Template/Pro forma for Submission

NMHS-Himalayan Institutional Project Grant

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

NMHS Reference No.:	GBPNI/NMHS-2018-19/SG

Date of Submission:	1	2	1	2	2	0	2	2
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

PROJECT TITLE (IN CAPITAL)

ASSESSMENT OF NATURAL SPRING RELIABILITY FOR RURAL WATER SECURITY IN THE LESSER HIMALAYAN REGION- ARUNACHAL PRADESH

Project Duration: *from* (**27.05.2019**) *to* (**26.05.2022**).

***Submitted to*:**
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National Mission on Himalayan Studies, GBP NIHE HQs
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GENERAL INSTRUCTIONS:

1. The Final Technical Report (FTR) has to commence from the date of start of the Project (as per the Sanction Order issued at the start of the project) till its completion. Each detail has to comply with the NMHS Sanction Order.
2. The FTR should be neatly typed (in Arial with font size 11 with 1.5 spacing between the lines) with all details as per the enclosed format for direct reproduction by photo-offset process. Colored Photographs (4-5 good action photographs), tables and graphs should be accommodated within the report or should be annexed with captions. Sketches and diagrammatic illustrations may also be given giving step-by-step details about the methodology followed in technology development/modulation, transfer and training. Any correction or rewriting should be avoided. Please give information under each head in serial order.
3. Training/ Capacity Building Manuals (with details contents of training programme technical details and techniques involved) or any such display material related to project activities along with slides, charts, photographs should be brought at the venue of the Annual Monitoring & Evaluation (M&E) Workshop and sent at the NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora 263643, Uttarakhand. In all Knowledge Products, the Grant/ Fund support of the NMHS should be duly acknowledged.
4. The FTR Format is in sync with many other essential requirements and norms desired by the Govt. of India time to time, so each section of the NMHS-FTR needs to duly filled by the proponent and verified by the Head of the Lead Implementing Organization/ Institution/ University.
5. Five (5) bound hard copies of the Project Final Technical Report (FTR) and a soft copy should be submitted to the **Nodal Officer, NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora, Uttarakhand**.

The FTR is to be submitted into following two parts:

Part A – Project Summary Report

Part B – Project Detailed Report

Following Financial and other necessary documents/certificates need to be submitted along with Final Technical Report (FTR):

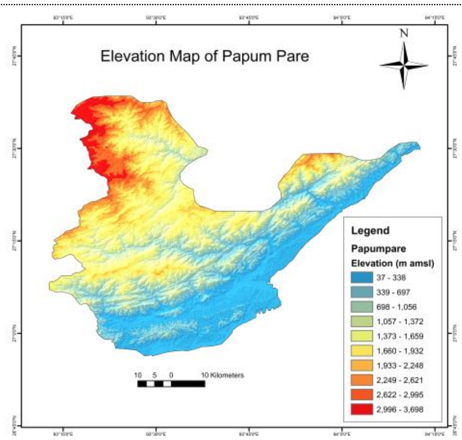
Annexure I	**Consolidated and Audited Utilization Certificate (UC) & Statement of Expenditure (SE)**, including interest earned for the last Fiscal year including the duly filled GFR-19A (with year-wise break-up)
Annexure II	**Consolidated Interest Earned Certificate**
Annexure III	**Consolidated Assets Certificate** showing the cost of the equipment in Foreign and Indian currency, Date of Purchase, etc. (with break-up as per the NMHS Sanction Order and year wise).
Annexure IV	**List of all the equipment, assets and peripherals** purchased through the NMHS grant with current status of use including location of deployment.
Annexure V	Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department
Annexure VI	**Details, Declaration and Refund of any Unspent Balance transferred through Real-Time Gross System (RTGS) in favor of NMHS GIA General**

DSL: Date of Sanction Letter							
2	1	1	2	**2**	**0**	**1**	**8**
d	d	m	m	y	y	y	y

DPC: Date of Project Completion							
2	6	0	5	**2**	**0**	**2**	**2**
d	d	m	m	y	y	y	y

Part A: Project Summary Report

1. Project Description

i.	Project Reference No.						
ii.	Type of Project	Small Grant		Medium Grant		Large Grant	
iii.	Project Title	**Assessment of natural spring reliability for rural water security in the lesser Himalayan region- Arunachal Pradesh**					
iv.	State under which Project is Sanctioned	**Arunachal Pradesh**					
v.	Project Sites (IHR States covered) (Maps to be attached)						
vi.	Scale of Project Operation	**Local**		Regional		Pan-Himalayan	
vii.	Total Budget/ Outlay of the Project	0.46 (in Cr)					
viii.	Lead Agency	NERIST					
	Principal Investigator (PI)	Dr. Pankaj Kumar Pandey					
	Co-Principal Investigator (Co-PI)	Mrs. Vanita Pandey					
ix.	Project Implementing Partners	NIL					

	Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail	Dr. Pankaj Kumar Pandey, Deptt. of Agricultural Engineering North Eastern Regional Institute of Science & Technology Nirjuli-791109 Arunachal Pradesh Phone No.: 9436229229, Email: pkpnerist@gmail.com

2. Project Outcomes

2.1. Abstract (not more than 500 words) [it should include background of the study, aim, objectives, methodology, approach, results, conclusion and recommendations).

Background: Natural springs in the region is drying or vanishing and becoming seasonal due to climate change and anthropogenic activities, such as climate change, especially rainfall, landsliding, hill cutting for new construction, forest burning for farming, and deforestation. In recent decades, water scarcity in the region was noticed during the lean period. The study's primary aim is to prepare the spring inventory map, springshed delineation, and assessment of spring water quality and reliability to rural water security. The different methodology was used in this investigation, such as field approach, questionnaire survey, remote sensing and GIS, isotope techniques, and technical analysis to estimate the region's spring reliability for rural water security. About 102 spring was identified and geotagged. Based on discharge data recorded of 11 springs hydrograph, recession curve and spring yield were estimated. The recession period started from mid-October to March (140 to 180 or 190 days), but most water scarcity was noticed during January to March. The recession curve estimated the best fit model. The spring's water quality was monitored, and it was noticed that most parameters are under acceptable or permissible limit, except the pH of most spring water is below the acceptable limit (6.5). Primarily, water quality parameters are above the permissible limit in springs recharge areas dominated by population. So, water filtration was recommended before drinking water. The spring yield was estimated based on the recorded discharge data, and demand was also based on users' dependability. Hence, based on spring yield, the water harvesting structure recommended for low (very low & low), medium, and high discharge are closed circuits for very low discharge, open circuits for low to high discharge, and spring-fed ponds for high discharge springs. Spring rejuvenation and protection are required to achieve the region's future water scarcity. Due to less care, springs are drying or vanishing; hence spring protection is more required in the region. Therefore, train or educate the local communities to protect the spring head and recharge area.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (in bullets points)
1	• Identifying and mapping of spring-shed of Arunachal Pradesh using geospatial tools	• Spring inventory map was prepared • Spring potential zonation was prepared • Springshed is delineated.
2	• To monitoring hydrological indices of spring, recharge area, and source and predict the spring water discharge pattern and yield for future climate change scenario.	• Spring discharge data of 3 years was collected. • Spring hydrograph prepared • Spring recession curve and yield generated.
3	• To examine qualitative reliability of springs based on the hydro-chemical indicator of drinking /agricultural water use.	• Onsite water quality data, metals, and chemical parameters collected (some results yet to be received) • Spring protection from contamination was recommended to users
4	• Quantitative estimation of spring water budget and recommend optimum spring water storage capacity structures for the lean period.	• The water demand of families depending on spring has been estimated. • The capacity of the water harvesting structure has been estimated

5	• Capacity building through management techniques and databases	

2.3. Outputs in terms of Quantifiable Deliverables*

S. No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, & Reason thereof:
1	Inventory and mapping of village-wise springs/seeps and spring-fed streams in 2 districts of AP.	• Spring location • Potential mapping • Springshed delineation	102 1 district 7	
2	Revival and recharge of spring in 01 district of Arunachal Pradesh.	nil		
3	01 Workshop/ Conference on spring rejuvenation.	nil		
4	Database on Spring's hydrological characteristics, Physical and chemical properties, Isotopic composition, etc., for 2 Years	Discharge data, Water quality data	3 years 1 Year 4 samples	

(*) As stated in the Sanction Letter issued by the NMHS-PMU.

2.4. Strategic Steps with respect to Outcomes (in bullets)

S. No.	Particulars	Number/ Brief Details	Remarks/ Attachment
1.	New Methodology developed		
2.	New Models/ Process/ Strategy developed	RS and GIS, Isotopes	
3.	New Species identified		
4.	New Database established	Inventory map, springshed, discharge data, water quality data	
5.	New Patent, if any	nil	
	I. Filed (Indian/ International)		
	II. Granted (Indian/ International)		
	III. Technology Transfer (if any)		
6.	Others (if any)		

3. Technological Intervention: NA

S. No.	Type of Intervention	Brief Narration on the interventions	Unit Details (No. of villagers benefited / Area Developed)

1.	Development and deployment of indigenous technology	Seepage spring development, springshed protection	
2.	Diffusion of High-end Technology in the region		
3.	Induction of New Technology in the region	Remote sensing and GIS use in springshed mapping and Isotopes techniques	
4.	Publication of Technological / Process Manuals	nil	
	Others (if any)	nil	

4. New Data Generated over the Baseline Data

S. No.	New Data Details	Status of Existing Baseline	Additionality and Utilisation New data
1	**Spring Locations**	102	
2	**Springshed delineation**	7	
3	**Discharge data**	11 springs (3 years)	
4	**Isotope data**	The analysis result was partial received and partial is under analysis at CWRDM Kerla	
4	**Water Quality**	Recorded, partial recieved and some reports yet to be received	

5. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S. No.	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	**ST**	**Woman**	**Total**
1.	Workshops	nil					
2.	On Field Trainings	nil					
3.	Skill Development	nil					
4.	Academic Supports	1(Ph.D) & 1(JRF)			01		
	Others (if any)	Research staffs and student interaction with communities			Local communities	Both men and women	

6. Linkages with Regional & National Priorities (SDGs, INDC, etc)/ Collaborations

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held	Beneficiaries

1.	Sustainable Development Goal (SDG)	NA		
2.	Climate Change/INDC targets	NA		
3.	International Commitments	NA		
4.	Bilateral engagements	NA		
5.	National Policies	NA		
6.	Others collaborations	NA		

7. Project Stakeholders/ Beneficiaries and Impacts

S. No.	Stakeholders	Support Activities	Impacts
1.	Gram Panchayats	nil	
2.	Govt Departments (Agriculture/ Forest)	nil	
3.	Villagers	nil	
4.	SC Community	nil	
5.	ST Community	nil	
6.	Women Group	nil	
	Others (if any)	nil	

8. Financial Summary (Cumulative)

S. No.	Financial Position/Budget Head	Funds Received	**Expenditure/ Utilized	% of Total cost
I.	Salaries/Manpower cost	456000.00	445190.00	97.63
II.	Travel	200000.00	67400.00	33.7
III.	Expendables &Consumables	450000.00	363055.00	80.68
IV.	Contingencies	100000.00	100000.00	100
V.	Activities & Other Project cost	150000.00	nil	0.0
VI.	Institutional Charges	Nil	nil	nil
VII.	Equipments	1150000.00	977606.00	85.01
	Total	2506000.00	1953251.00	77.95
	**Interest earned			
	Grand Total			

* Please attach the consolidated and audited Utilization Certificate (UC) and Year wise Statement of Expenditure (SE) separately, *ref*. **Annexure I.**

**Approximate values and exact values will reflected in final UC & SE statement

9. Major Equipment/ Peripherals Procured under the Project** (if any)

S. No.	Name of Equipments	Cost (INR)	Utilisation of the Equipment after project

1.	pH/EC/TDS Meter	64050/-	For regular moinetoring of spring and groundwater onsite and laboratory use.
2.	Multiparameter Photometers	131250/-	For water quality assessment at Departmental laboratory.
3.	rain gauges and H-flume	235725/-	Onsite measurement of rainfall and spring discharge at institute farm and nearest spring.
4.	Mini disk infiltrometer	63000/-	infiltration measurement for spring related PG and Ph.D studies
5.	GPS	35175/-	For departmental use
6.	Electronic Balance	70039/-	Laboratory use PG and Ph.D studies
7.	LCD projector with display	76650/-	Training and demonstration for students research
8.	Computer & Printer and acceries	199500/-	Analysis work in the department PG and Ph.D studies
9.	Camera	102217/-	For field photograph for departmental students

Details should be provided in details **(*ref* Annexure III &IV).

10. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States Covered	*1*	
2.	Project Site/ Field Stations Developed	*102 sites were identified, and 11 sites were regularly monitored*	*attached*
3.	New Methods/ Modeling Developed	*RS and GIS to predict the potential zone, and springshed delineation*	
4.	No. of Trainings arranged	*NIL*	
5.	No of beneficiaries attended trainings	*NIL*	
6.	Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA):	*JRF-1* *PhD-1*	
7.	SC stakeholders benefited	*NIL*	
8.	ST stakeholders benefited	*More than 200*	
9.	Women Empowered	*NA*	
10.	No of Workshops Arranged along with level of participation	*NIL*	
11.	On field Demonstration Models initiated	*NA* (attach maps about location & photos)	
12.	Livelihood Options promoted	*NA*	
13.	Technical/ Training Manuals prepared	*nil*	
14.	Processing Units established	*....* (attach photos)	
15.	No of Species Collected	*NIL*	
16.	New Species identified	*NIL*	
17.	New Database generated (Types):	*Spring inventory, Discharge data, water quality*	
	Others (if any)	*NIL*	

11. Knowledge Products and Publications:

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal Research Articles/ Special Issue:	nil	4		
2.	Book Chapter(s)/ Books:	nil	1		
3.	Technical Reports	nil	nil		

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
4.	Training Manual (Skill Development/ Capacity Building)	NA	NA		
5.	Papers presented in Conferences/Seminars		4		
6.	Policy Drafts/Papers		1(under review)		
7.	Others:	nil			

* Please append the list of KPs/ publications (with impact factor and further details) with due Acknowledgement to NMHS.

12. Recommendation on Utility of Project Findings, Replicability and Exit Strategy

Particulars	Recommendations
Utility of the Project Findings	Project findings can be used for formulate springshed development plan for the study site
Replicability of Project	The adopted methodology in current Project can be replicated in other districts of Arunachal Pradesh as well as other states of Northeastern region for India
Exit Strategy	Please describe the Exit Strategy of the project, self-sustaining and benefitting the stakeholders and local community: The Springs inventory & Discharge data helpful to stakeholder for formulating suistanable water menegement plan for local community. In general water quality of springs is acceptable and permissible limit . The pH is slightly acedic in nature so have some concern. Except in few springs in general water potable after narmal sand filtration. The recorded spring discharge data showing the discharge variation, hence based on the data water harvesting structures and spring-fed ponds can design and it will be helpful for stakeholder to self-sustaining.

(**PROJECT PROPONENT/ COORDINATOR**)

(Signed and Stamped)

(**HEAD OF THE INSTITUTION**)

(Signed and Stamped)

Place: ………………..
Date: …../……/……

PART B: PROJECT DETAILED REPORT

The Detailed report should include an Executive Summary and it should have separate chapters on (i) Introduction (ii) Methodologies, Strategy and Approach (iii) Key Findings and Results (iv) Overall Achievements (v) Project's Impacts in IHR (vi) Exit Strategy and Sustainability (vii) References and (viii) Acknowledgement (It should have a mention of financial grant from the NMHS, MoEF&CC)

Further, description of Technical Activities, List of Trainings/ Workshops/ Seminars with details of trained resources, list of New Products developed under the project, Manual of Standard Operating Procedures (SOPs) developed, Technology developed/Transferred etc should be enclosed as Appendix.

1 EXECUTIVE SUMMARY

The state of Arunachal Pradesh is gifted with high rainfall and natural or hot springs. These springs are essential in the state's socio-cultural, economic, and ecological setting. The springs have been poorly altered, degraded, and contaminated in recent decades due to various anthropogenic activities. However, understanding and quantifying the 'threats' remains one of the least attended problems. The uncertainty of rainfall and change in land use and land cover is one of the critical factors of variability and drying of spring discharge. Considering all these views, the present project proposes quantitatively estimating the spring discharge rate, yielding to frame mitigation and management strategies to conserve spring water for lean periods and development of springs.

The investigators were able to detect the gap in the current knowledge pool due to their exhaustive survey and thorough scanning of the relevant published material relative to the topic under investigation. Despite this, a great deal of published material is available on the drying up of springs in the northeast Himalayan region. The ecosystem of the Himalayan springs is highly delicate and subject to several changes brought about by both natural dynamics and artificial interventions. The unpredictable pattern of rainfall, seismic activity, and ecological degradation that are all related to changes in land use for infrastructure development are putting great demands on mountain aquifer systems. It has been estimated that half of the perennial springs have already dried up or turned into seasonal springs, leading to an extreme water deficit for drinking and other household needs in hundreds of Himalayan settlements. As a direct consequence, the ongoing crisis will impact the lives of millions of people living in the mountains. Half of the perennial springs had already dried up or become seasonal, and approximately eight to ten years ago, thousands of towns were currently dealing with a severe lack of water for drinking purposes. This is a figure that may be even more pertinent today. There has been hardly any research conducted on the springs in Arunachal Pradesh. As a result, the study that has been proposed will be an innovative piece of work in determining the effect that climate change will have on the springshed in the area.

Based on the literature, there have been many pragmatic gaps in our understanding; we are constantly improving knowledge; not many qualitative and quantitative detail studies are available about mountain ecosystems' susceptibility to climate change. The high-elevation region of Arunachal Pradesh faces water scarcity while receiving extensive orographic rainfall for both physical and artificial reasons. Spring water management projects are already run by different institutions/societies. But there is a need for an intense investigation into climate change's impact on spring discharge fluctuation and which climatic causes essential effects. Also, anthropogenic activities impair the springshed and its water quality. It was discovered that the people reduced hills to limit roads, factories, and new buildings.

Reduced recharge of the springs' catchments is attributable to climatically-induced shifts in hydrological events, and as a result, the vast majority of springs are either permanently dry or only flow during certain times of the year. As a whole, the average discharge rate of the region's perennial springs is falling. Himalayan locals claim that during the past four to five decades, they have seen a dramatic decrease in the flow rate of springs and streams and that the situation is so dire now that most water supplies dry up during the winter. Women and children in rural areas often have to get up early to trek great distances to get water. 72% of women and 14% of children in the Uttarakhand region are responsible for transporting clean water, according to recent research. Sixty percent of the women had to walk half a kilometer, while ten percent had to trek four kilometers to get water for their families. If no reliable source of perennial irrigation is available, people are forced to forsake their farmland during the dry season. It is not possible to obtain such information in the eastern Himalayas. The planned study is being conducted to ensure the natural springs in rural parts of the state are managed sustainably and to better the quality of life for the local inhabitants. The situation is not different in the western Himalayas.

In the current project, a field survey was conducted to identify the groundwater springs in the different circles of the Papum Pare district. The investigation was carried out by questioning the local communities regarding the number, location, and accessibility of the springs in their locality. Once a spring was identified, its latitude and longitude were recorded using a handheld GPS receiver. Additionally, the onsite occurrence of topography, land use, water discharge, access, and purpose of use was recorded. About 102 springs were identified in the survey. After identifying each spring, a unique name was tagged to that spring for future reference. The place or landowner named all the identified springs. A geo-tagged map was prepared using the collected spring locations. Spring potential zone map is based on recorded data and collected maps from different agencies. The potential zone map shows the possible occurring areas of groundwater zones and is helpful for policymakers and researchers to implement water management and protection projects in the region. Based on collected information and trans walk, the delineation of the springshed was conducted with the help of remote sensing and the GIS method.

The 11 springs were regularly monitored from January 2019 to May-July 2020. Based on discharge data recorded of 11 springs hydrograph, recession curve and spring yield were estimated. The recession period started from mid-October to March (140 to 180 or 190 days), but most water scarcity was noticed during January to March. The recession curve estimated the best fit model. The spring's water quality was monitored, and it was noticed that most parameters are under acceptable or permissible limit, except the pH of most spring water is below the acceptable limit (6.5). Primarily, water quality parameters are above the permissible limit in springs recharge areas dominated by population. So, water filtration was recommended before drinking water. The spring yield was estimated based on the recorded discharge data, and demand was also based on users' dependability. Hence, based on spring yield, the water harvesting structure recommended for low (very low & low), medium, and high discharge are closed circuits for very low discharge, open circuits for low to high discharge, and spring-fed ponds for high discharge springs. Spring rejuvenation and protection are required to achieve the region's future water scarcity. Due to less care, springs are drying or vanishing; hence spring protection is more required in the region. Therefore, train or educate the local communities to protect the spring head and recharge area.

2 INTRODUCTION

2.1 Background of the Project (max. 500 words)

The Himalayas are known as the "water towers of the Earth." The Himalayan range provides water to the millions of people at the downstream end through the perennial rivers. It is reported that rainfall will be slightly increased along with greater intensity in the Himalayan region. In the past five decades, it has been witnessed that the rainfall pattern has changed from low-intensity longer-duration events to high-intensity smaller-duration events. It is reported that more than 90 percent of annual rainfall is concentrated from April to September. Monthly, 70–85 percent of the rainfall is reported from April to September, whereas the remaining 15–30 per cent of the rainfall is observed from October to March (Kusre et al. 2017). The change in land use and land cover is another issue in water resource management. Many studies found that deforestation, grazing, and trampling by livestock, soil erosion, forest fires, and development activities reduce the infiltration capacity. The groundwater recharge is reduced due to a change in land use and land cover pattern, resulting in the higher runoff. However, these life-supporting springs are either drying up or becoming seasonal over the last few decades, causing a hydrological imbalance in the fragile upland watersheds (Negi and Joshi, 2002; Vashisht, 2017). Like many other places, the Himalayan region is experiencing rapid climate change, likely influencing local ecosystems, biodiversity, agriculture, and human well-being. The weather has become unpredictable and erratic, snow is melting rapidly, and water sources are drying up (Sharma et al., 2009; Chaudhary and Bawa, 2011; Chaudhary et al., 2011; Tambe et al., 2011). Water is one of the most critical sectors on which climate change can have a profound impact, which can have second-order impacts on other associated sectors. While a consensus exists on the likely impacts of climate change on the water resources of the Himalayas, quantitative analyses of such changes are sparse due to the dearth of baseline data essential for such analyses. As per the literature, not many qualitative and quantitative detail studies are available about mountain ecosystems' vulnerability to climate change.

The present study is proposed to be undertaken in the Papum Pare district of Arunachal Pradesh, Northeast India. Papum Pare is situated between latitudes 26°56′11″ to 27°35°44″N and latitudes 93°12′45″ E to 94°13′30″ E. It borders with Lower Subansiri district in the north East Kameng district in the West. West Siang district falls in its eastern boundary, while the North Lakhimpur district of Assam is situated in the south. Papumpare district is divided into two sub-divisions viz., 1) Sagalee and 2) Itanagar, further divided into 4 blocks, 9 circles, and 273 villages.

The majority (75%) of the district is covered by thick forest, with tropical, subtropical, deciduous, and humid vegetation. Inhabitations occupy the low land and valleys. The rainy or monsoon season starts from May and continues until September/ October. The average annual rainfall is 3200 mm. The district is characterized by low to high-relief hills and corrugated landforms. The general trend of ridges is NE-SW, and the Siwalik Hills form hogback topography. The height of the steep terrain increases from south to north, ranging from about 300 m to 2700 m above msl. The general attitude in a significant part of the district ranges from 1000 m to 2000 m msl. Various geomorphic features in the district can broadly be grouped into six geomorphic units. Based on the literature, it has been many pragmatic gaps in our knowledge, constantly improving knowledge, the excellent need for spring water management in the Himalayan region, and to produce an up-to-date checklist for the Himalayan water resources.

2.2 Overview of the Major Issues to be Addressed (max. 1000 words)

The state of Arunachal Pradesh is gifted with high rainfall and natural or hot springs. These springs are essential in the state's socio-cultural, economic, and ecological setting. The springs have been poorly altered, degraded, and contaminated in recent decades due to various anthropogenic activities. However, understanding and quantifying the 'threats' remains one of the least attended problems. The uncertainty of rainfall and change in land use and land cover is one of the critical factors of variability and drying of spring discharge. Considering all these views, the current project proposes quantitatively estimating the spring discharge rate, yielding to frame mitigation and management strategies to conserve spring water for lean periods and development of springs.

