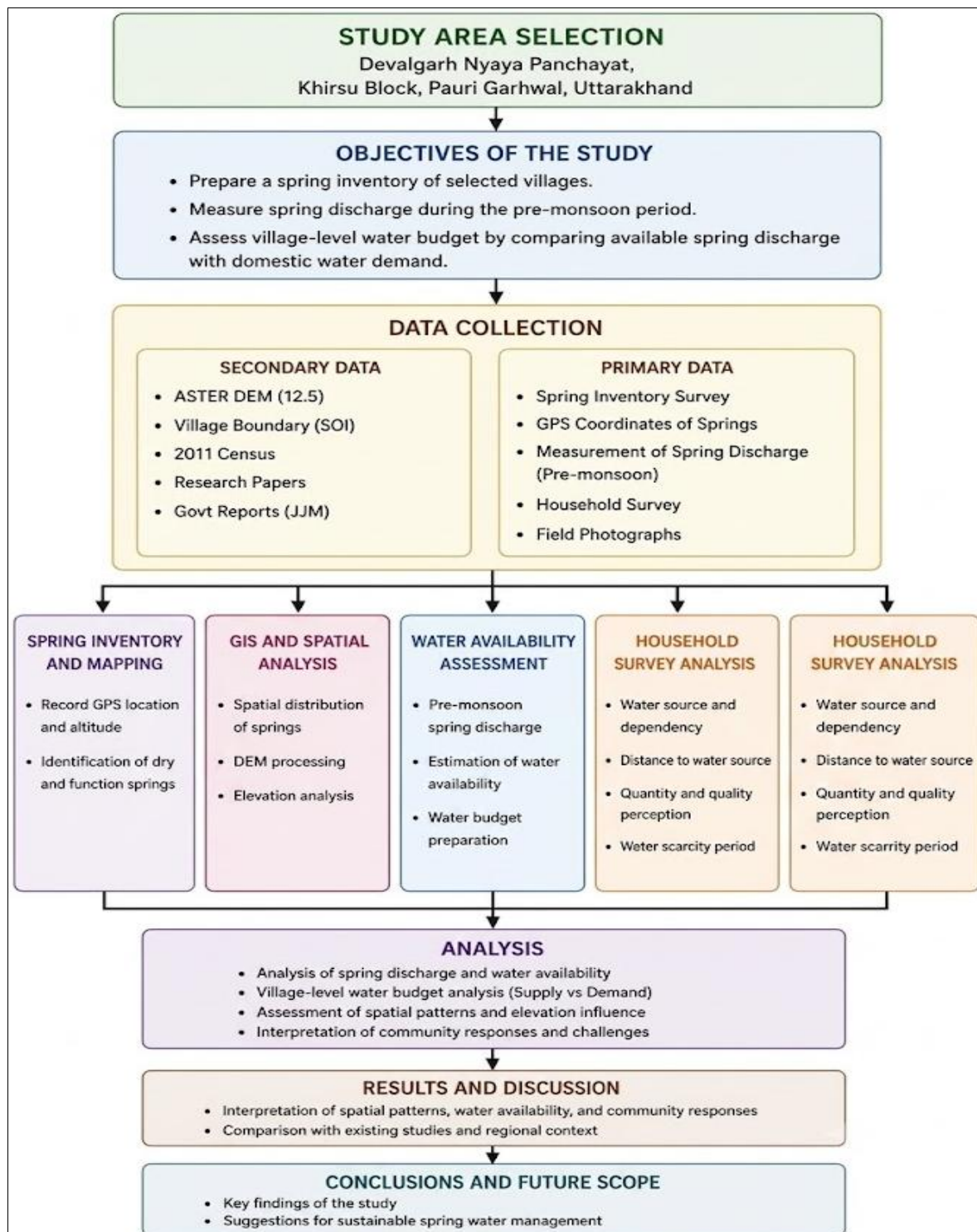


Fig 2: Detailed flowchart of methodology

3.3 Water demand estimation

Village population data were obtained from the Khirsu Block Development Office. Rural Domestic water demand was estimated based on the Jal Jeevan Mission Standard of the Government of India, at 55 litres per capita per day (LPCD), a transition from the old 40 LPCD set by NRDWP (National Rural Drinking Water Programme).

