



Review Paper

Natural Springs in Hilly and Arid Regions: A review of their conservation and management

Anil Khole

Dept. of Zoology, B. Raghunath College, Parbhani - Affiliated to Swami Ramanand Teerth Marathwada University, Nanded (Maharashtra), India
kholeanilm@gmail.com

Available online at: www.isca.in, www.isca.me

Received 9th February 2026, revised 10th March 2026, accepted 1st April 2026

Abstract

On Earth, natural springs constitute core elements of water resource geography; in India, hilly and arid landforms serve as permanent sources of freshwater for domestic, agricultural, and ecological sustenance. The attempt to focus on the spring hydrology, usage patterns, and socio-agricultural significance, with geographical lenses on the Himalayan and Western Ghats regions and dominated terrains. The natural springs are facing critical challenges, including irregular climatic conditions, anthropogenic land-use alterations, and declining spring discharge, thereby underscoring the urgency of integrated spring water management and conservation. The research further examines community-led management and conservation efforts, policy frameworks, government schemes, and technological interventions aimed at spring rejuvenation. The Northern States, like Himachal Pradesh and Uttarakhand (Dev Bhoomi), had over 60 percent of rural households and were rich in biodiversity. Studies have shown that in arid and semi-arid regions, springs make their contribution for the formation of micro-habitats and frigid climate endurance through flowing spring-linked recharge kinetics. This review focuses attention on strategic parameters to sustain natural spring-based water systems in fragile, water-scarce regions. Natural springs are a vital source for the ecosystems and local livelihoods, especially in hilly regions. Their existence requires integrated management, catchment care, water quality checks, and safeguards. The conservation movement should be advanced by strengthening institutions and eco-education, particularly through student and local communities' involvement, which is crucial for preserving natural springs.

Keywords: Spring, Hydrology, Natural, Ecosystem, Conservation.

Introduction

The water scarcity problem comprises enduring and intensifying challenges in our country's hilly, arid, and semi-arid regions, where unpredictable precipitation models and declining groundwater tables weaken ecological connectivity and well-being. Within these circumstances natural springs evolving distinct groundwater lay-off points offer sustainable, low-energy sources of freshwater crucial for domestic, agricultural, and livestock management in arid environments.

Whereas their significance, springs mainstream water governance homilies, especially in the hilly terrains of the country. Mountainous regions in India, which include the Himalayan and the Western Ghats, are tribe-dominated areas where natural springs serve as permanent water sources and consist of local hydrological routines that have intense cultural and spiritual values. While in arid regions water scarcity is acute, both surface and subsurface water resources have ecological, cultural, and economic importance. Springs in these regions contribute disproportionately to ecological resilience by raising microhabitats and supporting critical ecosystem acts beyond their immediate catchments¹. The classification of 12 discharge types, grounded in hydrological characteristics, allied

with microhabitats, and the ecological system they support². This system underscores the multifaceted role of springs as links between hydrology, ecology, and socio-cultural systems. In the Indian linguistic context, natural springs are often permeated with spiritual and therapeutic significance, particularly within *Hindu* customs, where they are esteemed for their spiritual and therapeutic characteristics³. People commonly believe that the mineral-rich waters of many natural springs hold healing properties. Experimental analysis from the Himalayan region makes it known that springs represent the primary source of freshwater for millions, especially in the mid-Himalayan elevation belt (900-2000 meters above sea level), where riverine approach is limited. However, mounting evidence indicates a decline in spring discharge, attributed to ecological degradation, land-use changes, and climate-induced variability in rainfall patterns^{4,5}.

These variations in natural spring seep have direct effect on water safety, public health, and ecological services, impelling urgent attention to natural spring conservation and integral watershed management. The *formation of natural spring* outlets where ground water surfaces, shaped by geology, recharge sources, and hydrogeological conditions. Spring emergence is driven by gravity and pressure differences, occurring at water

table intersections, in Karst limestone terrains, and in volcanic or geothermal zones.