The investigators were able to detect the gap in the current knowledge pool due to their exhaustive survey and thorough scanning of the relevant published material relative to the topic under investigation. Despite this, a great deal of published material is available on the drying up of springs in the northeast Himalayan region. The ecosystem of the Himalayan springs is highly delicate and subject to several changes brought about by both natural dynamics and artificial interventions. The unpredictable pattern of rainfall, seismic activity, and ecological degradation that are all related to changes in land use for infrastructure development are putting great demands on mountain aquifer systems. It has been estimated that half of the perennial springs have already dried up or turned into seasonal springs, leading to an extreme water deficit for drinking and other household needs in hundreds of Himalayan settlements. As a direct consequence, the ongoing crisis will impact the lives of millions of people living in the mountains. Half of the perennial springs had already dried up or become seasonal, and approximately eight to ten years ago, thousands of towns were currently dealing with a severe lack of water for drinking purposes. This is a figure that may be even more pertinent today. There has been hardly any research conducted on the springs in Arunachal Pradesh. As a result, the study that has been proposed will be an innovative piece of work in determining the effect that climate change will have on the springshed in the area.

2.3 Baseline Data and Project Scope (max. 1000 words)

- Reduced recharge of the springs' catchments is attributable to climatically-induced shifts in hydrological events, and as a result, the vast majority of springs are either permanently dry or only flow during certain times of the year. As a whole, the average discharge rate of the region's perennial springs is falling. Himalayan locals claim that during the past four to five decades, they have seen a dramatic decrease in the flow rate of springs and streams and that the situation is so dire now that most water supplies dry up during the winter. Women and children in rural areas often have to get up early to trek great distances to get water. 72% of women and 14% of children in the Uttarakhand region are responsible for transporting clean water, according to recent research. Sixty percent of the women had to walk half a kilometer, while ten percent had to trek four kilometers to get water for their families. If no reliable source of perennial irrigation is available, people are forced to forsake their farmland during the dry season. It is not possible to obtain such information in the eastern Himalayas. The planned study is being conducted to ensure the natural springs in rural parts of the state are managed sustainably and to better the quality of life for the local inhabitants. The situation is not different in the western Himalayas.

2.4 Project Objectives and Target Deliverables (as per the NMHS Sanction Order)

Objectives

i. Identifying and mapping of springshed of Arunachal Pradesh using geospatial tools.
ii. To monitor hydrological indices of spring, recharge area, and source and predict the spring water discharge pattern and yield for future climate change scenario.
iii. To examine qualitative reliability of springs based on the hydro-chemical indicator of drinking /agricultural water use.
iv. Quantitative estimation of spring water budget and recommend optimum spring water storage capacity structures for the lean period.
v. Capacity building through management techniques and databases.

Target deliveries

i. Inventory and mapping of village-wise springs/seeps and spring-fed streams in 2 districts of AP.
ii. Revival and recharge of spring in 01 district of Arunachal Pradesh.
iii. 01 Workshop/ Conference on spring rejuvenation.
iv. Database on Spring's hydrological characteristics, Physical and chemical properties, Isotopic composition, etc., for 2 Years

3 METHODOLOGIES, STRATEGY, AND APPROACH

3.1 Methodologies used for the study (max. 1000 words)

Identifying spring's location: A field survey was conducted to identify the groundwater springs in the different circles of the Papum Pare district. The investigation was carried out by questioning the local communities regarding the number, location, and accessibility of the springs in their locality. Once a spring was identified, its latitude and longitude were recorded using a handheld GPS receiver. Additionally, the onsite occurrence of topography, land use, water discharge, access, and purpose of use was recorded.

Spring name and coding: After identifying each spring, a unique name was tagged to that spring for future reference. All the identified springs were named with the name of the place or landowner where the spring is located, followed by the serial number of sightings of the spring in that place in roman numerals, and the spring code was assigned as per standard water quality and isotope analysis. Such as AR/PP/GU/SP, where AR is Arunachal Pradesh (state), PP is Papum Pare (district), GU-Gumto (source name), and SP- is spring water (source type).

Geo-tagging map: A geo-tagged map was created using ArcMap in the lab once the latitudes and longitudes of the identified springs were recorded in the field.

Identification of Spring Potential Zone: In the present study, ten influencing parameters (drainage density, slope, lineament density, rainfall, geomorphology, lithology, soil texture, land use and land cover, groundwater level, and spring discharge) related to spring occurrence and groundwater movement were used. An integrated approach of RS and GIS, analytic hierarchy process (AHP), and fuzzy-AHP based on multicriteria decision-making (MCDM) were used to generate the spring potential zones. The flow chart (**Fig. 1**) illustrates the complete spring potential zone generation process. The analysis output was categorized into low, moderate, and high. The generation of thematic layers includes digital image processing and digitalization of conventional or existing maps.

Springshed Delineation using Geospatial Tools: Recharge areas of spring systems can be hard to identify, but it is essential for any springshed management practices such as rejuvenation and protection of springs. Different methods of identifying or delineating recharge areas or springshed include RS and GIS, isotopic studies or tracing techniques, geological studies, and a combination of different methods. For the analysis of stable water isotopes, grundwater samples were taken fortnightly from springs (n=15) of the Papumpare district in 50-ml high-density polyethylene (HDPE) bottels. Springs recharge had been identified based on field survey, elevation profile observations, isotopes, and RS and GIS techniques. The flow chart (**Fig. 2**) shows the complete springshed delineation process.

Spring Discharge: The elven springs were selected based on depending on its accessibility and to study their discharge rates, such as low, medium, and high discharge. The discharge rate was measured using a measuring beaker and a stop watch. Spring water was collected in the beaker, and its time was recorded simultaneously. To minimize human error, the spring's discharge rate was sampled at weekly intervals for each of the selected springs, and to minimize human error, the discharge rate was measured three times in the low season and five times in the peak season. An average of all the readings was then taken as its final reading, where flow (Q) of spring will be collected into a container of known volume (V) with time (t) for determining discharge rate.

Spring hydrographs: Spring hydrograph is the graphical representation of a spring's discharge rate (Q) concerning time (*t*). The spring behavior will be analyzed and predicted. Spring discharge rate varies with the temporal variations of rainfall in the catchment. In the monsoon and post-monsoon period discharge of springs are the peak, then its discharge rate is decreased with minor ups and downs up to the next monsoon. The spring hydrograph curve that ranges after a base to the peak discharge is known as the "accession curve" (or rising limb). However, the part from peak discharge to the base of the subsequent rise is known as the "recession curve" (or falling limb). Generally, the accession curve is not uniform because the increase in discharge rate is irregular due to intermittent recharging from non-uniform rainfall events. On the other hand, a drop-in recession curve is comparatively uniform due to the lack of any catchment recharging and is commonly opted for study. For developing the recession curve, the peak discharge data of the spring will be plotted against time.

Recession Curve Analysis: To achieve more accuracy in this study, different mathematical equations will be used for the recession curve analysis. It may be a linear equation, a polynomial equation, a logarithmic equation, an exponential equation, or any other combination.

Master recession curve: The master Recession Curve method permits to work at the same time with several recession periods, making negligible the influence used by precipitation and finding an average value that shows the recharge area. This method allows the recession curve to be separated into different parts with similar trends, thereby enabling separate analyses. The separation model scenario that shows the highest average coefficient of determination R^2 is chosen as the optimal/most appropriate scenario. This separation scenario is considered by an optimal set of percentages of flow rate duration (**Posavec *et al*. 2006, 2010**).

Spring Yield: Spring yield will be monitored regularly; it will be estimated by summing up the daily discharge values of springs for the measured period. Though, predicting the spring yield an upcoming lean or recession period.

Water Quality Assessment: Assessment of water quality analysis for drinking or domestic purposes: Spring water quality will be analyzed as per the prescribed standard of WHO (2011) and IS-10500 (2012) in terms of drinking or domestic purpose. Essential cations and ions' monthly variation will also be determined, along with pH and EC.

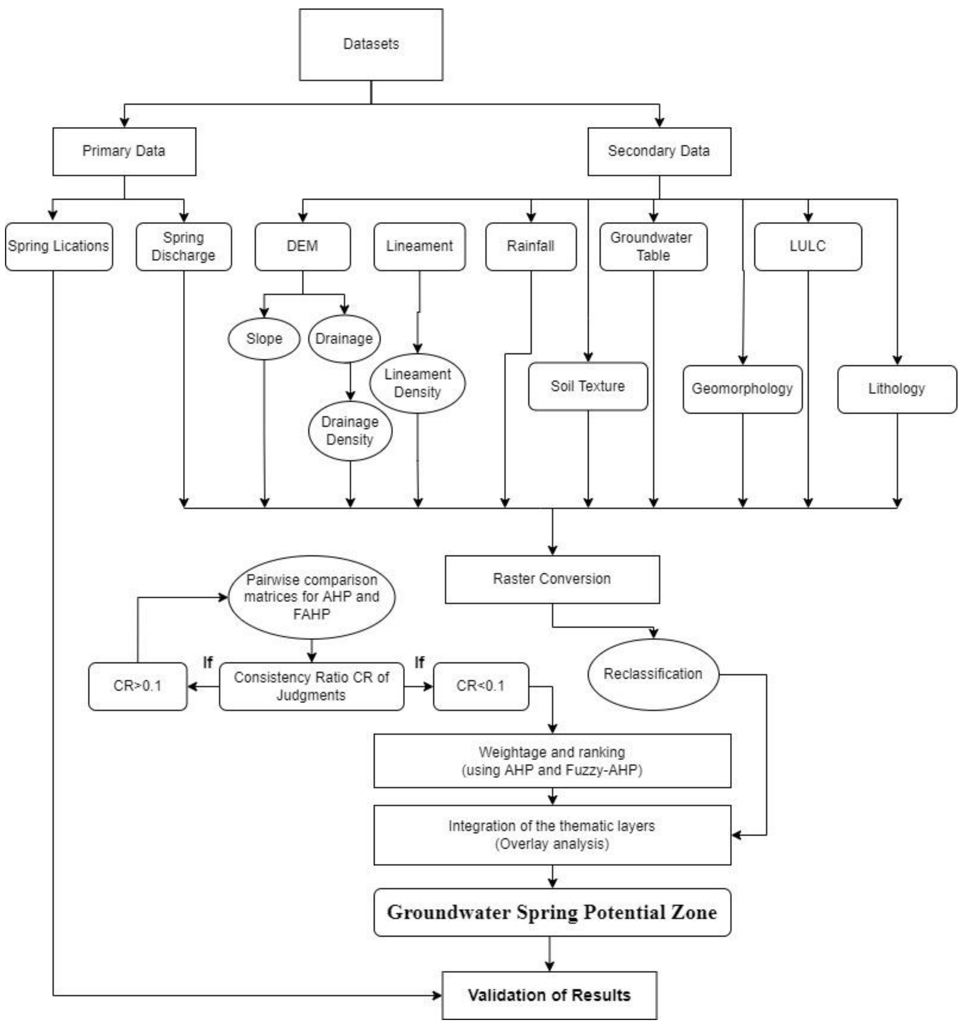


Fig. 1 Flow chart of identification of spring potential zone

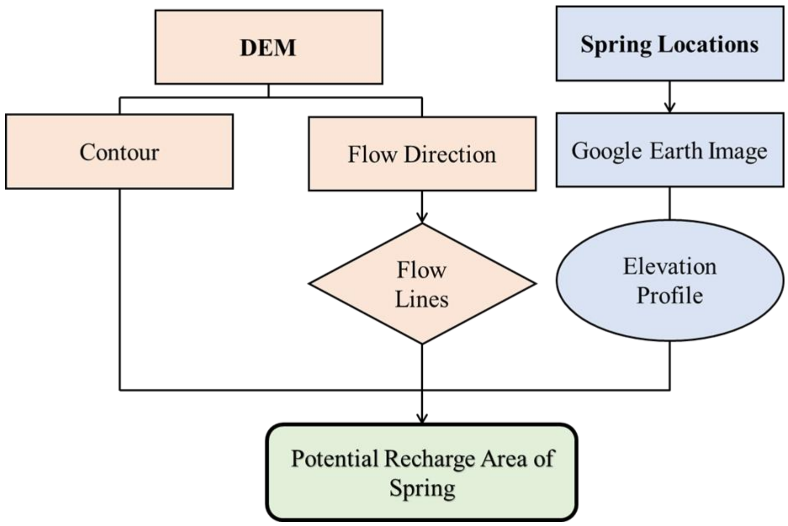


Fig 2: Flow chart of identification of potential recharge area

Water Quality Indexes (WQI): Water quality indices are tools to determine water quality conditions and, like any other tool, require knowledge about principles and basic concepts of water and related issues (**Nikbakht, 2004**). It is a well-known method of expressing water quality that offers a stable and reproducible unit of measure which responds to changes in the principal characteristics of water (**Brown *et al*. 1972**). WQI summarizes large amounts of water quality data into simple terms (*e.g*., excellent, good, bad, etc.) for reporting to management and the public consistently.