Water demand for a village was calculated as:

$$\text{Water Demand} = \text{Population} \times 55$$

where water demand is expressed in Litres per Day (L/Day).

3.4 Water budget analysis

The village water budget was assessed by comparing the

total available spring discharge with the estimated domestic water demand. In villages having more than one spring, the discharge of all springs was summed to determine total water availability.

$$\text{Village Water Budget} = \text{Water availability} - \text{Water demand}$$

A positive value indicates water surplus, while a negative value indicates water deficit.

3.5 GIS mapping and spatial analysis

The spatial distribution of the springs was mapped in ArcGIS by converting marked locations to point features using geographic coordinates. Village boundaries were downloaded from the Survey of India Portal. Elevation and

the other data were integrated into a GIS environment. Graduated symbols were prepared to represent variation in each spring discharge. Spatial interpolation techniques were also used to visualise the distribution of discharge across the study area.

Result and Discussion

This assessed the existing water availability in the study area. The primary focus of this study was to locate and map existing spring sources and their status in terms of water discharge and water budget for villages during the pre-monsoon period in Devalgarh Nyaya Panchayat.

4.1 Spring inventory and mapping

A comprehensive field survey conducted during the pre-

monsoon season identified springs across the villages in the study area. This study covers 25 villages in Devalgarh Nyaya panchayat, based on Khirsu Block Office data (2011), and identified a total of 12 active and 6 dry springs across the region (*Fig 3 & Table 1*). One spring in the village of Sarna and Akhara has dried up, while 3 springs in the village of Kanda have also dried up. While 10 villages named Sankholi, Ratura, Toulyu, Gawad, Reitpur, Katakholi, Gairu, Rampur, Badarpur, and Bugani do not have any springs. They totally depend on the pipeline connected to springs in another village or to the Srinagar town, primarily serving the surrounding villages through the PM Jal Yojna. But during the lean season, all the villages faced severe water scarcity.