Materials and Methods

The present review paper is based on a systematic analysis of published literature from SCOPUS, peer-reviewed journals, technical reports, referred books, and open-access sources. Including materials from journal articles, must focus on management/conservation of natural springs in hilly and arid regions hydrology and be published within a relevant timeframe. Studies focusing simply on natural springs.

Results and Discussion

Natural springs constitute an acute component of water security in arid and hilly regions in India and other countries. The conventional water sources, e.g., surface reservoirs, wells, and borewells, commonly prove inadequate due to climatic irregularity and geological limitations. This review emphasizes the strategic vital role of springs, particularly fracture-controlled and streaming types, which offer reliable, low-maintenance natural freshwater accessible in terrains characterized by fractured lithology and upward hydrostatic pressure. Earliest knowledge systems have traditionally directed local communities in the identification, protection, and sustainable management and conservation of natural spring resources. Cultural customs such as the conservation of ritualistic groves, adherence to seasonal utilization norms, and community-led conservation regimes illustrate a subtle ecological awareness rooted within traditional framework. The union of these informal approaches with modern water evaluation and national policy gears such as Jal Shakti Abhiyan and Atal Bhujal Yojana keeps significant ability for enhancing natural spring rejuvenation, recharge intrusions, and long-term hydrological governance. Table-1 presents a curated list of prominent springs across various regions of the country, while, Table-2 highlights regions in India with critical dependency on springs, particularly in the Northern region. Figure-1 and 2 Map showing natural spring distribution across India, highlighting regional patterns and hydrological relevance^{6,7}.

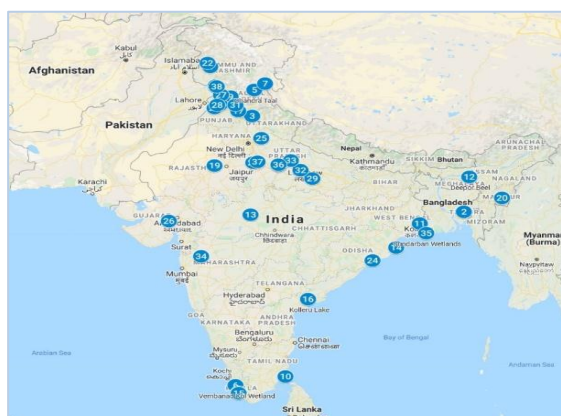


Figure-1: Distribution of natural springs in India⁶.

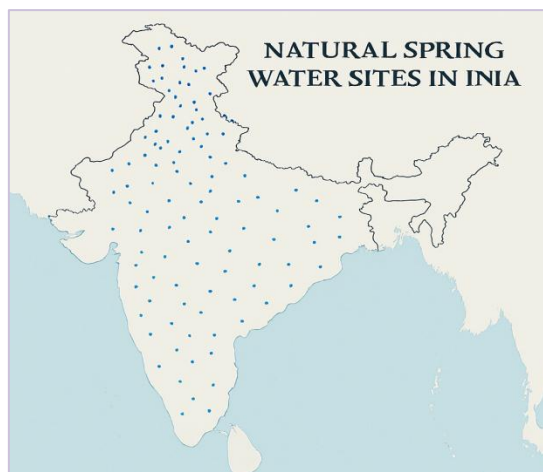


Figure-2: Natural spring water sites in India⁷.

Table-1: Curated list of prominent springs across regions^{29,30}.