Estimating Household Consumption of Families Depending on Springs: Field survey collected springwise user dependability and location. We'll estimate that home water needs two methods. In the first method, the family's actual household water use (drinking, washing, animal use) is surveyed. Survey data will be categorized by spring to predict demand and consumption. The water stress on each spring will be identified by comparing the maximum, average, and minimum spring flow with actual and needed residential water demand for three spring use scenarios. First, spring water is used 24 hours a day, then 12 hours, and finally 6 hours.

Storage Structure capacity optimization: In a water-scarce environment, local communities collect water from distant sources. Plastic pipes transport water from the spring orifice to storage tanks if the springs are far, and springs can be directly tapped if they are nearby. Broken pipes, leaks, blocked pipes from the air or solid particles, and other difficulties plagued residents. Management measures improve spring discharge. Managing spring discharge storage is also critical. You must know the spring discharge rate, tank size, and water demand to store water. Generally, storage tank capacity is determined by a family's 1- or 2-day needs. Estimating water demand depends on population and another usage. Assume the Dd (L/d) is the daily water requirement of a person and PN is the total number of persons. Then, the total daily demand (TD) will be evaluated (**Eq. 1**) as

$$T_D = P_N \times D_d \qquad (1)$$

If TD is less than the daily discharge rate of spring, there will be no need for any storage structure. The duration for which total demand (TD) remains higher than the daily discharge rate of spring is known as the water shortage or stress period (**Vashisht 2016**) and is termed as "Tshort". For evaluating the storage structure's capacity considering no wastage and excess use (Osc-w) can be written as **Eq. (2)**. The mathematical equation is

$$O_{sc-w} = P_N \times D_d \times T_{short} \times \left[\sum_{t_i = T_{i-1}}^{T_i - 1} Q_{0_i} \times e^{-\alpha_i \times (t_i - T_{i-1})} \right] + \left[\sum_{t_N = T_{N-1}}^{T_N} Q_{0_N} \times e^{-\alpha_N \times (t_i - T_{i-1})} \right] \qquad (2)$$

The symbol Qsc–w letter "sc" denotes 'storage capacity, and the letter 'w' is the excess use and wastage of water. The key to the projected solution will be making efficient use of the existing water and increasing available water resources.

Sometimes due to other uses and increasing family members, water use and wastage will increase. This increased use and wastage increase the total daily water demand by W percent. So, the analytical function for estimating optimized storage capacity "Qsc" of structure can be written as (**Eq. 3**):

$$Q_{sc} = Q_{sc-w} \times \left(1 + \frac{W}{100}\right)$$

3.2 Preparatory Actions and Agencies Involved (max. 1000 words)

----------NA------------

3.3 Details of Scientific data collected and Equipment Used (max 500 words)

- Spring locations were recorded using handheld GPS.
- Onsite water quality was measured using the multiparameter water test kit.

3.4 Primary Data Collected (max 500 words)

Spring locations and other important information: A field survey was conducted to identify the groundwater springs in the different circles of the Papum Pare district. The investigation was carried out by questioning the local communities regarding the number, location, accessibility, and user dependability of springs in their locality. A total of 102 spring locations and their information were collected, shown in **Table (1).**

Table 1: Spring location and important details

Sr. No	Spring Code	Village Name	Spring Name	Latitude	Longitude	Status	Use	Land Use
1	UD-1	Nahalagun	Upper Dam-Site 1	27°05'36.9312"N	93°42'07.3980"E	Seasonal		Populated
2	UD-2		Upper Dam-Site 2	27°05'40.3512"N	93°42'09.4464"E	Perennial	5 Families	Populated
3	UD-3		Upper Dam-Site 3	27.093668	93.701861	Seasonal		Mixed land
4	UD-4		Upper Dam-Site 4	27.090575	93.703259	Perennial		Mixed land
5	UD-5		Upper Dam-Site 5	27.089321	93.703997	Seasonal		Mixed land
6	UD-6		Upper Dam-Site 6	27.086281	93.705154	Seasonal		Mixed land
7	UD-7		Upper Dam-Site 7	27.087275	93.704429	Seasonal		Mixed land
8	MD-A		Middle Dam-Site A	27°05'51.1440"N	93°42'04.2228"E	Perennial	Ungauged	Populated
9	MD-B		Middle Dam-Site B	27°05'51.8712"N	93°42'03.4488"E	Seasonal		Populated
10	LD-1		Lower Dam-Site 1	27°05'57.3396"N	93°42'06.1236"E	Perennial	10 Families	Populated
11	LD-2		Lower Dam-Site 2	27°05'55"N	93°42'19"E	Seasonal		Populated
12	LD-3		Lower Dam-Site 3	27°05'43"N	93°42'25"E	Perennial		Populated
13	DS		D-Sector	27°05'57.8040"N	93°41'22.5564"E		3 Families	Populated
14	BP		Barapani	27°06'01.5876"N	93°41'18.0960"E	Perennial	20 Families	Populated
15	PR		Prem Nagar	27°06'34"N	93°41'46"E	Perennial	50-60 Families	Populated
16	PN-A	Pappu Nallah	Pappu Nallah A	27°5'59.2188"N	93°40'14.3508"E	Seasonal		Mixed land
17	PN-B		Pappu Nallah B	27°5'44.4192"N	93°40'02.2116"E	Seasonal		Mixed land
18	DT		Dupit Tiniale	27°6'28.6092"N	93°39'09.0828"E	Seasonal		Mixed land
19	SM		Shiv Mandir	27°6'22.5324"N	93°39'26.2656"E	Perennial	For temple use	Mixed land
20	PP		Petrol Pump	27°6'13.0932"N	93°40'08.0256"E	Perennial		Mixed land
21	PT-A	Paga Tarah and Juli Basti	Paga Tarah A	27°5'22.4988"N	93°39'59.6808"E	Seasonal		Mixed land
22	PT-B		Paga Tarah B	27°5'18.9672"N	93°40'06.7836"E	Seasonal		Mixed land
23	JB-1		Juli Entry Gate	27°5'09.3408"N	93°36'47.2824"E	Seasonal		Mixed land
24	JB-2		Juli Car Wash Centre	27°5'09.1716"N	93°36'44.7804"E	Seasonal		Mixed land
25	CH-1	Chimpu	Chimpu - I	27°03'28.1268"N	93°36'45.0324"E	Perennial		Forest land
26	CH-1A		Chimpu - IA	27°03'32.4756"N	93°36'45.2160"E	Seasonal		Forest land
27	CH-II		Chimpu - II	27°03'47.8080"N	93°36'34.1424"E	Perennial		Forest land
28	CH-IIA		Chimpu - IIA	27°03'43"N	93°36'37"E	Seasonal		Forest land
29	CH-III		Chimpu - III	27°04'24.2832"N	93°35'39.0192"E	Perennial		Forest land
30	CH-IV		Chimpu - IV	27°02'47"N	93°37'19"E	Seasonal		Forest land
31	KAR-A	Karsingsa	Karsingsa A	27°07'16.9500"N	93°45'42.7428"E	Seeps		Forest land
32	DM		Durga Mandir	27°07'21.5544"N	93°45'33.2568"E	Perennial	1Restaurant,	Forest land

							1 Family, Temple use	
33	KAR-C		Karsingsa C	27°07'22.6560"N	93°45'27.7596"E	Seasonal		Forest land
34	KAR-1A		Karsingsa 1A	27°07'15"N	93°45'47"E	Perennial	Workers, pedestrian	Forest land
35	KAR-2A		Karsingsa 2A	27°07'16"N	93°45'47"E	Perennial		Forest land
36	GU	Gumto	Gumto	27°08'22.3"N	93°48'08.5"E	Perennial	12 Families	Forest land
37	LRGU-1	RGU	Lower RGU 1	27°08'37.7"N	93°45'47.8"E	Seasonal	1 Family	Forest land
38	LRGU-2		Lower RGU	27°08'41.2"N	93°45'42.4"E	Perennial	1 Family	Forest land
39	HL-1	Holangi	Holangi-1	27°00'57"N	93°37'7"E	Perennial		Forest land
40	HL-B		Holangi-B	27°00'18"N	93°36'55"E	Perennial	4 Families using B and C	Forest land
41	HL-C		Holangi-C	26°59'53.11"N	93°36'58"E	Perennial		Forest land
42	HL-D		Holangi-D	26°59'53"N	93°36'58"E	Perennial	4 Families	Forest land
43	HL-E		Holangi-E	26°59'52"N	93°36'59"E	Perennial	4 Families	Forest land
44	HL-F		Holangi-F	26°59'45"N	93°37'1"E	Seasonal	1 Family	Forest land
45	GLA-1	Ganga Lake Area	Ganga Lake Area A	27°04'38.2"N	93°34'40.9"E	Perennial	1 Family	Mixed land
46	GLA-2		Ganga Lake Area B	27°04'42.1"N	93°34'20.3"E	Perennial	1 Family	Mixed land
47	MID-1A	Midpu	Midpu-IA	27°10'24"N	93°46'10"E	Seasonal		Forest land
48	MID-1B		Midpu-IB	27°10'26"N	93°46'11"E	Perennial		Forest land
49	MID-1C		Midpu-IC	27°10'29"N	93°46'14"E	Seasonal		Forest land
50	MID-1D		Midpu-ID	27°11'50"N	93°46'58"E	Seasonal	Ungauged	Forest land
51	MID-1E		Midpu-IE	27°13'41"N	93°48'00"E	Seasonal		Forest land
52	MID-1F		Midpu-IF	27°13'43"N	93°48'01"E	Seasonal		Forest land
53	MID-1G		Midpu-IG	27°13'50"N	93°48'12"E	Seasonal	1 Family	Forest land
54	HJ-A	Hoj	Hoj A	27°16'26"N	93°47'54"E	Perennial	1 Family	Forest land
55	HJ-B		Hoj B	27°16'57"N	93°47'57"E	Perennial		Forest land
56	YU-1	Yupia	Yupia 1	27°08'29"N	93°42'33"E	Seasonal	2 Families (5 Person)	Mixed land
57	YU-2		Yupia 2	27°08'29"N	93°42'43"E	Seasonal		Mixed land
58	KC-1		Khula Camp 1	27°09'44"N	93°44'26"E	Perennial	3 Springs	Mixed land
59	KC-2		Khula Camp 2	27°09'47"N	93°44'28"E	Perennial		Mixed land
60	SC-1	Itanagar	Statistic colony	27°04'35.8"N	93°35'51"E	Perennial	4 Families	Mixed land
61	SC-2		Sinrikapa colony	27°03'51.3"N	93°35'26.8"E	Perennial		Mixed land
62	ZG		Zoology garden	27°04'31"N	93°34'56.9"E	Perennial	5 Families	Mixed land
63	LO-1	Lora-I	Lora-1	27°17'15.84"N	93°58'39.41"E	Perennial	40 Families	Forest land
64	KT-1	Kimin town	Kimin Town-1	27°18'28.33"N	93°58'07.09"E	Perennial	50 Families	Mixed land
65	KS-1	kamasaki	kamasiki-1	27°19'48.63"N	93°58'44.18"E	Seasonal	2 Families	Forest land
66	UJR-1	Upper Jumi	Upper Jumi Road-1	27°20'02.22"N	93°58'40.05"E	perennial		Forest land
67	UJR-2		Upper Jumi Road-2	27°20'05.42"N	93°58'44"E	Perennial	4 Families	Forest land
68	UJ-1		Taba Nobin-1	27°20'07.49"N	94°00'26.72"E	Perennial	2 Families	Tea Garden
69	UJ-2		Taba Nobin-2	27°20'13.64"N	94°00'32.96"E	Perennial	4 Families	Tea Garden
70	UJ-3		Taba Nobin-3	27°20'00.03"N	94°00'38.99"E	Perennial	3 Families	Paddy field
71	UJR		Upper Jumi Road-3	27.33499	93.981	Seasonal		
72	SR-M	Lower Sher	8-Mile	27°21'02.10"N	93°58'53.35"E	Seasonal	1 Families	Forest land
73	SR-1		Sher	27°21'09.75"N	93°58'11.01"E	Perennial		Forest land
74	HC-1	Upper Sher	Hawacamp-1	27°21'11.62"N	93°56'26.76"E	Perennial	4 Families	
75	HC-2		Hawacamp-2	27°20'58.20"N	93°56'18.25"E	Perennial	6 Families	Jhum cultivation
76	JL-1	Lower Jumi	Lower Jumi-1	27°21'16.64"N	94°01'37.48"E	Perennial	2 Families	Forest land
77	JL-2		Lower Jumi-2	27°21'38.16"N	94°01'52.20"E	Seasonal	1 Families	Jhum cultivationn
78	KK-1	Kakori	Kakori-1	27°21'47.53"N	94°02'15.15"E	Seasonal	1 Families	Forest land
79	KK-2		Kakori-2	27°21'46.27"N	94°02'29.41"E	Seasonal	2 Families	Forest land
80	JH-1	Joha	Joha-1	27°18'14.74"N	93°58'10.84"E	Perennial		Mixed land
81	JH-2		Joha-2	27°16'08.96"N	93°30'26.19"E	Perennial		Mixed land
82	TH	Tani Happa		27°14'25.35"N	93°29'59.73"E	Seasonal		Mixed land
83	Sk-01	Karoi village road	Sagalee Karoi-01	27°14'11.17"N	93°30'14.23"E	perennial		Mixed land
84	Sk-02		Sagalee Karoi-02	27°13'01.28"N	93°29'57.33"E	Perennial		Mixed land
85	sk-03		karoi	27°12'13.27"N	93°28'47.99"E	Perennial		Mixed land