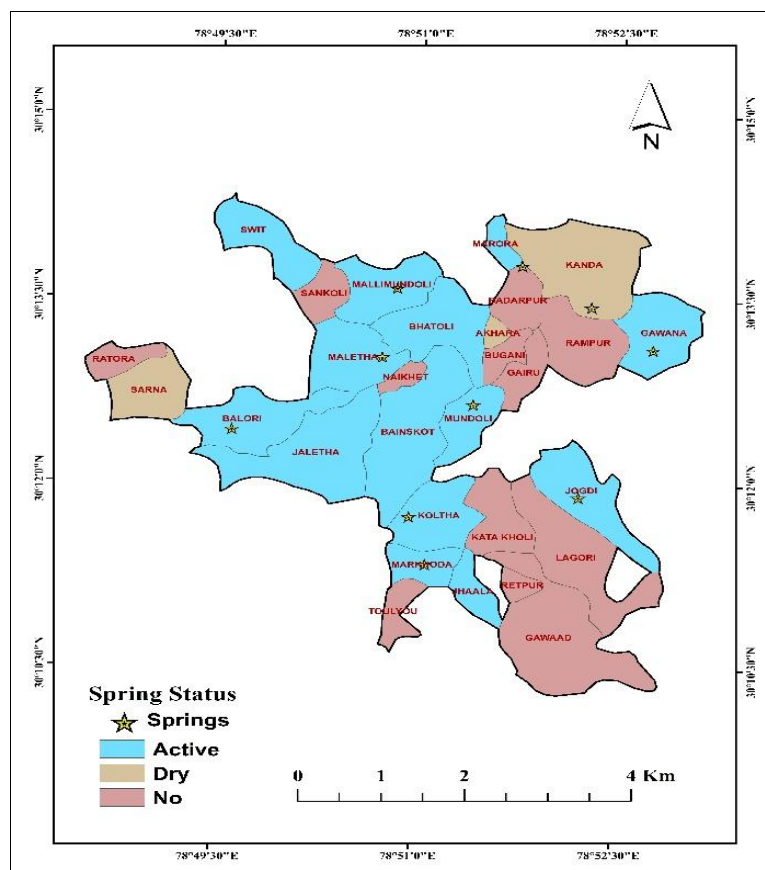


Fig 3: Village-wise spring status in the study area

Table 1: Spatial inventory of the active springs

S. No.	Spring ID	Latitude	Longitude	Altitude (m)
1	S1	30.22967	78.86272	722
2	S2	30.22414	78.87146	853
3	S3	30.22647	78.84718	972
4	S4	30.21076	78.85695	1061
5	S5	30.21711	78.84549	1065
6	S6	30.21842	78.87925	1088
7	S7	30.2071	78.82691	1186
8	S8	30.19832	78.8703	1260
9	S9	30.11433	78.5117	1303
10	S10	30.19547	78.8492	1368
11	S11	30.18903	78.85132	1401
12	S12	30.11352	78.51274	1418

4.2 Spring discharge characteristics

The pre-monsoon period represents the critical low-flow season when water availability is generally at its minimum. The variation in measured discharge values among the villages indicates differences in recharge conditions, geological structures, and catchment characteristics. The discharge of active springs varied from 0.63 to 15.77 litres per minute. Based on this discharge classification, springs

were categorised into low, moderate, and high discharge rate (Fig 4 & Table 2). The highest discharge was recorded at Balodi (S7) village, whereas the lowest discharge was observed at spring ID S1 at village Maroda. This variation in discharge may be attributed to differences in the slope characteristics, vegetation cover, and groundwater storage capacity.

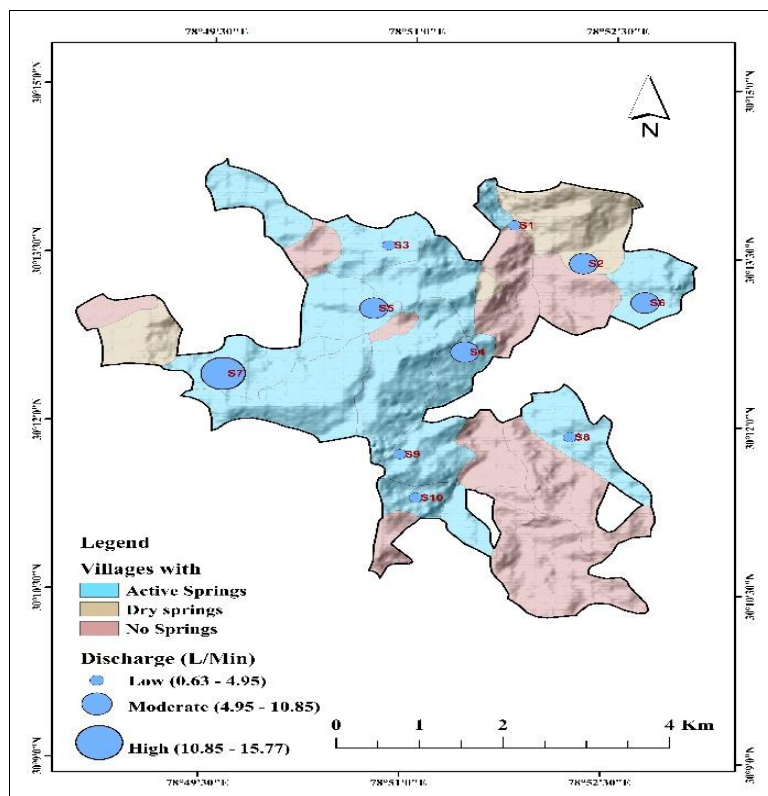


Fig 4: Discharge map of springs (L/Min)