	Natural Spring	Location
Northern India:	Manikaran Springs	Located in Parvati Valley, (Himachal Pradesh)
	Kheer Ganga Springs	Located on snow-capped peaks, (Himachal Pradesh)
	Tattapani Springs	Located near the Sutlej River (Himachal Pradesh)
	Vashisht Springs	Located at Vashisht temple, (Manali, Himachal Pradesh)
Ladakh & Jammu & Kashmir region:	Panamik Springs	Located at 10,442 ft, at (Nubra Valley, Ladakh)
	Chuma Thang Springs	Located at Indus River, (Leh District, Ladakh)
Uttarakhand region:	Sahastradhara	Located at scenic caves, (Dehradun)
	Tapovan & Suryakund	Located at (Chamoli District & Yamunotri)
Eastern India:	Taptapani Springs	Located at Odisha
	Yumthang & Reshi Springs	Located in high-altitude valleys, (Sikkim)
Western & Central India:	Akoli Springs	Located at (Maharashtra)
	Unai Springs	Located at (Gujarat)

Natural spring dependency and conservation in India's highland regions: Highland tribes all over India display a profound dependence on natural springs as fundamental sources of freshwater for drinking, domestic use, and agricultural activities. In the central and eastern Himalayas, natural springs are locally referred to as 'dhara', 'mool', and 'kuan', while in the western Himalayan belt, terms such as 'chashma' and 'naula' are traditional. The hydrogeological characteristics constitute prime lifelines, particularly in remote and high-altitude areas where

piped water infrastructure is either limited or entirely absent. Natural springs are spread across ten states and four hillock districts within the Indian Himalayan Region (IHR), collectively supporting the water needs of over 50 million individuals⁸. Despite their critical role, India lacks an official inventory of springs; however, estimates suggest the existence of approximately 2 to 3 million springs nationwide^{9,11}. Communities in mountainous terrains, including those beyond the Himalayan arc, have historically relied on these sources for generations, underscoring their socio-hydrological significance. The ecological instability of the IHR requires a structured and regionally adaptive approach to natural spring identification, rejuvenation, and long-term conservation¹². The dependency on spring water in the northeastern hilly states and other mountainous zones reflects not only a hydrological imperative but also an ecological and cultural resilience mechanism. However, the evolution of modern water supply projects has led to the overlooking of traditional spring systems, while rising population pressures and tourism have worsened contamination and discharge decline. Several natural springs in the Himalayan region continue to serve as critical water sources. For instance, the *Bhagsu Nag Spring* in Dharamshala, Himachal Pradesh, caters to both local residents and tourists and is currently regenerating due to reduced discharge. In Uttarakhand, *naulas*, traditional stone-lined spring tanks, are being revived through community-led initiatives and state-supported programmes. Notably, Sikkim's *Dhara Vikas Programme* has successfully mapped and regenerated over 700 springs, significantly improving water security for thousands of households.

Table-2: Regions with critical spring dependency in Northern region of India^{29,30,31}.

Region	Role of Springs	Local Names
Himachal & Uttarakhand	Drinking, irrigation, cultural rituals	Naula, Baori
Sikkim & Meghalaya	Sole source for most villages	Dhara, Jhora
Odisha (tribal belts)	Supports sanitation, nutrition, agriculture	Jharana, Chuan
Ladakh & J&K	Bathing, spiritual use, dry-season flows	Chhimik, Chashma

Natural springs as livelihood anchors in India's arid and semi-arid regions: India's arid and semi-arid regions have natural springs, which, though limited in spatial distribution, function as crucial lifelines for domestic, agricultural, and livestock use, particularly within remote settlements and desert-margin ecosystems. Regions such as Rajasthan, parts of Gujarat, and the Deccan Plateau are typified by poor rainfall and severe groundwater scarcity. Springs emerging from fault zones or deep aquifers provide significant perennial or seasonal water sources, often serving as the only reliable supply in ecologically stressed landscapes. In India, these regions are increasingly burdened by economic and environmental pressures linked to water scarcity, with groundwater now constituting the principal

source for both domestic consumption and irrigation^{13,14}. Natural Spring discharge in such environments is highly sensitive to rainfall variability, especially where springs are fed by shallow aquifers or surface recharge zones. Discharge patterns exhibit temporal inconsistency; some springs respond immediately to peak rainfall, while others demonstrate a slowdown of several weeks. Empirical data reveal that means annual discharge in certain springs is twice the regional average, with others recording up to 2.3 times greater discharge per 1000 litres of rainfall. The correlation between rainfall and spring discharge ranges from weak to strong, depending on local hydrogeological conditions^{15,16}.