86	k-01	Khimlee village	Khemlee-01	27°14'05.80"N	93°28'10.93"E	Perennial	2 Families	Mixed land
87	K-02		Khemlee-02	27°14'03.19"N	93°27'37.86"E	Perennial	3 Families	Mixed land
88	LG-01	Lower Gai	Lower gai-01	27°14'01.81"N	93°26'35.66"E	Seasonal	1 Families	Mixed land
89	Go-01	Gotopu	Gotopu-01	27°14'07.54"N	93°25'58.13"E	Perennial	2 Families	Mixed land
90	S-01	Sagalee	3km Sagalee	27°15'08.39"N	93°30'29.33"E	Seasonal	1 Families	Mixed land
91	R-01	Rach village	Rach-01	27°14'47.68"N	93°30'46.23"E	Perennial		Mixed land
92	Ho-01	Hoj	Hoj-01	27°15'40.03"N	93°47'12.88"E	Perennial	1 Families	Mixed land
93	BAN-GJ	Banderdewa	Ganga-Yamuna Mandir	27°06'22"N	93°49'35"E	Perennial	40-50 families and Temple	Mixed land
94	BAN-GA		Bandedewa Gate	27°06'20"N	93°49'25"E	Perennial	Shop owners	Mixed land
95	BAN-01		Banderdewa-01	27°06'26"N	93°49'31"E	Seasonal		Forest land
96	NIR-1	Nirjuli	Nirjuli-1	27.10734444	93.74203611	Perennial	1 Families	Forest land
97	NIR-2		Nirjuli-2	27.10539722	93.74300833	Perennial	1 Families	Forest land
98	NIR-3		Nirjuli-3	27.10345	93.74495278	Perennial		Forest land
99	NIR-4		Nirjuli-4	27.10418333	93.74669722	Perennial		Forest land
100	LA-1	Laptap	Laptap-1	27.220682	93.597984	Seasonal		Forest land
101	KH-1	Kheel	Kheel-1	27.225002	93.70617	Seasonal		Forest land
102	SK-4	Karoi	Karoi-4	27.204582	93.1438	Seasonal		Forest land

Spring discharge: The discharge data of 11 spring was collected from January 2019 to May 2022 (which covers the 3 monsoon and non-monsoon period) from selected spring within the administrative boundary of Papumpare. This includes Chimpu, Itanagar, Naharlagun, Karshingsa, Doimukh and Gumto. It was collected at a weekly interval each spring. To minimize human error discharge rate will be measured three times or in peak season five times and averaged for final reading.

Water Isotopes: Spring water samples were collected for stable isotope analysis (O18 and D). The analysis result was partially received and partially at under analysis at CWRDM Kozhikode Kerla.

Water Quality: Onsite water quality data such as pH, EC, TDS, DO, ORP, and Temp was collected monthly and bimonthly basis from January 2021 up to July 2022. Apart from the onsite data, water samples were collected for chemical and metal analysis (some results will incorporate after receiving the analysis results).

3.5 Details of Field Survey arranged (max 500 words)

A field survey was conducted to identify the groundwater springs (Figure 6) in the different circles of the Papum Pare district. The investigation was carried out by questioning the local communities regarding the number, location, and accessibility of the springs in their locality. Once a spring was identified, its latitude and longitude were recorded using a handheld GPS receiver. Additionally, the onsite occurrence of topography, land use, water discharge, access, and purpose of use was recorded. The elven springs were selected based on depending on its accessibility and to study their discharge rates, such as low, medium, and high discharge.

Thus, weekly field visits were conducted to collect the discharge rate of water. The discharge rate was measured using a measuring beaker and a stop watch. Spring water was collected in the beaker, and its time was recorded simultaneously. To minimize human error, the spring's discharge rate was sampled at weekly intervals for each of the selected springs, and to minimize human error, the discharge rate was measured three times in the low season and five times in the peak season. An average of all the readings was then taken as its final reading. Where flow (Q) of spring will be collected into a container of known volume (V) with time (t) for determining discharge rate. During the field survey spring, wise user dependability and water use were collected.

3.6 Strategic Planning for each Activities (max. 1000 words)

Objective 1: To identifying and mapping of springshed using geospatial tools of Arunachal Pradesh.

Step 1: Inventory of springs – in the selected district of Arunachal Pradesh by undertaking an extensive survey to gather basic information of the existing survey to facilitate the selection of springs, which need special attention for the study. Gathering basic information about springs and characterizing them is the first sensible step toward any conservation drive. This can be carried out in a short time frame but should have extensive coverage. In addition, a survey about the nearest communities and households depends on these springshed.

Step 2: Collecting remote sensing/GIS data-The collected image will be processed using GIS software such as ArcGIS and ERDAS. The processed and classified image will be used for delineating the springshed boundary, recharge area, and type of land use/land cover.

Objective 2: To monitoring hydrological indices of spring, recharge area, and recharge source and predict the spring water discharge pattern and yield for future climate change scenario.

Step 1: Collecting of discharge and rainfall data-- discharge data will be collected every week for 2 years. Rainfall data will be collected from the local meteorological stations (or IMD) or may also collect at some selected study sites.

Step 2: Infiltration test in springshed– Selected springshed will be randomly studied for infiltration to determine the soil infiltration parameters to understand the contribution of rainfall in the recharge area. Step 2: Hydrological data analysis- The discharge data and rainfall data will be used for measurement of discharge rate, the yield of springs, formulating time lag and recession curve or depletion of springs.

Step 3: Prediction of spring discharge rate and yield- Discharge rate and yield springs will be predicted with the help of observed data. The mathematical models will be used to make the future prediction.

Step 4: Climate change impact on discharge rate and yield- observed spring data, meteorological data, and land use/land cover other parameters will be correlated for the analysis of climate change impact on spring.

Step 5: Isotopes/hydrochemical analysis- analysis of water isotopes/hydro-chemical will be done for determining the recharge zones and origin, the contribution of rainwater, the age of water, delineation of the springshed boundary of the springs.

Objective 3: To examine the qualitative reliability of springs based on hydro-chemical indicator drinking/agricultural water use.

Step 1: Collection of samples and analysis- The samples will be collected weekly or monthly (to measure the major cations and anions) in the first 2 years. Onsite measurement data such as pH, EC, temperature and dissolved oxygen will also be collected during the sampling. In addition, water quality indices will be developed.

Step 2: Mapping of hydrochemical data- Spatial maps will be developed for hydrochemical data per permissible drinking and agricultural aspects limit.

Objective 4: Quantitative estimation of spring water budget and recommend optimum spring water storage capacity structures for the lean period.

Step 1: Analysis of spring water budget – Mathematical approaches will be used for studying the water budgets of the springshed.

Step 2: Recommendation of optimum structure- Based on the data of the water budgets along with data collected through a survey on the dependency of the nearest household and its water demand, the structure of the springshed will be recommended. The data on measured spring discharge, yield, and prediction (refer to objective 2) will also be used to develop the harvesting structure.

Objective 5: Capacity building through management techniques and databases.

Step 1: Conservation practices- To revive dying springs, it is necessary to protect the springshed recharge area through various activities such as restricted human interventions, agricultural activities, new construction, planting of a local tree, and developing forest. In-situ rainwater harvesting with the help of trenches and bunds.

Step 2: Training/ workshop- too aware people, researcher, government officers and policymakers, and NGOs, several awareness programmed will be organized. To develop and protection of this available resource which is degrading per day due to less attention

3.7 Activity wise Time frame followed [using Gantt/ PERT Chart (max. 1000 words)]

Activity	Ist Year				IInd Year				IIIrd Year			
Appointment of project staff and purchase of equipment's	■	■	■	■								
Acquisition and processing of satellite images		■	■	■	■							
Field visits for site selection and data collection on springsheds		■	■	■	■	■	■	■	■			
Sample collection and analysis of hydrochemical parameters, meteorological data collection			■	■	■	■	■	■	■	■		
Isotopic assessment of rainfall and spring water to identify the source of recharge			■	■	■	■	■	■	■	■		
Prediction of discharge rate and optimizing of suitable storage structure for a lean period				■	■	■	■	■	■	■	■	
Report writing												■

4 KEY FINDINGS AND RESULTS

4.1 Major Research Findings (max. 1000 words)

1. Spring Inventory and Geotagging

The field survey was conducted in different circles of the Papumpare district of Arunachal Pradesh. The inventory survey was started in January 2019, and a total of 102 spring locations were identified in the different circles of the district (**Table 1**). The geo-locations of the spring were recorded using handheld GPS. Additionally, onsite cooccurrence of topography, land use, water discharge, access, and purpose of use was recorded. Most springs were identified near the population, at farms and roadside, and used by local communities, farmers, and pedestrians for drinking, household use, irrigation, washing vehicles, and fish farming. Table 1 contains the list of springs and their locations with their nature and the number of families depending on them.

Geo-Tagging map: Based on collected spring locations geotagged map was developed, such as circle wise and elevation, respectively shown in **Fig. (3)**.

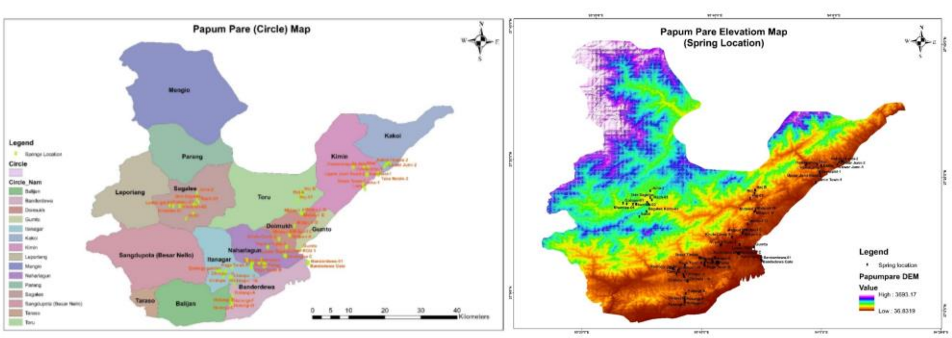


Fig. 3: Geo-tag map of the identified spring circle-wise and elevation in Papum Pare district, A.P.

2. Spring Potential Zonation using AHP and Fuzzy-AHP:

2.1 Preparation of different thematic layers of Papum Pare district

***Slope Map*:** The slope of the region has been categorized into five classes. The slope values are nearly level (<20), very gently sloping (20-40), gently sloping (40-60), moderately (60-80), and strongly sloping (>80), shown in **Fig. 4(a)**. The area recorded under nearly level is 148.7 km^2 (4.3%), very gently sloping 596.36 km^2 (17.32%), gently sloping 1026.82 km^2 (29.81%), moderately 1248.38 km^2 (36.24%), and strongly sloping 423.84 km^2 (5 1.89%), which refers the situation of infiltration and recharge to the groundwater.

Drainage Density Map**:** The drainage density map was classified and resampled into five classes very low (0.02- 0.4 km/km^2), low (0.4- 0.6 km/km^2), medium (0.6- 0.8 km/km^2), high (0.8- 1.2 km/km^2), and very high (1.2- 2 km/km^2) as shown in **Fig. 4(b)**. The area recorded under very low density 255.16 km^2 (7.41%), low density 346.36 km^2 (9.67%), moderate 799.33 km^2 (23.11%), high 979.51 km^2 (28.74%), and very high 1063.71 km^2 (17%), which refers the situation of infiltration and recharge to the groundwater.

Lineament Density Map**:** Lineament Density has been categorized into five classes such as very low (0-0.3 km/km^2), low (0.3-0.5km/km^2), moderate (0.5-0.7 km/km^2), high (0.7-0.9 km/km^2), and very high (0.9-1.2 km/km^2) as shown in **Fig. 4(c)**. The area falls under deficient (36.84%), low (24.42%), moderate (17.04%), high (11.98%), and very high (9.72%).