Table 2: Village-wise spring discharge

S. No.	Village	Spring ID	Q = Lit/min	Q = L/Day
1	Maroda	S1	0.63	900
2	Kanda	S2	10.85	15624
3	Mallimandoli	S3	3.99	5746
4	Mundoli	S4	7.97	11479
5	Maletha	S5	9.01	12974
6	Gawana	S6	9.02	12989
7	Balodi	S7	15.77	22714
8	Jogdi	S8	3.99	5751
9	Koltha	S9	5.18	7459
10	Bhenskot	S10	2.14	3080
11	Markhoda	S11	4.95	7120
12	Jhala	S12	2.13	3067

4.3 Water availability and domestic water demand

Calculated domestic water demand based on the standard norm of Jal Jeevan Mission as Litres Per Capita Per Day. Uneven population distribution results in varying water

demand among villages. Comparison of available spring water with estimated water demand (Table 3) provides valuable insight into the sustainability of existing water resources.

Table 1: Spring water availability & demand

S. No.	Village	Population	Water availability (L/Day)	Demand (L/Day)
1	Maroda	55	900	3025
2	Kanda	184	15624	10120

3	Mallimandoli	58	5746	3190
4	Mundoli	54	11479	2970
5	Maletha	142	12974	7810
6	Gawana	102	12989	5610
7	Balodi	95	22714	5225
8	Jogdi	334	5751	18370
9	Koltha	155	7459	8525
10	Bhenskot	293	3080	16115
11	Markhoda	238	7120	13090
12	Jhala	27	3067	1485

4.4 Village-wise water budget assessment

Water budget analysis shows the balance between available water resources and domestic demand among villages. It is a calculation used to measure the ratio of water demand to supply for a particular water body, e.g., a spring in a mountain. The concept behind a water budget is that the rate of change of water stored in an area is balanced by the quantity and rate at which water flows into and out of that area.

Villages with lower discharge and higher population are

associated with limited water scarcity, particularly during the lean season, whereas higher spring discharge related to population indicates surplus water availability. The prepared water budget (table) indicates that Kanda, Mallimandoli, Mundoli, Maletha, Gawana, Balodi, and Jhala villages had a water surplus, while Maroda, Jogdi, Koltha, Bhenskot, and Markhoda Villages showed a deficit during the pre-monsoon period. The daily discharge rate of every village is shown in Table 4.

Table 2: Water budget status of villages

S. No.	Village	Water Availability (L/Day)	Demand (L/Day)	Budget status	Water status
1	Maroda	900	3025	-2125	Deficient
2	Kanda	15624	10120	5504	Surplus
3	Mallimandoli	5746	3190	2556	Surplus
4	Mundoli	11479	2970	8509	Surplus
5	Maletha	12974	7810	5164	Surplus
6	Gawana	12989	5610	7379	Surplus
7	Balodi	22714	5225	17489	Surplus
8	Jogdi	5751	18370	-12619	Deficient
9	Koltha	7459	8525	-1066	Deficient
10	Bhenskot	3080	16115	-13035	Deficient
11	Markhoda	7120	13090	-5970	Deficient
12	Jhala	3067	1485	1582	Surplus

