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Augmenting spring discharge using Geospatial cum soil and water conservation technique: A case study of Almora

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ABSTRACT

Springs are the lifeline of people living in the Himalayan regions. However, increasing population and largescale development in the region has led to drying up of many springs which in turn has led to water scarcity. Rain water harvesting is less feasible in the Himalayan region due to adverse topography. The depletion of spring discharge is also intensified by change in land-use pattern, climate change and anthropogenic activities. Conventional method for managing the spring has not been substantially effective to combat the combined ill-effects of the climate change and anthropogenic activities. Hence, it is the need of the hour to incorporate the scientific knowledge into local community for efficient management of springshed.

Scientific approach includes the use of remote sensing data, Geographic Information System (GIS) and hydrologic monitoring, while community-based approach incudes the use of traditional knowledge from the community, involvement in each process of springshed development. We conclude that the management of springshed includes both community-based and scientific approach for holistic management. Further, simple step by step approach is discussed in the chapter for awareness of stakeholder related to springshed.

1. Introduction

Geographically 22% of land surface area is occupied by mountain and are home to 13% world population (FAO 2015). Rainfed agriculture (~82.6 %), irregular and small land holding distributed area over adverse topography, insufficient and constraints for adopting intensive agriculture are prime factors which make mountain agriculture unsustainable (Negi and Joshi 2002; Kumar et al. 2020; Kumar et al. 2021a; Kumar et al. 2021b). Springs are well-known manifestations of groundwater discharge. Most of the river in the world originates from springs. 64 % of agricultural area is irrigated by spring in Indian Himalaya Region (IHR) (Rana and Gupta 2009). They are the part of freshwater ecosystem. Spring forms the life-line, about 15 % of country's population in Himalayan and sub Himalayan regions, the eastern and Western Ghats as well as all mountain ranges across the country. In the Uttarakhand, approximately 90% of drinking water supply comes from springs and in Meghalaya all Villages generally uses spring water for drinking and irrigation purposes (Shabog and Swer 2015; Tambe et al. 2009).Due to scarce spring data, the exact status of most of spring is still unknown.

Rana and Gupta 2009 reported that more than 50 % springs have dried or become seasonal in the IHR. Numerous studies have been done on the behaviour of spring discharge on rainfall pattern and catchment degradation (Singh and Rawat 1985; Singh andPande 1989; Valdiya and Bartarya 1989; Valdiya and Bartarya 1991; Bisht and Srivastava 1995; Sahin andHall 1996; Negi and Joshi 1996; Negi and Joshi 2004).The significant decrease in spring discharge is also observed by (Sharda2005). Importance of comprehensive

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understanding of aquifer groundwater recharge is highlighted by (Jeelani2008; Mahamuni andKulkarni2012). The effect of land use change pattern and soil erosion on spring discharge is studied by various researchers (Singh and Pande1989;Valdiya and Bartarya1989; Tiwari and Joshi 2014). (Negi and Joshi1996; Negi et al. 2001; Kumar et al. 2021c) showed that spring discharge is function of both rainfall pattern and recharge area characteristics. Sanctuary approach which include biological and engineering approach show promising result in western Himalaya (Negi and Joshi 2002).However, most of the rainfall in mountain regions escapes as runoff and does not percolate into the aquifers due to undulating topography; groundwater is not recharged and natural springs begin to dry up.The vital components of biodiversity and ecosystems are dependent on the numbers of springs of a region. Although, spring emerge onto the surface and may be treated as surface water after they discharge. It is the part of a sub-surface system of aquifer that includes hydrogeological system. However, the spring discharge is declining gradually due rapid deforestation, changing land use patterns, increased demand of water and ecological degradation and climate change(Vashisht and Bam2013;Mukherji et al.2016). For this Himalayan state, where about 20% of the 15,165 villages face problems related to drinking water and more than 180 villages do not have a designated source of drinking water, this loss is colossal. Combination of a landscape, watershed and aquifer forms the integral unit of springshed. Therefore, it is essential to employ hydrogeology approach to map both the surface and groundwater component of springshed. The formation of springs is controlled by the geological and structural setting and the drainage system. Some springs are active round the year, though with reduced discharge during the dry season. Some springs are completely dry up during summer. Springs develop at places where erosional channels intersect an aquifer, or along traces of tectonic fractures. Gravity spring occur at the contact between an aquifer and aquitard. Some springs occur in gullies along the edge of a slope wash.