Soil Texture Map**:** The soil texture found in the study area was categorized into six classes which are course loamy (12.27%), fine loamy/gravelly subsurface (49.48%), loamy (17.70%), fine loamy (18.26%), fine (0.48%) and coarse loamy/gravelly subsurface (1.69%) shown in **Fig. 4(d)**. The soil texture in the study area is a fine loamy/gravelly subsurface of 1685.37 km^2, with loamy soil of 621.77 km^2 and 602.70 km^2.

Lithology Map**:** The analysis shows that the significant lithologic formations covered in the area are sandstone, clay, conglomerate, coal, and fossil wood (11.62%); garnetiferous mica schist (7.75 %), sst, calcareous nodules, carbonized wood, coal seam (16.95%); augen gneiss, biotite gneiss and granite gneiss (23.46%); sandstone, nodular clay beds and plant fossils (11.35%); unmapped region (16.18%); granitoid gneiss (7.66%) and other remaining features are less than 1% shown in **Fig. 4(e)**.

Geomorphology Map**:** The geomorphological formations of the study area are divided into moderately dissected structural hills and valleys, low dissected structural hills and valleys, piedmont slope, mass wasting products, older alluvial plain, pediment peneplain complex, younger alluvial plain, older flood plain, active flood plain, piedmont alluvial plain, river, highly dissected structural hills and valleys, pond, and other water bodies-lake shown in **Fig. 4(f)**. The total area under the river is 52.26 km^2 (1.54%), and ponds and other water bodies are 0.14 km^2 (0.004%), which refers significant function in groundwater storage. The alluvial plains cover 47.19 km^2 (1.38%), the flood plain covers 53.02 km^2, and highly dissected structural hills and valleys cover 685.48 (20.13%), which refers to the high potential groundwater because of the high infiltration rate.

Rainfall Map**:** The average annual rainfall map was classified into five classes shown in **Fig. 4(g)**: very low (<1700 mm/year), low (1700.1-1800 mm/year), moderate (1800.1-1900 mm/year), high (1900.1-2000 mm/year) and very high (>2000.1 mm/year). As per the rainfall distribution map, the area falls under very high (13.5%), high (30%), moderate (19%), low (20.3%), and very low (17.2%), respectively

Land Use/ Land Cover Map (LULC)**:** The LULC of the study area is categorized into eight classes: trees, crops, water bodies, grass, scrub/shrub, flooded vegetation, built area, and barren land shown in **Fig. 4(h)**. Trees covered the largest area of 3275.8 km2 (95.1%), followed by built area 89.97 km^2 (2.7%), crops 35.87 km^2 (1.04%), scrub/shrub 24.099 km^2 (0.71%), waterbodies 10.89 km^2 (0.32%), grass 5.34 km^2 (0.16%), barren land 1.87 km^2 (0.06%) and flooded vegetation (0.01%).

Ground Water Level Map**:** The groundwater level map was classified into five categories: very low, low, moderate, high, and very high shown in **Fig. 4(i)**. The area falls under very and high is 391.81 km^2 (11.38%) and 669.48 km^2 (19.3%), respectively, followed by 630.26 km^2 (18.3%) in moderate, 1507.82 km^2 (43.48%) in low and 244.67 km^2 (7.1%) in low groundwater level. The weight is assigned high to the very low and low groundwater levels and low for high groundwater levels.

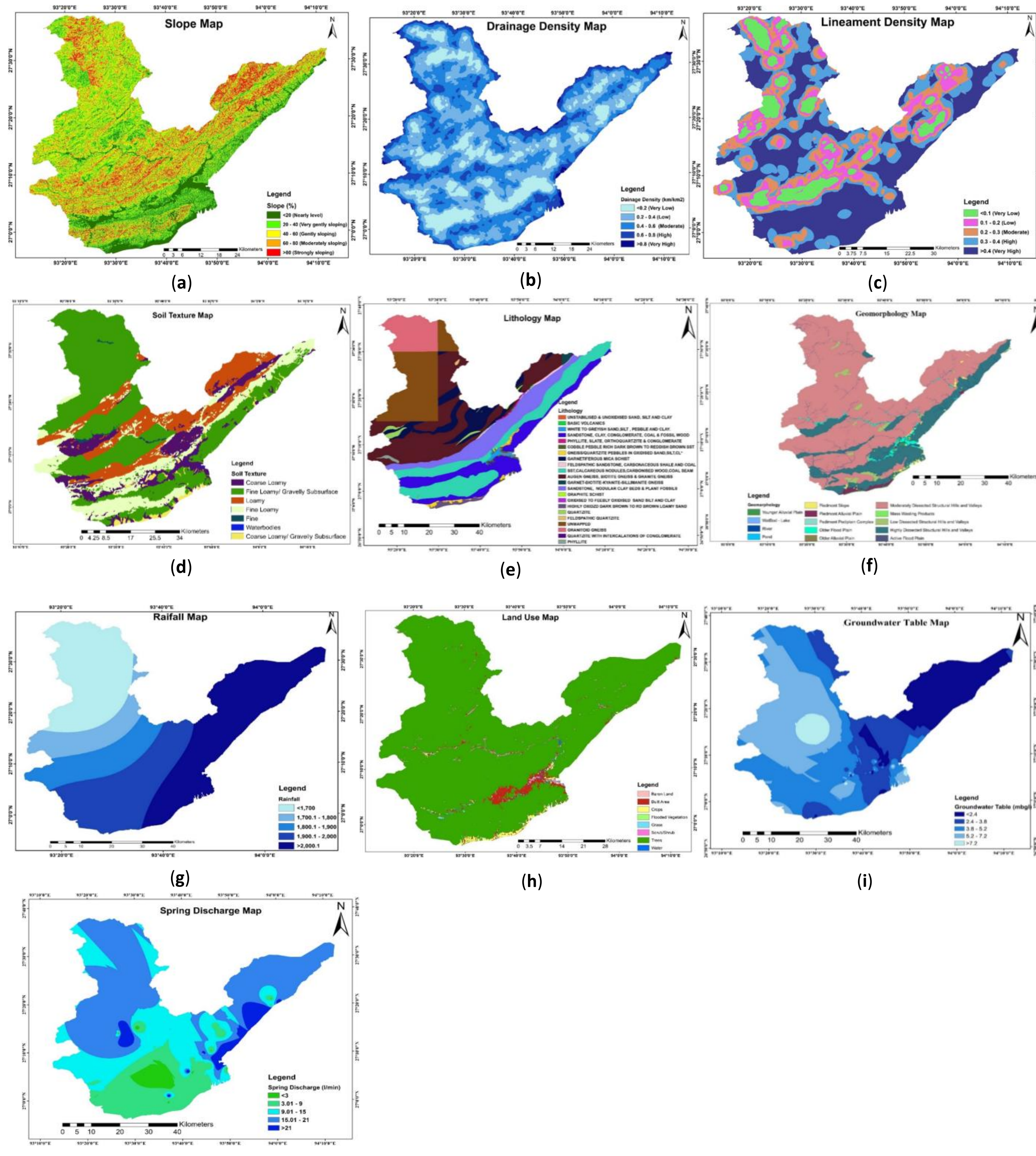
Spring Discharge Map: The spring discharge map was classified into five categories: very low, low, moderate, high, and very high shown in **Fig. 4(j)**. The area falling under very high and high discharge is 172.38 km^2 (5%) and 44.25 km^2 (44.26%), followed by 921.25 km^2 (26.75%) in moderate, 671.01km^2 (19.448%) in low and 155.16 km^2 (4.51%) in low. The high weight was given to the high discharge area and the lower weight to the low discharge area.

Pairwise comparison matrices of AHP and Fuzzy-AHP

The identification of GSPZ was investigated by analyzing various thematic layers using an integrated AHP and Fuzzy-AHP method. The AHP relative weights were assigned for each thematic layer, and the cumulative weights were calculated using pairwise matrices. The weights are assigned based on actual field circumstances. Pairwise comparisons were computed using personal or subjective judgments, so there is a chance of some degree of inconsistency; as a result, the CR should not be higher than 10%. (Goitsemang *et al*. 2020; Mahato *et al*. 2022). Hence, a CR of ≤0.1 indicates an excellent decision to carry on the AHP analysis. The assigned score value is changed or readjusted if the condition is not met to ensure consistency. If the CR value in the study is equal to zero, the pairwise comparison matrix judgment is perfectly consistent (Ahmadi *et al*. 2021; Mukherjee and Singh 2020). The present study's CR is 0.093 for n = 10, which is less than 0.10. It implies that the pairwise comparison matrix has a reasonable level of consistency.

Groundwater Spring Potential Zonation

Using AHP**:** The total weights from all the factors combine to form the representative weight of a particular feature of the potential zone. The weight value of a feature indicates how much of an impact it has on the GSPZs; a higher weight value indicates a more significant impact, and a lower weight value indicates a more negligible impact. The essential step in an integrated analysis is deciding how much weight each class should receive because it influences the result. Each thematic level was suitably weighted in the pairwise comparison matrix based on their respective influence on groundwater recharge (**Table 2**). The pairwise comparison matrix's bias/subjectivity was reduced by normalizing the data. The Consistency Ratio (CR) tested the normalized weight for consistency. The ArcMap spatial analyst tools were used to overlay the various layers after taking the weight assessment into account (**Table 5**), and the GSPZ map of the Papum Pare district was generated. Low, moderate, and high were categorized into three potential zones (**Fig. 5a**). The area that falls under the high and moderate zone was 584.56 km^2 (16.61) and 2080.79 km^2 (60.42%), respectively, followed by 778.71 km^2 (22.61%) in the low potential zone (**Table 6**). The highest area falls under moderate potential zones 2080.79 km^2 (60.42%).



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j)

Figure 4(a) slope map, (b) drainage density map, (c) lineament density map, (d) soil texture map, (e) lithology map, (f) geomorphology map, (g) rainfall map, (h), land use map, (i) groundwater level map, and (j) spring discharge map.

Table 2 Pairwise comparison matrix table of thematic layers used in the present study

Variables	RF	LT	SL	DD	LULC	LD	ST	GM	GL	SD
RF	1	1	3	3	3	3	3	3	3	3
LT	1	1	3	3	5	3	3	3	5	3
SL	1/3	1/3	1	1	3	3	5	3	3	3
DD	1/3	1/3	1	1	3	1	3	3	3	3
LULC	1/3	1/5	1/3	1/3	1	3	1/3	1	1	1/3
LD	1/3	1/3	1/3	1	1/3	1	1	3	1	1
ST	1/3	1/3	1/5	1/3	3	1	1	1	1	1/3
GM	1/3	1/3	1/3	1/3	1	1/3	1	1	3	1/3
GL	1/3	1/5	1/3	1/3	1	1	1	1/3	1	1
SD	1/3	1/3	1/3	1/3	3	1	3	3	1	1

RF- Rainfall, LI- Lithologic, SL- Slope, DD-Drainage Density, LULC-Land Use/Land Cover, LD- Lineament Density, ST- Soil Texture, GM- Geomorphology, GT- Groundwater Level, SD- Spring Discharge.