Despite their moderate size, springs in arid environments play an extremely significant role in supporting biodiversity and ecological processes. Springs that host endemic species serve as evolutionary and ecological shelter, contributing to landscape-level resilience. However, arid land springs are increasingly vulnerable to climate-induced stressors, including erratic rainfall, elevated evaporation rates, and extreme temperatures, all of which compromise aquifer recharge and threaten long-term water availability. Some examples of spring dependency in arid and semi-arid India include: i. Mount Abu (Rajasthan): Natural springs Nakki and Adhar Devi provide essential water for local residents and tourists, supporting domestic use and horticultural practices. ii. Western Ghats Fringe Zones: The semi-arid belts of Maharashtra and Karnataka, spring-fed tanks and stepwells are integral to irrigation and potable water supply. iii. Aravalli Foothills: Springs in these ancient hillranges (north western region of India) sustain biodiversity and tribal communities within otherwise water-inadequate environments.

Ecological roles of natural springs in forest ecosystems: Springs serve as major hydrological and ecological assets within forested landscapes, particularly during extended dry periods. Their role in sustaining perennial stream flows, maintaining soil moisture, and supporting biodiversity is essential to forest ecosystem liveliness. Deciduous forest springs exhibited enhanced organic microhabitat coverage and increased biodiversity, characterised by both species' richness and individual abundance¹⁷. Springs provide high-quality groundwater, the characteristics of which are governed by aquifer lithology, residence time, and recharge dynamics. Springs serve as crucial resource nodes in woodland ecologies, providing stable microhabitats and hydrological continuity that sustain a diverse range of flora and fauna. The perennial springs in the *Western Ghats*, when left undisturbed, support forest regeneration through strategic water diversion, and that 121 such springs, shaped by basaltic lithology, terrain, rainfall, and aquifer dynamics, act as vital forest lifelines¹⁸. Mineral-rich springs serve as vital ecological niches, sustaining hygrophilous vegetation and offering breeding habitats and shelter for amphibians, avifauna, and invertebrates. Springs enhance the structural and functional integrity of forest ecosystems, underscoring their significance as keystone hydrological

elements within integrated conservation frameworks. Table-3 presents the ecological functions of springs in forested regions.

Hydrological link between rainfall and spring discharge in India: In the Indian hilly and arid region, the hydrological link between rainfall and spring discharge represents a critical component of groundwater-surface water interactions, particularly in mountainous and basaltic terrains. According to geologists, natural springs are generated when groundwater, replenished by meteoric inputs such as rainfall, percolates through permeable geological strata and is subsequently deflected by an underlying impermeable layer, resulting in its emergence at the Earth's surface.

Arushi's research study highlights a significant decline in spring discharge across Uttarakhand, primarily driven by decreasing precipitation trends¹⁹. Probable estimation suggests a decline of up to 50% in annual spring discharge between 1975 and 2030, raising a significant risk to drinking water availability in Himalayan regions.

Meteorological and hydrological factors, especially rainfall spring correlations, show trends in precipitation variability and spring discharge patterns. Spring discharge varies over time due to rainfall fluctuations, with stable watershed conditions confirming rainfall as the key driver. Rainfall is a key variable in hydrological stimulation and water planning, requiring insight into its patterns and impacts for effective resource management.

Recharge Dependency: Spring discharge is principally regulated by the intensity, duration, and spatial distribution of rainfall. Monsoonal precipitation serves as the principal source of groundwater recharge, sustaining spring flow during non-rainfall periods through submerged hydrological connectivity.