It is needless to mention that reduction in water supply and water quality has considerable impact on regional livelihood, health, biodiversity, agriculture, tourism, power generation and industry.

In response to the deterioration of springs, actors across the country are giving spring protection a renewed focus. The Government of Sikkim and Meghalaya have initiated state-wide programmes to prepare inventory, monitor, protect and rejuvenate springs. NGOs in all major mountain chains have also developed successful spring programmes, many of which are now being emulated by local government at block and district levels. The Central Himalayan Research and Action Group (CHIRAG) and People Science Institute (PSI) have well-established spring protection programmes in Uttarakhand and Himachal Pradesh.

Springs are now beginning to be recognized within the policy and public institutions at the national level. For example, aquifer mapping is now recognized as a sanctioned activity under National rural Employment Guarantee Act, 2005. It has made a part of the mandate and the training for central Ground Water Board aquifer mapping activities. To develop innovative solutions towards sustainable management of these traditional sources of water, there are large gaps in data and understanding that must first be filled. There is also a need to raise awareness among relevant policy and decision makers and to develop skills and share knowledge on this critical topic with field practitioners and community members. There is a gap in quality data on the level of dependence of local populations on springs and the role these play in nurturing cultural services and building resilience.

In the light of previous discussionto mitigate the water crisis caused by these dried-upsprings, springshed-management strategies and conservationmeasures should be developed by merging scientific andcommunity knowledge. The present case study is organised as follows: first, suitable site selection for water harvesting structure using RS and GIS, the behaviour of daily spring discharge and rainfall series was observed, its monthly variation has been presented, and then, the dependence of spring discharge on rainfall was investigated. It is believed that the present case study will offer a new insight to understand the dynamics of spring discharge, researcher, planners and policy makers to take suitable intervention.

Major Challenges for water resources management in hilly region:

The major water resource management problems of Himalayan region are as follows:

Lack of irrigation infrastructure:

There is constraint on development of irrigation facilities in hills due to undulating topography. Only small irrigation structure has been developed by constructing Guls (small canals) by diverting stream/river water to downstream terraced land. In addition to this lift irrigation system is also developed by government to irrigate land near to stream bed.

Adverse topography: Most of field in Himalayan region is of adverse topography which requires huge money and energy for uniform application of irrigation water. Most of field is irrigated by diverting water from one field to another, by doing so there is huge loss of water including seepage and runoff.

Climate change:

The Indian Himalayan Region (IHR) is facing the problem of quick translation of rainfall to surface runoff because of slope and faces the problems of landslide. Land use and land cover changes directly impacts the environment and is the primary cause of soil degradation.Uncertainty in water supplies and agricultural production for human populations could have serious implication.

Socio-economic threat:

Socio-economic effect is one of prime result of climate change. Agriculture in this region is mostly depend on rainfall and therefore vulnerable to climate change directly influencing the livelihood of the people in this region. As a result of this, livelihood asset of people living in this region is altered and hence national economy is reduced.

The major problem is that intervention done in one particular watershed doesn't always guarantee the revival of those springs in the same watershed. This is due to sub-surface hydrology. Some springs are fed mainly by ground water, while others are nourished by direct precipitation, and rest by a mix between the two. Hence, understanding the typology of springs is vital in identifying the most appropriate combination of interventions, an integrated approach can offer a more sustainable and long-term solution for upper watershed management.