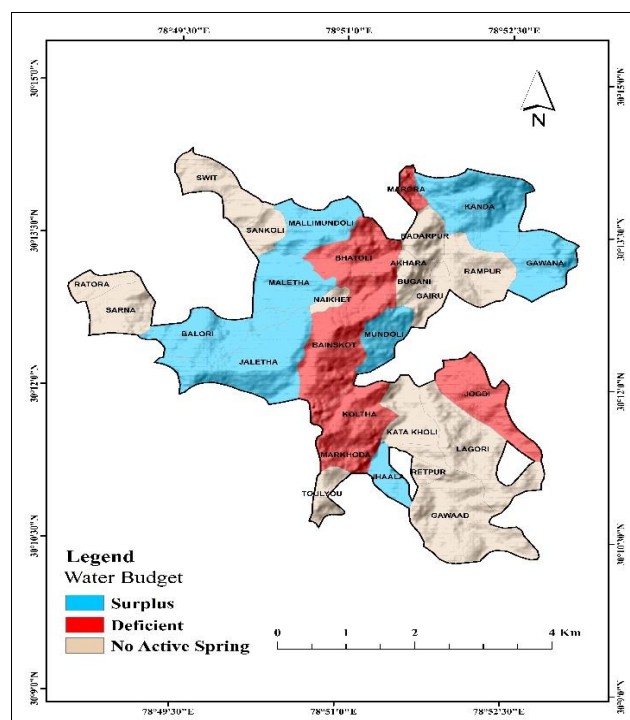


Fig 5: Water budget status of villages

Fig 5 highlights the water-deficient and surplus areas in Devalgarh Nyaya Panchayat. It underscores the importance of spring discharge monitoring and recharge-area management to ensure long-term water security. Maroda, Bhatoli, Bainskot, Koltha, Maekhoda, and Jogdi villages face acute water shortages during the pre-monsoon season. Although all villages are connected by a pipeline, those without natural springs lack alternative water sources, so water shortages are a permanent issue there. Villages experiencing water deficits require measures to enhance recharge, spring rejuvenation activities, or alternative water supply arrangements.

4.5 Elevation and spring discharge characteristics

The Devalgarh Nyaya Panchayat region lies within an elevation range of 563-1854 m above sea level and is classified into three elevation zones: low (563-1071 m), moderate (1071-1496 m), and high (1496-1854 m) (Fig 6). The highest discharge was observed in Balodi (15.77 L/min), located at an elevation of 1186m, whereas the lowest discharge was recorded at Maroda Spring (0.63 L/min) situated at 722 m. This analysis indicates that spring discharge does not show a consistent increase or decrease with elevation. For example, Bhainskot and Markhoda have low discharge values despite not occurring at higher elevations of 1368m and 1401m, respectively.

Conversely, Balodi and Kanda show higher discharge rates.

The shows that the concentration of active springs within the low- and moderate-elevation zones has good hydrogeological conditions for groundwater energy.

4.6 Challenges faced by villagers

The author conducted an intensive household survey to document the issues faced by local communities. Five household respondents from each village reported irregular water supply, which relies on a distant water source and increases the time required for daily water collection. But some villages don't even have a tap water supply, and there is severe water scarcity, particularly in the pre-monsoon lean season. The major problem is that the increased burden on women and elderly family members, who are primarily responsible for fetching water. Villages like Ratura, Akhara, Badarpur, and Sarna depend on tanks during periods of acute scarcity. An example of inadequate spring management was observed in Bhainskot village, where a spring-fed water supply system connected to the Naulli, but the structure was poorly designed and maintained. As a result, spring water was partially exposed, leading to increased turbidity and deteriorating water quality over time, yet people had to use this water for domestic purposes. All this information highlights that spring degradation is not only a hydrological issue but also a socioeconomic challenge.