Groundwater properties: Research findings indicate that the hydrogeological properties of groundwater, particularly the presence of fractured magma and interconnected rock formations, play a crucial role in changing the rate and efficiency of rainfall infiltration and its subsequent contribution to spring discharge, thereby influencing both the response and yield of spring systems.

Regional disparities: Natural Spring systems in the Himalayas and Western Ghats show distinct regional disparities shaped by geological conditions, climate, and terrain, affecting discharge, recharge, and quality of water. Table-4 delineates regional variations in spring systems across the *Himalaya* and *Western Ghats*, emphasising geological controls as the primary determinants of spring typology and discharge characteristics. Whereas, Table-5 categorises spring types based on underlying geological formations, providing a comparative framework for hydrogeological classification. Table-5 illustrates the types of springs classified by geological conditions across different regions.

Table-3: Ecological functions of springs in forest^{32,33}.

Hydrological Support:	Springs maintain stream flow in dry seasons, providing year-round water for forests and wildlife.
Biodiversity Hotspots:	Spring-fed zones shelter rare species and act as moist refuges for amphibians, insects, and riparian plants.
Soil Moisture & Vegetation Health:	Springs boost soil moisture, support forest undergrowth, and lower fire risk during dry spells.
Nutrient Cycling & Microclimate Regulation:	Spring discharge zones aid nutrient flow and create cooler, humid microclimates that stabilize forest ecosystems.

Table-4: Regional Variations in Springs - Himalayas vs Western Ghats^{29,33}.

Feature	Himalayas	Western Ghats
Dominant Lithology	Crystalline & sedimentary rocks	Deccan basalt and colluvial deposits
Recharge Sources	Rainfall + snowmelt	Monsoonal rainfall
Spring Types	Fracture, colluvial, karst, contact	Cold, thermal, fracture, seepage
Discharge Variability	Seasonal + climate-sensitive	Monsoon-dependent + anthropogenic impact
Intervention Focus	Watershed-based rejuvenation	Ecohydrological and community planning

Table-5: Types of springs based on geological conditions^{29,33}.

Type	Description
Depression Spring	Forms in low-lying areas where the water table meets the surface
Contact Spring	Occurs at the boundary between permeable and impermeable rock layers
Fracture Spring	Emerges where rock fractures or joints intersect the surface
Fault Spring	Develops along fault zones due to pressure differences
Karst Spring	Found in limestone areas with underground channels and caves
Artesian Spring	Water is forced to the surface from a confined aquifer under pressure
Volcanic Spring	Associated with geothermal heat and volcanic activity

In the *Western Ghats*, spring systems governed by volcanic rocks and fractured geological structures display significant ecohydrological variability across Maharashtra and Kerala

states. Discharge systems are principally impact by monsoonal precipitation, while hydrochemical properties reflect distinct regional water quality patterns.

In the *Himalayan region*, springs originate from diverse geological formations sedimentary and fractured rocks that impact their characterisation and discharge properties. Forested watersheds assist recharge, with natural springs functioning as delayed outlets for seasonally refilled groundwater. The spring discharge is more seasonal and responsive to rainfall variability and terrain slope.

Medicinal Importance and Aesthetic Value of Spring Water:

Since ancient times in India and across the world, natural springs have served as important freshwater sources, particularly in India's hilly and tribal regions, supporting potable water needs, maintaining ecological balance, and preserving cultural heritage. Rooted within traditional knowledge systems, they function as sites for rituals, festivals, and community-led conservation, especially in the Himalayan and tribal belts.