2. Case study

2.1 Study area description

This study was conducted on the spring located in one spring at Attadhar location of ICAR-VPKAS, Experimental farm, Hawalbagh which is located in one micro-watershed (small drainage-catchment) as shown in Fig. 1. Geologically the study area lies in the Lesser Himalayan region and constituted by Almora group of rocks. Springs located in Western Himalayan are mostly dependent on rainfall and uneven distribution of rainfall in space and time directly affect the availability of spring flow (Negi and Joshi 2004).

3. Materials and Methods

The continuous daily spring discharge data from July 2019 to July 2020 were collected from Attadhar location of Hawalbagh experimental farm, ICAR-VPKAS, Almora (Fig. 2). Time series daily spring data revealed that the spring discharge fluctuates and monthly mean discharge varies; therefore, the discharge from the Attadhar spring is non-stationary.

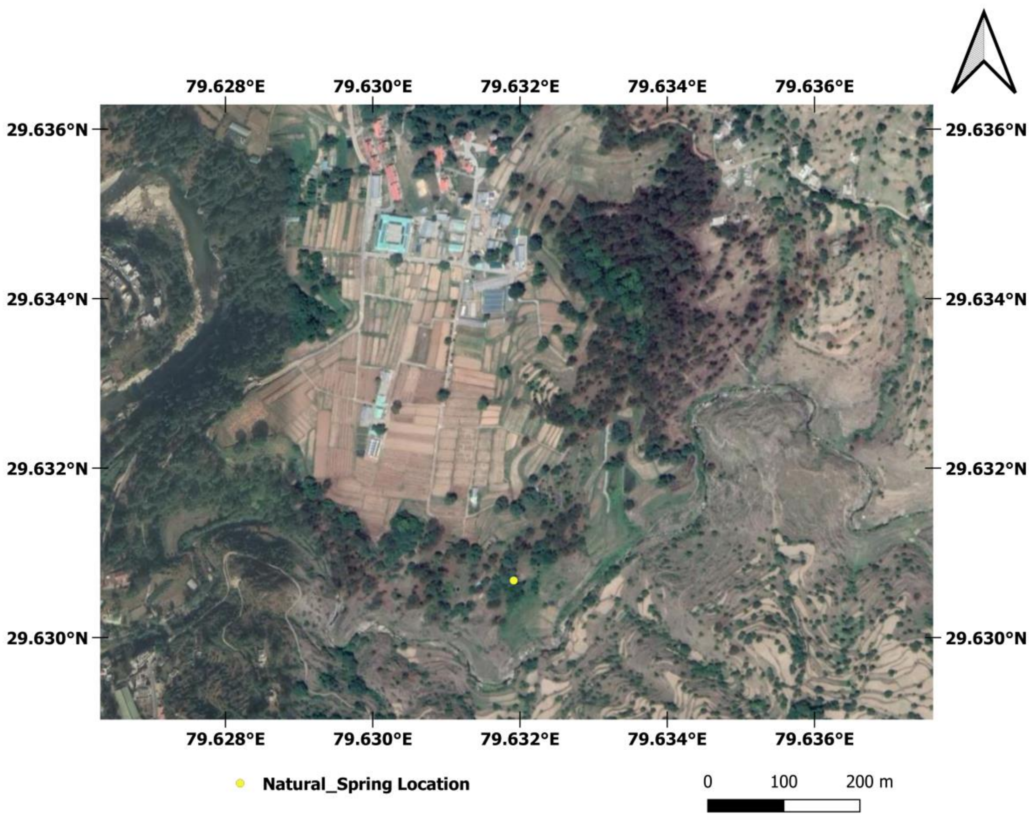


Figure 1. Location of study area.