Table 3 Fuzzy pairwise comparison matrices

Vari-ables	RF	LT	SL	DD	LULC	LD	ST	GM	GT	SD
RF	1,1,1	1,1,1	2,3,4	2,3,4	2,3,4	2,3,4	2,3,4	2,3,4	2,3,4	2,3,4
LT	1,1,1	1,1,1	2,3,4	2,3,4	4,5,6	2,3,4	2,3,4	2,3,4	4,5,6	2,3,4
SL	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1,1,1	1,1,1	2,3,4	2,3,4	4,5,6	2,3,4	2,3,4	2,3,4
DD	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1,1, 1	1,1,1	2,3,4	1,1,1	2,3,4	2,3,4	2,3,4	2,3,4
LULC	1/4, 1/3, 1/2	1/6, 1/5, 1/4	1/4, 1/3, 1/2	1/4,1/3,1/2	1,1,1	2,3,4	1/4,1/3,1/2	1,1,1	1/4,1/2,1/3	1/4,1/3,1/4
LD	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1,1,1	1/4,1/3, 1/2	1,1,1	1,1,1	2,3,4	1,1,1	1,1,1
ST	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1/6, 1/5, 1/4	1/4,1/3,1/2	2,3, 4	1,1,1	1,1,1	1,1,1	1,1,1	1/4,1/3,1/2
GM	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1/4,1/3, 1/2	1,1,1	1/4, 1/3, 1/2	1,1,1	1,1,1	2,3,4	1/4,1/3,1/2
GT	1/4, 1/3, 1/2	1/6, 1/5, 1/4	1/4, 1/3, 1/2	1/4,1/3,1/2	2,3,4	1,1,1	1,1,1	1/4,1/3,1/2	1,1,1	1,1,1
SD	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1/4,1/3,1/2	2,3,4	1,1,1	2,3,4	2,3,4	1,1,1	1,1,1

Table 4 Fuzzy geometric mean, fuzzy weight, and normalized weight criteria

Variables		Ri			Wi		Mi	Ni
RF	1.74	2.41	3.03	0.12	0.20	0.32	0.21	0.20
LT	2.00	2.67	3.29	0.13	0.22	0.35	0.24	0.22
SL	1.23	1.63	2.08	0.08	0.14	0.22	0.15	0.14
DD	1.07	1.39	1.74	0.07	0.12	0.19	0.12	0.12
LULC	0.39	0.49	0.66	0.03	0.04	0.07	0.05	0.04
LD	0.62	0.72	0.87	0.04	0.06	0.09	0.06	0.06
ST	0.59	0.61	0.76	0.04	0.05	0.08	0.06	0.05
GM	0.47	0.58	0.76	0.03	0.05	0.08	0.05	0.05
GT	0.51	0.61	0.76	0.03	0.05	0.08	0.06	0.05
SD	0.71	0.90	1.15	0.05	0.07	0.12	0.08	0.08

Ri- Geometric mean, Wi- Fuzzy weight, Ni- Normalized weight criteria

Table 5 Weight and ranking for different themes and sub-classes.

SN	Thematic layers and Sub-classes	Rank	Weight
1	**Drainage Density (km/km^2)**		**11**
	<0.2	5	
	0.2-0.4	4	
	0.4-0.6	3	
	0.6-0.8	2	
	>0.8	1	

2	**Lineament Density (km/km^2)**		**6**
	<0.1	1	
	0.1-0.2	2	
	0.2-0.3	3	
	0.3-0.4	4	
	>0.4	5	
3	**Rainfall (mm)**		**19**
	<1700	1	
	1701-1800	2	
	1801-1900	3	
	1901-2000	4	
	>2001	5	
4	**Slope (%)**		**14**
	<20	5	
	20-40	4	
	40-60	3	
	60-80	2	
	>80	1	
5	**Geomorphology**		**5**
	Active Flood Plain	5	
	Highly Dissected Structural Hills and Valleys	1	
	Low Dissected Structural Hills and Valleys	1	
	Mass Wasting Products	1	
	Moderately Dissected Structural Hills and Valleys	1	
	Older Alluvial Plain	4	
	Older Flood Plain	5	
	Pediment Pediplain Complex	3	
	Piedmont Alluvial Plain	4	
	Piedmont Slope	2	
	Pond	5	
	River	5	
	WatBod - Lake	5	
	Younger Alluvial Plain	4	
6	**Lithologic**		**21**
	Augen gneiss, biotite gneiss and granite gneiss	1	
	Basic volcanics	3	
	Cobble pebble rich dark brown to reddish brown sst	5	
	Feldspathic quartzite	4	
	Feldspathic sandstone, carbonaceous shale, and coal	4	
	Garnet-biotite-kyanite-sillimanite gneiss	3	
	Garnetiferous mica schist	3	
	Gneiss/quartzite pebbles in oxidized sand, silt, cl*	5	
	Granitoid gneiss	1	
	Graphite schist	3	
	Highly oxidized dark brown to red-brown loamy sand	4	
	Oxidized to feebly oxidized sand silt and clay	4	
	Phyllite	2	
	Phyllite, slate, orthoquartzite, and conglomerate	2	
	Quartzite	3	
	Quartzite with intercalations of conglomerate	3	
	Sandstone, nodular clay beds, and plant fossils	5	
	Sandstone, clay, conglomerate, coal, and fossil wood	5	

	Sst, calcareous nodules, carbonized wood, coal seam	4	
	Unmapped	2	
	Unstabilized and unoxidized sand, silt, and clay	5	
	White to greyish sand, silt, pebble, and clay.	5	
7	**Soil Texture**		**6**
	Coarse Loamy	5	
	Fine Loamy/ Gravelly Subsurface	2	
	Loamy	3	
	Fine Loamy	2	
	Fine	1	
	Waterbodies	5	
	Coarse Loamy/ Gravelly Subsurface	4	
8	**Land Use/Land Cover**		**5**
	Water	5	
	Trees	5	
	Grass	3	
	Flooded Vegetation	3	
	Crops	4	
	Scrub/Shrub	3	
	Built Area	1	
	Barren Land	2	
9	**Grondwater Level (mbgl)**		**5**
	<2.4	5	
	2.4-3.8	4	
	3.8-5.2	3	
	5.2-7.2	2	
	>7.2	1	
10	**Spring Discharge (l/m)**		**8**
	<3	1	
	3.01-9	2	
	9.01-15	3	
	15.01-21	4	
	>21	5	

FNW= Features Normalized Weight,

4.2.1 *Using Fuzzy-AHP*: In the present study, GIS-based Fuzzy-AHP to map GSPZ by upgrading the results of the AHP method. The pairwise comparison matrix was prepared using a fuzzy triangular scale, and the weight of each parameter was determined (**Tables 3 & 4**). The weightage of each parameter subcategory has been determined using the fuzzy membership function of the ArcGIS spatial analyst tool. After that fuzzy overlay function was used to integrate all thematic layers after taking the weight assessment into account (**Table 5**), and the GSPZ map of the Papum Pare district was generated. Low, moderate, and high were categorized into three potential zones (**Figure 5b**). The area falls under "high potential zone is 1046.97 km^2 (30.40%)," "moderate potential zone is 2080.79 km^2 (41.29%)," and "low potential zone is 778.71 km^2 (22.61%)" (**Table 6**). The highest area falls under moderate potential zones 2080.79 km^2 (60.42%).

Table 6 GSPZ categories using Fuzzy-AHP.

Class	GSPZ	Area		Area	
		km^2	%	km^2	%
1	High	584.56	16.61	974.89	28.31
2	Moderate	2080.79	60.42	1422.21	41.30
3	Low	778.71	22.61	1046.97	30.40

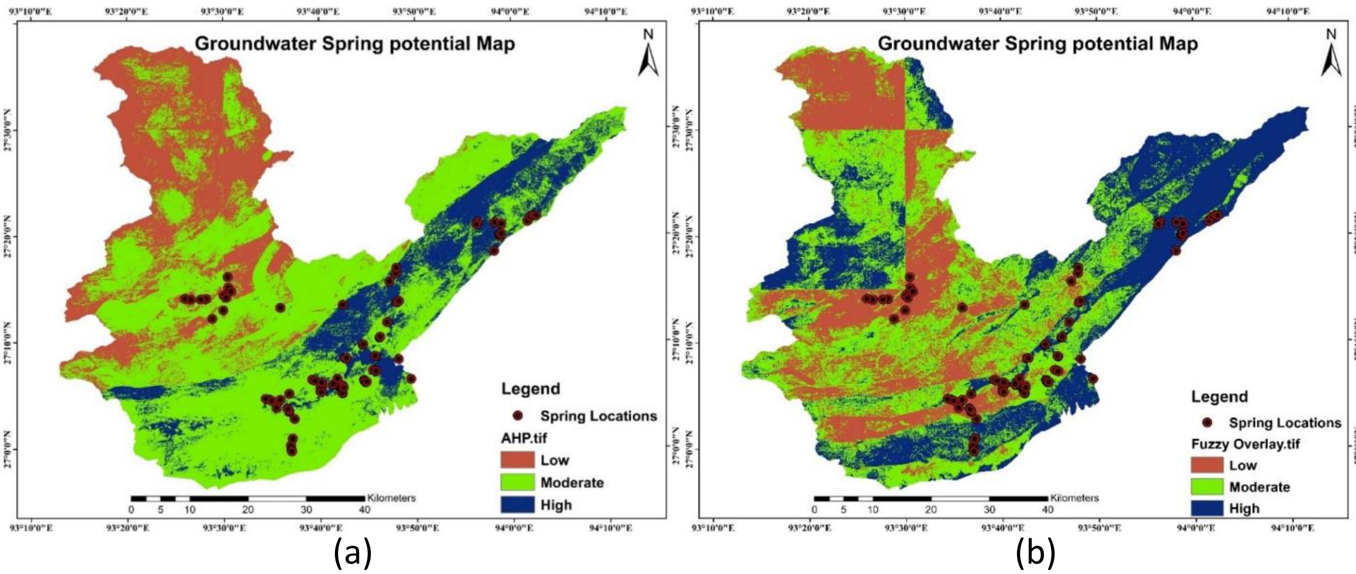


Figure 5: GSPZ map of the study area using (a) AHP and (b) Fuzzy-AHP.

4.3 *Validation of GSPZ map*

and Fuzzy-AHP technique results have been validated using spring locations. The spring locations were recorded with handheld GPS during the spring inventory survey. A total of 102 perennial and seasonal springs were identified in different circles of the Papum Pare district. The ROC curve was used to validate the generated GSPZ map to determine the model's accuracy. It helps set up the classifiers and visualize their effectiveness. It also calculates the AUC by analyzing and comparing techniques. The ROC/AUC was computed by comparing the cumulative proportion of GSPZ maps (on the x-axis) against the cumulative percentage of spring locations (on the y-axis). The ROC curve shows that the AUC is 0.779 (**Fig. 6a**) for the map generated using the AHP method and 0.806 for the map generated by Fuzzy-AHP (**Fig. 6b**). The validation results show that both methods are helpful in GSPZ mapping, whereas Fuzzy-AHP is more accurate than AHP.

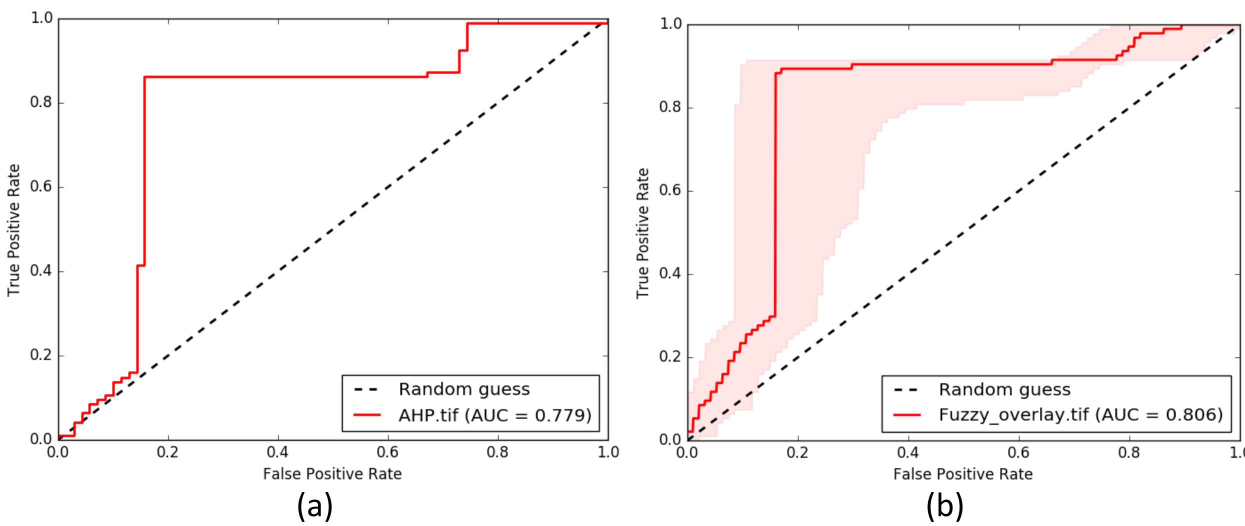


Fig. 6: (a) ROC curve for AHP and (b) Fuzzy-AHP derived map showing the relation between true positive rate and false positive rate

Springshed Delineation: A total of 7 springshed was delineated using RS and GIS and field approach. In the study area, springs showed wide variability in $\delta^{18}O$ and $\delta^{2}H$ (δ-values) at spatial and temporal scales. The $\delta^{18}O$ values range from − 5.33 to –7.3‰ while the $\delta^{2}H$ values range from – 41.58 to – 25.45‰. Based on the analyzed data, it was noticed that enriched isotopic values were observed during the summer months, while depleted values were reported during the spring and autumn months.