Therapeutic importance—Research studies confirm the medicinal potency of natural spring water, primarily characteristic of its mineral composition, natural purity, and sustained application within traditional therapeutic illustrations. In the Indian context, regions such as the Himalayas, Maharashtra, and Jharkhand exhibit a traditional engagement with natural spring water-based healing practices, indicating a deep-rooted integration of hydrotherapy into indigenous health systems and culturally rooted ritual backgrounds. Observations had shown that medical hydrology aids in treating skin disorders (e.g., eczema, psoriasis, acne, etc.) through thermal baths, where heat and mineral-rich water enable dermalabsorption²⁰. Deposited minerals in subcutaneous tissue execute therapeutic effects, relieving various skin-related conditions. Whereas, Thermal Spring water therapy is globally recognised for controlling chronic musculoskeletal pain²¹. Nepal's geothermal springs offer temporary relief through mineral absorption and heat, though the study also notes infection risks from communal bathing, stressing the need for regulated access and hygiene measures. Garima reported elevated concentrations of cadmium, mercury, chromium, and selenium in spring water samples from Sikkim, indicating significant public health risks²². Prolonged exposure to toxic elements such as cadmium and chromium results with carcinogenic effects, disrupted bone metabolism, and cardiovascular disorders. Spring water may offer limited therapeutic relief, but its health effects remain still unclear. Further research is needed to confirm its physiological impact and support evidence-based use. Figure-3 Spring-based hydrothermal bathing sites at Manikaran, Kullu District, Himachal Pradesh, India²³, and, Figure-4, thermal Spring bathing facility at Vashisht Hot Springs, Manali, Himachal Pradesh, India²⁴. Figure-5 showing thermal spring with bathing facilities at Vashisht Hot Springs, Vajreshwari, Maharashtra, India²⁵.



Figure-3: Hydrothermal bathing sites, Manikaran, Kullu, Himachal Pradesh²³.



Figure-4: Hot springs, Manali (H.P.)²⁴.



Figure-5: Vashisht hot springs, Thane (M.S.)²⁵.

Aesthetic value- Thermal springs support unique ecological, traditional and cultural systems, offering scientific and *aesthetic* value. In arid regions, they serve as vital water sources when managed through sustainable hydrogeological and community-led approaches. With social progress, spring water exceeds its functional role, contain aesthetic, humanistic, and religious significance across cultural and spiritual places. Spring water from arid and hilly regions supports spiritual and cultural practices while reflecting scientific and aesthetic beliefs that

balance nature and human environments²⁶. Beyond utility, it embodies ecological beauty and cultural honour, enhancing both the visual and symbolic landform.

Natural Springs Management and Conservation Strategies: Natural springs provide a vital, reliable water source for communities living in arid and hilly regions²⁷. The effective management and conservation of aquifers within ecologically fragile and water-scarce regions requires a comprehensive, incorporative basis that integrates ecological restoration and community-based governance. Some key management strategies are: i. Geospatial Mapping & Systematic Records: Undertaken geographical reviews to systematically map spring sites, classify flow dynamics kinetics and seasonal variability, and record discharge rates along with water quality parameters to illuminate evidence-based conservation provision. ii. Participatory Community Engagement: Promotes community engagement in spring supervision through involved networks that integrate traditional ecological customs and tribal therapeutic healing knowledge, thereby enhancing local management and sustainable resource management. iii. Groundwater recharge & ecosystem restoration: Apply catchment area treatment such as afforestation, canals, and check dams to set watersheds, while recharge pits and tanks enhance groundwater and sustain flow. iv. Policy integration & institutional support: Adjust Spring conservation with water policies and local authorities. Nature collective action across forestry, water, and rural development for integrated planning. v. Awareness & educational campaign: Engage students for outreach through posters, surveys, and eco-club activities to emphasise natural springs' medicinal and ecological value. vi. Hydrogeological Investigations and Scientific Monitoring: Evaluate natural spring water quality for medicinal and domestic use, and classify water source spring types for sustainable hydrological management. vii. Sustainable Use and Regulation: Create usage norms to mitigate overexploitation and contamination of natural springs, while developing ecotourism practices that conserve spring ecosystems and simultaneously enhance local livelihoods.