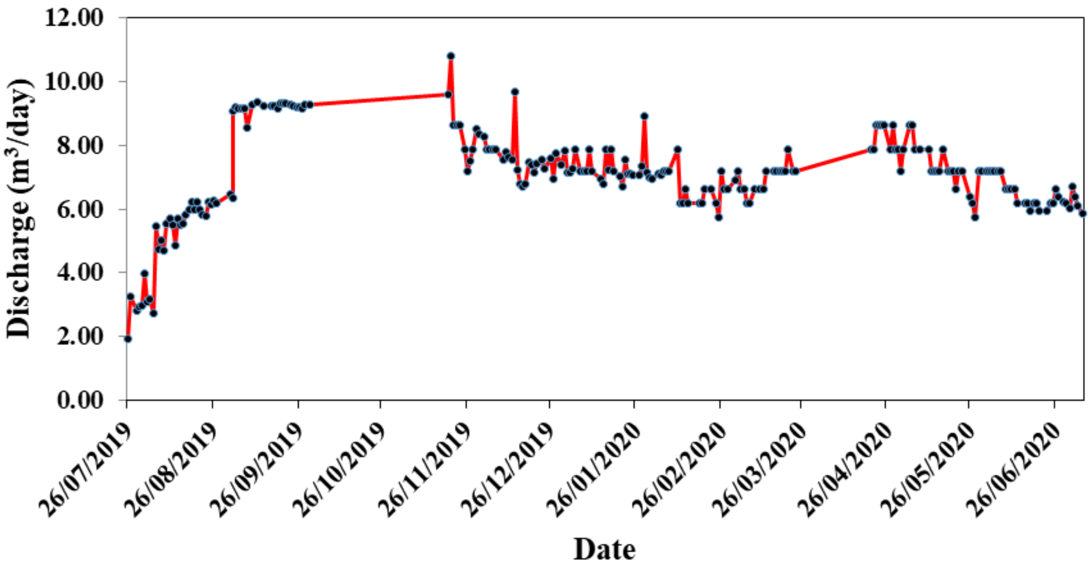


Figure 2. Variation of daily spring discharge

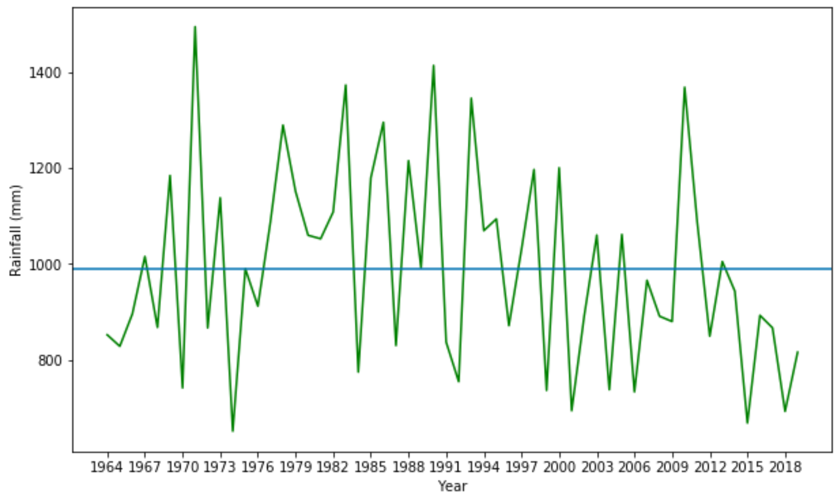


Figure 3. Annual time series of rainfall.

The rainfall data were collected from a non-recording rainguage, a pan evaporimeter, and a maximum-minimum thermometer were installed, which is located 200 m from the location of spring and data were collected daily. The time series graph of annual rainfall at VPKAS experimental farm, Hawalbagh is shown in figure 3.

Seasonal rainfall is most common in July-September and December-January which influence the behaviour of spring discharge dynamics. Monsoon season rainfall accounts for ~ 70% of annual rainfall at the location.