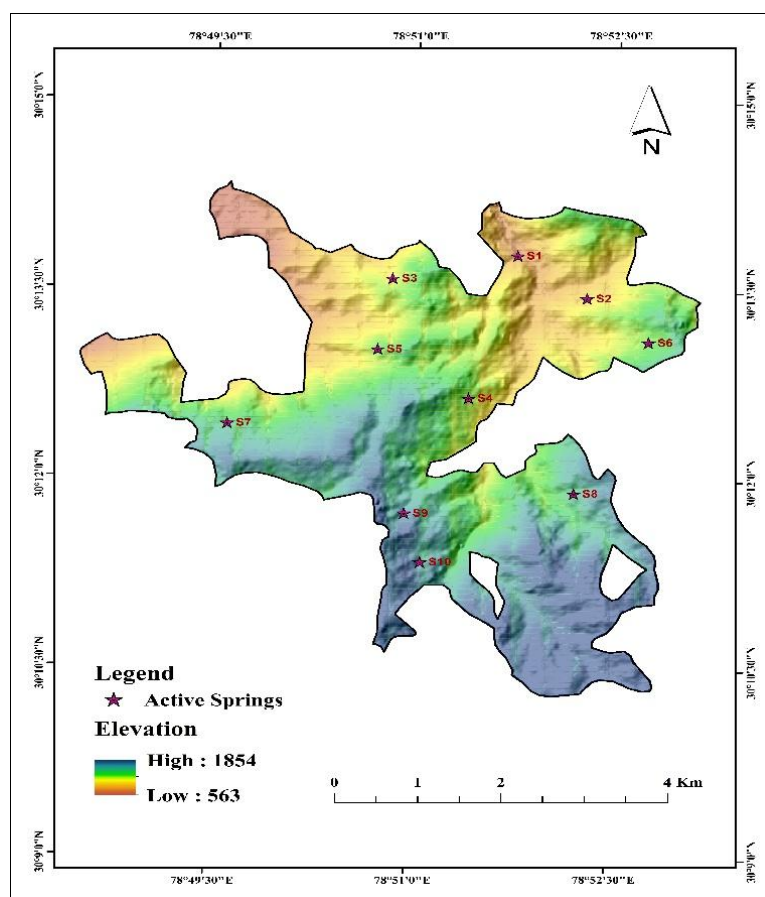


Fig 6: Location of spring on different altitude

5. Conclusion

A comprehensive spring inventory was conducted in the Devalgarh Nyaya Panchayat, Khirsu block, Pauri district, Uttarakhand. The dry springs were concentrated in four villages, named Akhara, Sarna and Kanda, where Kanda

also has one active spring, indicating localised water stress and declining spring conditions.

Spring discharge measurements reveal spatial variation among active springs, reflecting differences in recharge conditions, geological characteristics, and groundwater

availability. Village-level water budget analysis provided a scientific basis for evaluating the balance between water availability and village water demand. Although the villages have a piped water supply, the villagers experience water scarcity, and women must fetch water from distant springs. The occurrence of dry springs in several villages indicates potential impacts from reduced recharge, changing land-use patterns, and increased pressure on groundwater resources,

underscoring the need for continuous monitoring. The invented location and discharge are valuable baseline information for local planning, water security assessment, and spring conservation initiatives in Devalgarh Nyaya Panchayat. The methodology adopted in this study can be replicated in other Himalayan villages to support decentralised water resource planning and sustainable management of spring-fed water systems.



Some photographs of the springs were taken during the field

6. Future scope of study

Seasonal discharge monitoring during pre-monsoon, monsoon and post-monsoon periods.

Water quality assessment of all active springs.

Spring shed delineation using GIS so that planning and execution can be done for already dry springs and for the springs that are reducing with time.

References

1. Akhtar N, Syakir MI, Anees MT, Qadir A, Yusuff MS. Characteristics and assessment of groundwater. In: Groundwater management and resources. London: IntechOpen; 2020.
2. NITI Aayog. Inventory and revival of springs in the Himalayas for water security. New Delhi: Department of Science and Technology, Government of India; 2017.
3. Singh Thapa Chitra R. The implication of hydrogeological mapping and recharge structures to revive drying springs in hilly region of Nepal. Int J Sci Res (IJSR). 2023;12(5):2026-2032. DOI:10.21275/SR23522075701.
4. Srivastava P, Dubey S, Singh S. Sustaining Himalayan springs amidst the emerging water crisis. 2025;13:5.
5. Daniel D, Anandhi A, Sen S. Conceptual model for the

vulnerability assessment of springs in the Indian Himalayas. Climate. 2021;9(8).

DOI:10.3390/cli9080121.

6. Kim GB, Hwang CI, Choi MR. Assessment of the need and potential for groundwater artificial recharge based on the water supply, water demand, and aquifer properties in a water shortage region of South Korea. Environ Earth Sci. 2021;80(3). DOI:10.1007/s12665-021-09445-5.