Conclusion

Natural springs form vital, localized water sources in hilly and arid regions of India, supporting structure to ecological stability and sustaining local livelihoods. Securing their long-term sustainability requires an integrated management pattern surrounding hydrogeological investigations, catchment area treatment measures, policy convergence, and participatory governance. Conservation efforts must prioritize typological category, periodic water quality assessment, and protection against over-extraction and contamination. Institutional support and eco-educational outreach programs, particularly through student engagement and visual communication, are crucial for promoting community supervision. In the context of increasing climate variability, the protection and renewal of spring ecosystems are imperative for durable water security and

inclusive regional development. In this view, a comprehensive status report on Himalayan springs covering inventory, current conditions, causative factors of depletion, and revival initiatives across Himalayan states remains an urgent necessity²⁸.

Acknowledgements

I sincerely thank and gratefully acknowledge the support of Principal, B. Raghunath ACS College, Parbhani (M.S.), India, for facilitating academic research and student mobilization initiatives.

References

1. Davis, J.A., Kerezszy, A. & Nicol, S.S. (2017). Springs: Conserving perennial water is critical in arid landscapes. *Biological Conservation*, 211(B), 30-35.
2. Abraham Springer & Lawrence E. Stevens (2009). Spheres of discharge of springs. *Hydrogeology Journal*, 17(1), 83-93.
3. Vasudha Narayanan (2001). Water, Wood, and Wisdom: Ecological Perspectives from the Hindu Traditions. *JSTOR*, 130(4), 179-206.
4. Kaustubh Mahamuni & Himanshu Kulkarni (2013). Hydrogeology based Catchment Area Planning for Spring Water Management in Tuensang district, Nagaland under the North East Initiative (NEI). Report number: ACWA/2013/NEIDA Report/Tuensang 1 Affiliation: Advanced Center for Water Resources Development and Management.
5. Vashisht, A.K. & Sharma, H.C. (2007). Study on hydrological behaviour of a natural spring. *Current Science*, 93(6), 837-840.
6. Satpal S. B., Nagendra N. D., & Tripathy, N. K. (2011). Indian Hot- Water Springs: A Bird's Eye View. *Journal of Energy, Environment & Carbon Credits*, 1(1), 1-15.
7. Fahim Un Nisa & Rashid Umar. (2024). Spring water system classifications & their methods of study: An overview of the current & future perspectives. *Journal of Earth System Science, Springer Nature*, 133(10).
8. Kunal K. G., & Siddharth S.R. (2016). Managing the humanitarian relief chain: The Uttarakhand disaster issues. *Journal of Advances in Management Research, emerald Pub.*, 13(1).
9. Negi, G.C.S. & Joshi, V. (2004). Rainfall and spring discharge pattern in two small drainage pattern catchments in the western Himalayan Mountain, India. *The Environmentalist.*, Springer Nature Link, 24, 19-28.
10. Ayushi Vijhni, V.S.P. Sinha, C.A. Vishwakarma, P. Singh, S.K. Sharma (2022). Assessment of diminishing discharge of springs in Central Himalayan region, India, Hydrological Processes. *WILEY Pub.*, 36(5), e14582.