3.1 Quantifying the availability of spring water:

3.1 Spring yield: It is defined as volume of water collected per unit time. It can be expressed in various ways. The spring flow measurement was manually recorded by measuring the time taken for a specific amount of water to come out of the spring. The spring yield during rainy and non-rainy seasons is mainly affected by rainfall and recharge area characteristics. Most practical units of measurement are:

- Litres per second
- Litres per minute

The yield of spring ranges from few litres to thousands of litres per minute.

The Meinzer's classification of spring based on average flow is given in Table 1.

Table 1. Meinzer's classification of springs according to average flow

Magnitude	Average flow (m^3/day)
1st	≥244,657
2nd	24,465-244,657
3rd	2,446-24,465
4th	654-2,446
5th	65.4-654
6th	6.5-65.5
7th	0.8-6.5
8th	< 0.8

3.2.1. Index of variability and % Variability

While understanding availability of spring water, it is important to include measure of spring discharge variability, based on periods longer than one hydrologic year.

Index of variability: It is the simplest measure of variability and is defined as ratio of maximum and minimum discharge:

$$I_v = \frac{Q_{max}}{Q_{min}}$$

Springs with an index of variability (I_v) greater than 10 are considered highly variable, and those with I_v< 2 are sometimes called constant or steady springs.

Measure of variability (%)as expressed by Meinzer is given as

$$V = \frac{Q_{max} - Q_{min}}{Q_{avg}} \times 100\ (\%)$$

where,Q_{max}, Q_{min} *and* $Q_{avg}$is maximum, minimum and average discharge respectively. Spring with variability % less than 25 is considered constant and a variable spring would have variability greater than 100%

4. Results and discussion

4.1 Drainage line of catchment using GIS

Springshed mapping starts from a ground survey of the spring and surrounding area. Rock type and structure are mapped, including strike and dip of formation and features, and a geologic cross section is developed. Environmental, Infrastructure and socioeconomic data are collected. Hydrologic monitoring of discharge and water quality is initiated. Google earth satellite imagery, topo maps or other sources are used to delineate the local watershed and field survey information is placed on the top. This completes the first step of a conceptual model of a spring and provides information about the aquifer. The drainage line of spring catchment is shown in Figure 4.

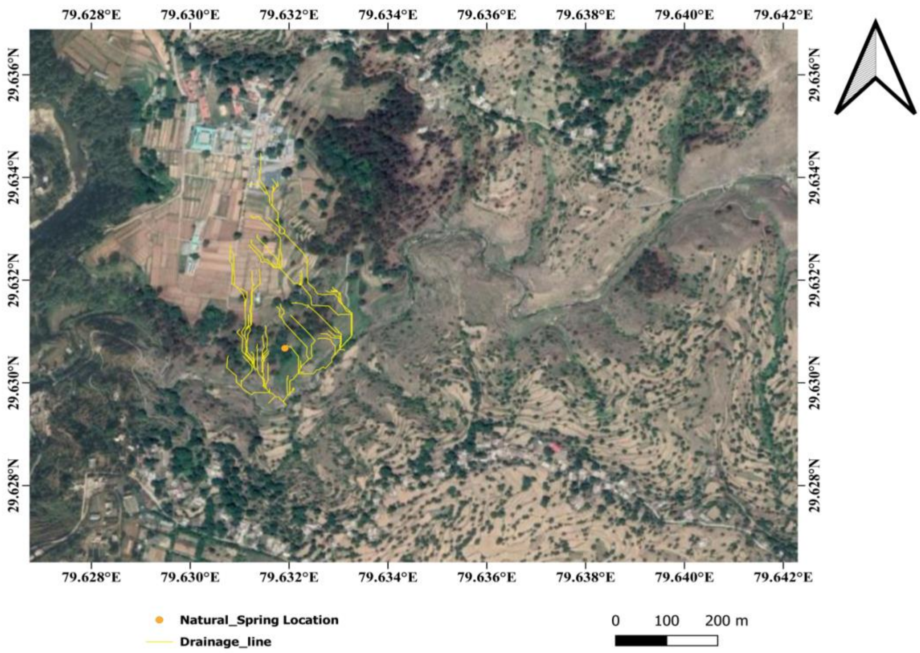


Figure 4. Drainage line of the springshed catchment

4.2 Selection of suitable site for proposed intervention

Once the springshed has been delineated and drainage line is identified. The suitable site is identified based on junction of stream order and availability of land. In the presentstrategies both engineering and mechanical measure has been implemented.

In present studies staggered trenches may be used in conjunction with hybrid Napier on border of pond to intercept runoff and increase natural rates of infiltration.It is important to keep in mind all the components of the springshedfor effective management. The ideal springshed management based on earlier various studies is shown in figure 5.

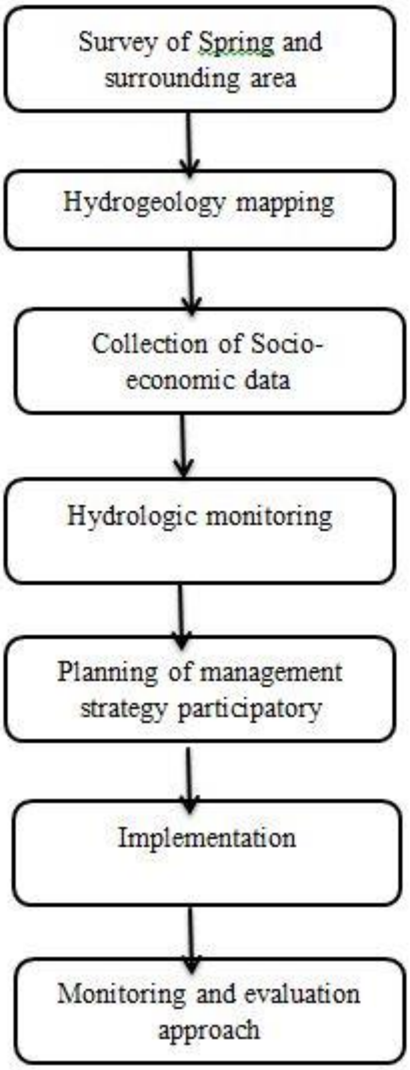


Figure 5. Step by step approach for springshed management

4.3 Classification of spring

5. Springshed management approach

5.1 Generalspring shed management strategy:

1. Work with traditional community-based approach to identify spring issue, initiate participatory monitoring which include data collection, training to community to understand the basic meaning of data
2. Hydrgeologic investigation to understand springshed, involving community in all aspect and incorporating the local knowledge
3. Following scientific understanding of springshed, identify target area for recharge and restoration, define collective management objective, identify interventions to be implemented
4. Encourage community-led implementation of interventions, continue participatory monitoring

5. Evaluation of impact, revisit objective if needed, transfer monitoring and management to the trained local communities or local institutions

5.2 Community level spring shed management

- Training local village men and women in basic hydrogeology and creating awareness of linking new knowledge to government schemes
- Socioeconomic surveys and improved understanding of existing traditional governance structures
  Conceptualizing springshed development programmes at local, district, and national level
- Implementation of spring management plans (including the construction of ponds and trenches, plantations in recharge zones, and addressing grazing and open defecation to ensure water quality)
- Monitoring spring revival, including continuous spring discharge measurements for which revival plans have been implemented
- Sensitizing policy makers and other research and development institutions to look at springshed management from a different angle.