11. Prasenjit Das, Maya, K & Padmalal, D. (2021). Hydrogeochemistry of the Indian thermal springs: Current status. *Earth-Science Reviews, Science Direct*, 24 (103890).
12. Neha, C. Anjali, N. & Negi, M.S. (2024). Rainfall dependency and water quality assessment of springs of three villages of Rudra Prayag Dist.: An analysis of veins of Uttarakhand, Himalaya. *Acta Geographica Debrecina Landscape & Environment series*, 18(1), 36-47.
13. Subhajyoti Das. (2018). Chapter: Water Management in Arid and Semiarid Areas of India, Ground water Development Issues & Sustainable Solutions. *Springer Nature Link Pub.*, 15-33. ISBN-13: 9789811317712.
14. Zubair, A. Khan., Rohitashw, K., Afzal, Husain Khan & Jagadesh P. (2025). Impact Asses. of Natural Springs for Irrigation Potential in the Hilly Areas of Kashmir. *Sustainability*, 17(12), 5490.
15. Agarwal, A., Bhatnaga, N.K., Nema R.K. & Agrawal, N. K. (2012). Rainfall Dependence of springs in the Midwestern Himalayan Hills of Uttarakhand. *Mt. Res. Dev.*: 446-455.
16. Kireet Kumar & Rawat D.S. (1996). Water management in Himalayan ecosystem: A study of natural springs of Almora. *Indus Pub. Company, New Delhi*. ISBN-13: 9788173870477.
17. Martin R. & Peter C. (2018). Different forest cover and its impact on eco-hydrological traits, invertebrate fauna & biodiversity of spring habitats. *Nature Conservation*, 27, 85-99.
18. Garima Dubey, Gauhar Mahmood and Amina Zakiah (2021). Impact assessment of spring water on human health in parts of Himalayan region. *JETIR*, 8(7), 709-723.
19. Bootheina Majoul, Digvijay Pandya and Lin Wang (2023). Proceedings of the 2022 4th International Conference on Literature, Art and Human Development (ICLAHD 2022). *Atlantis Press SARL*.
20. Jose M., Agustina O., Meliton J., L Vera-Romero (2015). Physical-Chemical and Therapeutic Properties of Hot Springs and Hydrothermal Waters. *IJRIS*, 2(1), 10-12.
21. Binit Vaidya & Shweta Nakarmi (2025). Epidemiology of Rheumatic & Musculoskeletal Disorders in Province 3 of Nepal: A COPCORD-Based Community Survey. *International Journal of Rheumatic Diseases*, 28(12).
22. Naik, P. K. & Awasthi, A. K. (2006). Role of springs in regeneration of forests in the Western Ghats, India. In: Proc., International Workshop on 'Impacts of Reforestation of Degraded Land on Landscape Hydrology in the Asian Region' At: Roorkee, India.
23. Sahay, H., Yadav, A.N., Singh, A.K. *et al.* (2017). Hot springs of Indian Himalayas: potential sources of microbial div. and thermostable hydrolytic enzymes. 3, *Biotech, Springer Nature*, 7(118).
24. Amitabha Roy. (2025). Multivariate Geospatial Heat Map Analysis for Interpretation of India's Peninsular and Extra-Peninsular Hot Springs Amitabha Roy. *OSR Journal of Applied Geology and Geophysics (IOSR-JAGG)*, 13(3),01-07.
25. Gurav, T., Singh, H.K. & Chandrasekharam, D. (2016). Major and trace element conc. in the geothermal springs along the west coast of Maharashtra, India. *Arab J Geosci*, 9(44).
26. Xiaohong, Liu & Jie., Cheng & Hongyan., Sun. (2023). Cultural Connotation of Mountains, Rivers, Forests, Farmlands, Lakes, Grasslands and Deserts. *Journal of Education, Society and Behavioural Science*, 36(9), 104-115.
27. Jaspal Singh Chauhan, Tarun Badwal & Neha Badola (2020). Assessment of potability of spring water and its health implication in a hilly village of Uttarakhand, India. *Springer Link*, 10(73).
28. Mohd. Imran, Jyesh Desai, Himanshu Kulkarni and Kaustubh Mahamuni (2019). Comprehensive report on springs in the Indian Himalayan Region. Report no. ACWA/Hydro/2019/H88.10.13140/RG.2.2.12104.06408.
29. NHP (2025). National Hydrology Project, Ministry of Water Resources, RD & GR, Govt. of India. www.nhp.mowr.gov.in
30. DST (2025). Department of Science & Technology, Govt. of India. www.dst.gov.in
31. UNDP (2026). United Nations Development Programme. www.undp.org
32. DLR (2025). Department of Land Resources, Govt. of India. www.dolr.gov.in,
33. IWP (2025). India Water Portal, Govt. of India. www.indiawaterportal.org