5.3. Scientific approach to springshedmanagement

It is simply defined as management of both surface-water and groundwater resources. Spring management can be done based on the following cases:

Case I: Spring water is not consumed in anyway and there is minimal disturbances of the spring site before formation of or discharge into a surface stream
The spring management should be focused on protecting the quality and quantity of groundwater in its drainage area for the specific spring use. For example, include recreation, fisheries and power generation

Case II: When the spring water is used for consumptive water supply, of any type
The additional spring management requirement include

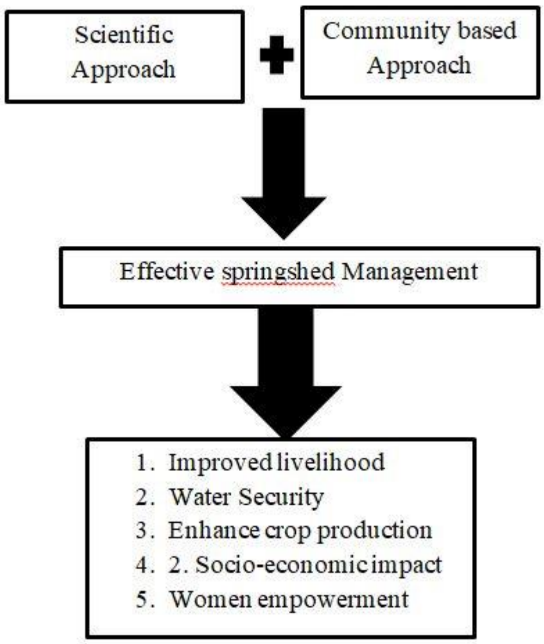
- Ensuring that reliable quantities of water are delivered to all user, including environmental flow
- Ensuring that an adequate quality of water is delivered to all user, including drinking water treatment
- Establishing spring protection zone

6. Conclusion

Greater awareness and understanding of springs will improve the surface-water and groundwater resources. Springs are the junction between them, a growing area of research. Springshed management also represents an opportunity. Finally, there is a need to employ citizen science approach for managing spring at community level as well as scientific approach. Improved method for managing springs should be disseminated at local level and should be integrated with local knowledge. Therefore, spring should be a national priority in terms of research, policy and implementation.Govt. and several NGOs plan to save watershed crisis by using several roadmaps. Like Setting up a data monitoring system, Hydrogeological mapping, developing springshed management protocols, measuring hydrological and other impacts of spring revival activities, creating a conceptual hydrogeological layout of springshed, etc.
Two main factors for realistic, workable spring management plan are:

1. Hydrogeologic and hydrologic characterization of spring type, drainage area, recharge area and discharge parameters, such as water quality and quantity
2. Modelling of spring discharge and water quality under natural and engineered condition, also during artificial regulation time

Spring management should have a clearly stated objective. The spring management objectives should include the objective of threshold values for readily measured quantities such as spring flows, water quality, or change in spring flow and surface water quality. Management objective may range from entirely qualitative to strictly quantitative.



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8. References

Bisht, B.K. and Mahamuni, K. (2015). CHIRAG`s Spring Protection Programme, PowerPoint presented at 3rd Annual Meeting of the springs Initiative, Bhimtal, Uttarakhand, May 15, 2015.

Bisht NS, Srivastava AC. 1995: Sustainable Management and Conservation of Drinking Water Sources in Himalaya. Indian Forester, 7, 608-612.

FAO. (2015).Mapping the vulnerability of mountain peoples to foodinsecurity. Rome, Italy: Food and Agriculture Organization of the United Nations

Jeelani, G. (2008). Aquifer response to regional climate variability in apart of Kashmir Himalaya in India.Hydrogeology Journal, 16(8), 1625–1633.

Mahamuni, K. and Kulkarni, H. (2012). Groundwater resources and Spring Hydrogeology in South Sikkim, with Special Reference to Climate Change, In: Arrawatia, M.L. and Tambe, S.(eds), Climate Change in Sikkim: Patterns, Impacts and Initiatives, Government of Sikkim, Gangtok, Sikkim.

Shabong, L. and Swer, A. (2015).Meghalaya's Spring Initiative under IBDLP. PowerPoint presented at 3rd Annual meeting of the springs Initiative, Bhimtal, Uttarakhand, May 15, 2015.

Kumar, U., Singh, S., Bisht, J.K., Kant, L. (2021a). Use of meteorological data for identification of agricultural drought in Kumaon region of Uttarakhand. J Earth Syst Sci., 130, 121.

Kumar, U., Meena, V.S., Singh, S., Bisht, J.K., Pattanayak, A. (2021b).. Evaluation of digital elevation model in hilly region of Uttarakhand: A case study of experimental farm Hawalbagh. Indian J. Soil Conserv., 49, 77–81.

Kumar, U., Sahoo, B., Chatterjee, C., Raghuwanshi, N. (2020) Evaluation of simplified surface energy balance index (S–SEBI) method for estimating actual evapotranspiration in Kangsabati reservoir command using landsat 8 imagery. J. Indian Soc. Remote. Sens., 48, 1421–1432.

Kumar, U., Panday, S.C., Kumar, J., Meena, V.S., Parihar, M., Singh, S., Bisht, J.K., Kant, L. (2021c). Comparison of recent rainfall trend in complex hilly terrain of sub–temperate region of Uttarakhand. MAUSAM*, 72*, 349–358.

Mukherji, A., Pradhan, N., Shrestha, R., Bhuchar, S., Dhakal, M.,Gurung, K. et al. (2016).Springs and springsheds: ICIMODposition paper. request.

Negi GCS, Joshi V. 1996: Geohydrology of springs in a mountain watershed: The need for problem solving research. Current Science, 1996, 71(10), 772–776.

Negi GCS, Joshi V. 2002: Drinking Water Issues and Development of Spring Sanctuaries in a Mountain Watershed in the Indian Himalaya.' Mountain Research and Development, 22(1), 29-31.

Negi GCS, Joshi V. 2004: Rainfall and Spring Discharge Patterns in two Small Drainage Catchments in the Western Himalayan Mountains, India. The Environmentalist, 24, 19-28.

Negi GCS, Kumar K, Panda YS, Satyal GS. 2001: Water Yield and water Quality of some Aquifers in the Himalaya.' Int. J. Ecol, and Envionm. Sci. 27, 55-59.

Rai RN, Singh KA Solanki RC. 1998: A Case Study of Water Flows of Some Hill Springs of Sikkim. Indian Journal of Soil Conservation,1998:16(1):52-56.

Sharda, V. (2005). Integrated watershed management: managingvalleys and hills in the Himalayas. Watershed ManagementChallenges, 61

Singh AK, Pande RK. 1989: Changes in the Spring Activity: Experiences of Kumaun Himalaya, India, The Environmentalist, 9(1), 25-29.

Singh AK, Rawat DS. 1985: Depletion of Oak Forests Threatening Springs: An Exploratory Study. The National Geog. J. India, 31(1), 44-48.

Sahin V, Hall MJ. 1996: The Effects of Afforestation and Deforestation on Water Yields,' J. Hydrol., 178, 293- 309.

Tiwari, P. C., & Joshi, B. (2014).Environmental changes and theirimpact on rural water, food, livelihood, and health security inKumaonHimalaya.International Journal of Urban and RegionalStudies on Contemporary India, 1,1–12

Tambe, S., Arrawatia, M., Kumar, R., Bharti, H., &Shrestha, P. (2009).Conceptualizing strategies to enhance rural water security inSikkim, Eastern Himalaya, India.Integrated Water ResourceManagement, 1.

Valdiya KS, Bartarya SK. 1989: Diminishing Discharges of Mountain Springs in a Part of Kumaun Himalaya, Current Science, 58(8), 417-426.

Valdiya KS, Bartarya SK. 1991: Hydrological Studies of Springs in the Catchment of the Gaula River, Kumaun Lesser Himalaya, India. Mountain Research and Development 11(3), 239-258.

Vashisht, A., & Bam, B. (2013).Formulating the springdischarge-function for the recession period by analysing itsrecession curve: A case study of the Ranichauri spring (India).Journal of Earth System Science, 122(5), 1313–1323