Gumto Spring: Based on field survey data and GIS applications such as GPS location of spring, elevation profile, nearest streams/rivers, LULC map, drainage map, and contour map, a potential recharge area has been identified and considered area has been subdivided into 8 parts to find the elevation profile (EP1-EP8) (shown in **Fig. 7 & 8**). Further, a flow accumulation map and elevation map of the identified area has been developed. As per the map, the elevation range between 100 to >280 has the spring's recharge area in the developed map, and the elevation range between 200 to >280 has a more significant impact on the spring. The discharge rate and yield of the spring are very high, generating a small stream. Which also proves that the springshed area is more significant. The recharge area characteristics are also shown in **Fig. 9**. The characteristics of the recharge area are shown in **Fig. 10**.

Fig 7: View of Gumto Springshed

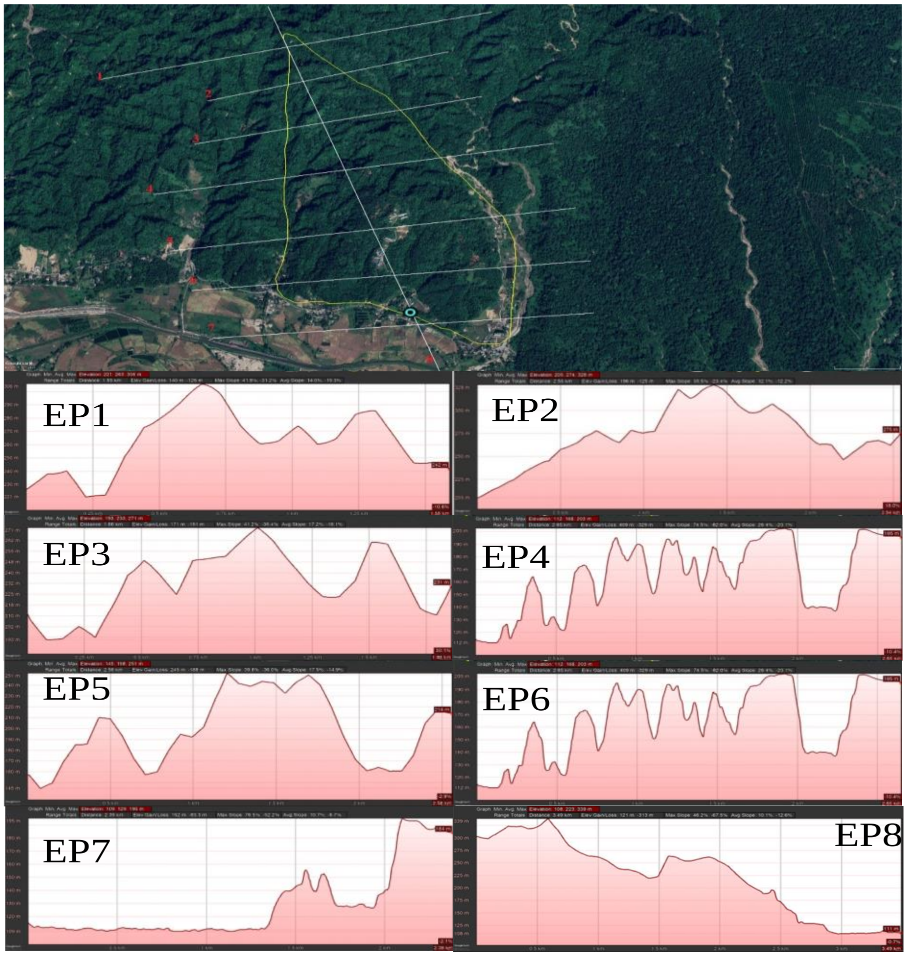


Fig 8: Elevation Profile of Gumto springshed

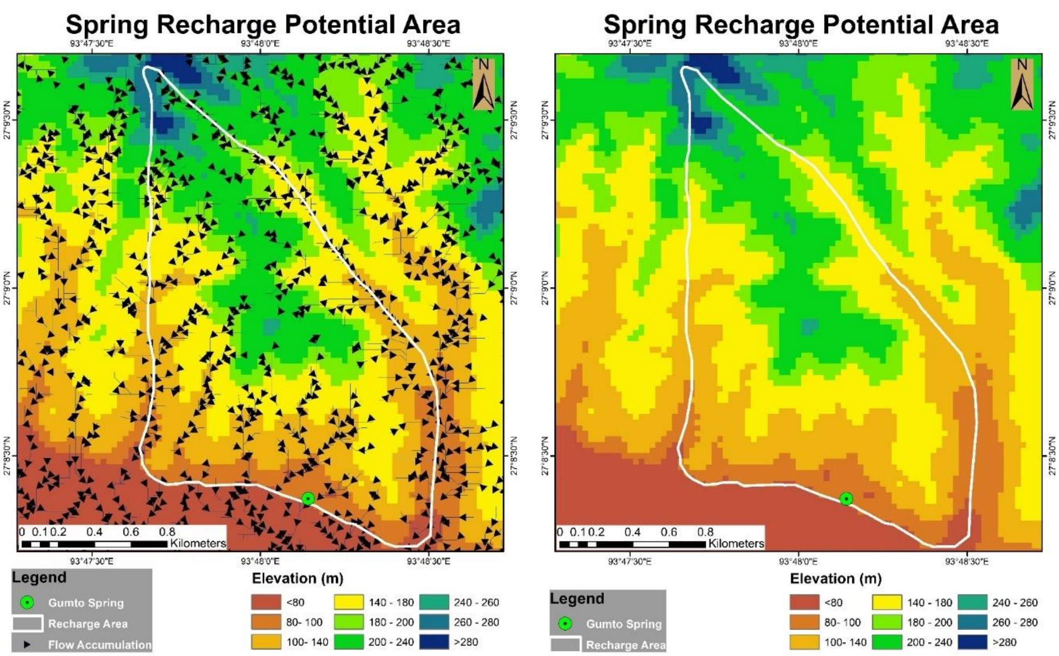


Fig. 9: Flow accumulation map and potential springshed recharge area of Gumto Spring

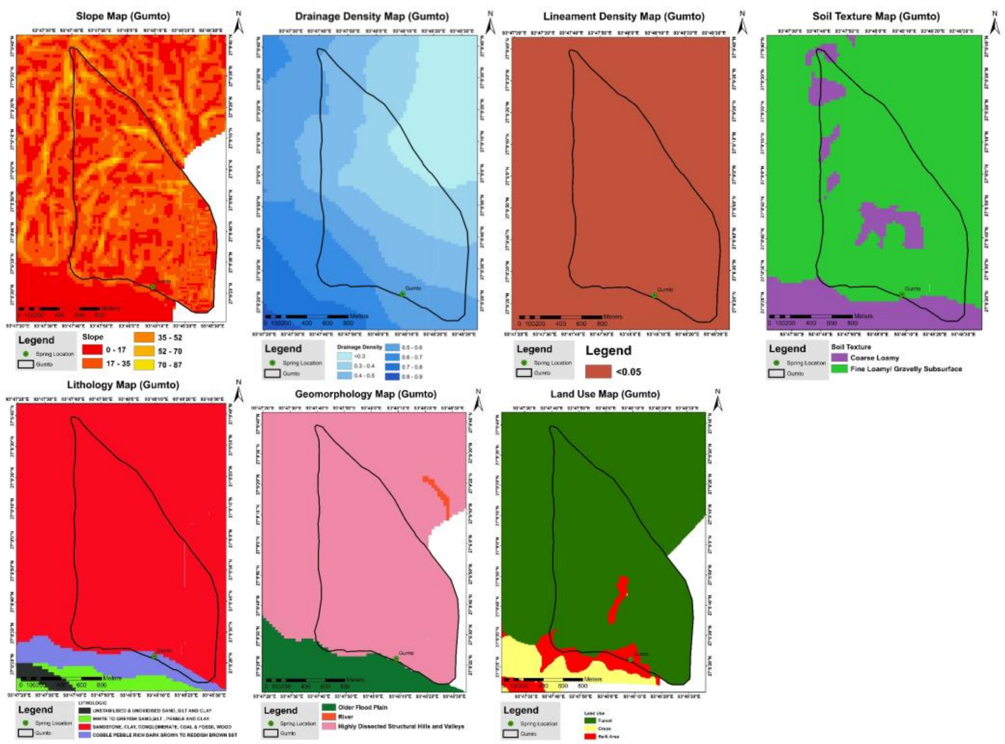


Fig. **10** Slope, drainage density, lineament density, soil texture, lithology, geomorphology, and land use map of the Gumto springshed

Barapani Spring: As per the map, the elevation range between 140 to 240 has the spring's recharge area in the developed map, and the elevation range between 180 to 200 and 200-240 has a more significant impact on the spring (**Fig 14**). The view of the springshed, elevation profile, and recharge area characteristics are shown in **Fig 11, 12,** and **13**, respectively.

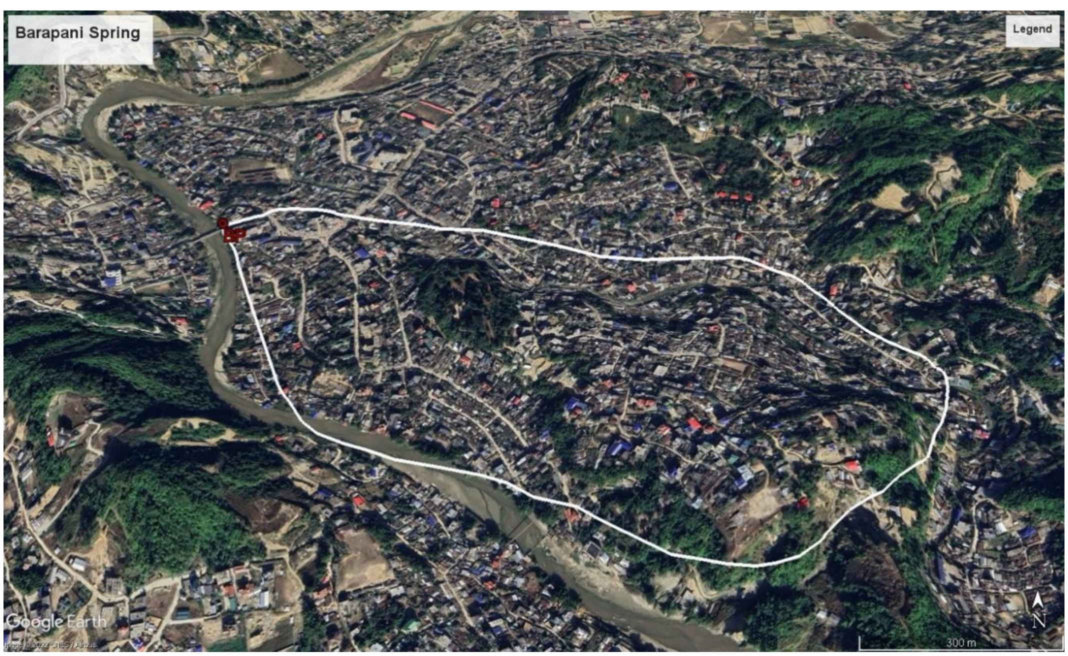


Fig: 11 View of Barapani Springshed

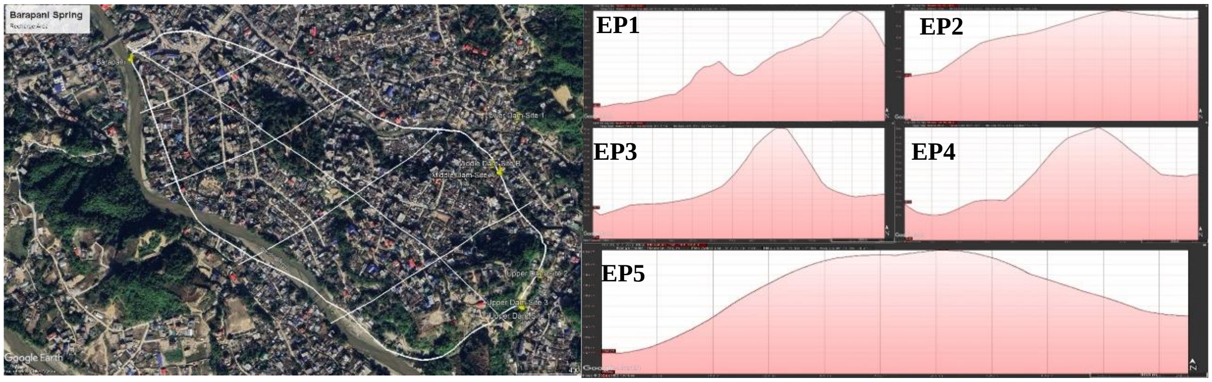


Fig. 12 Elevation Profile of Barapani Springshed (lines 1-5)

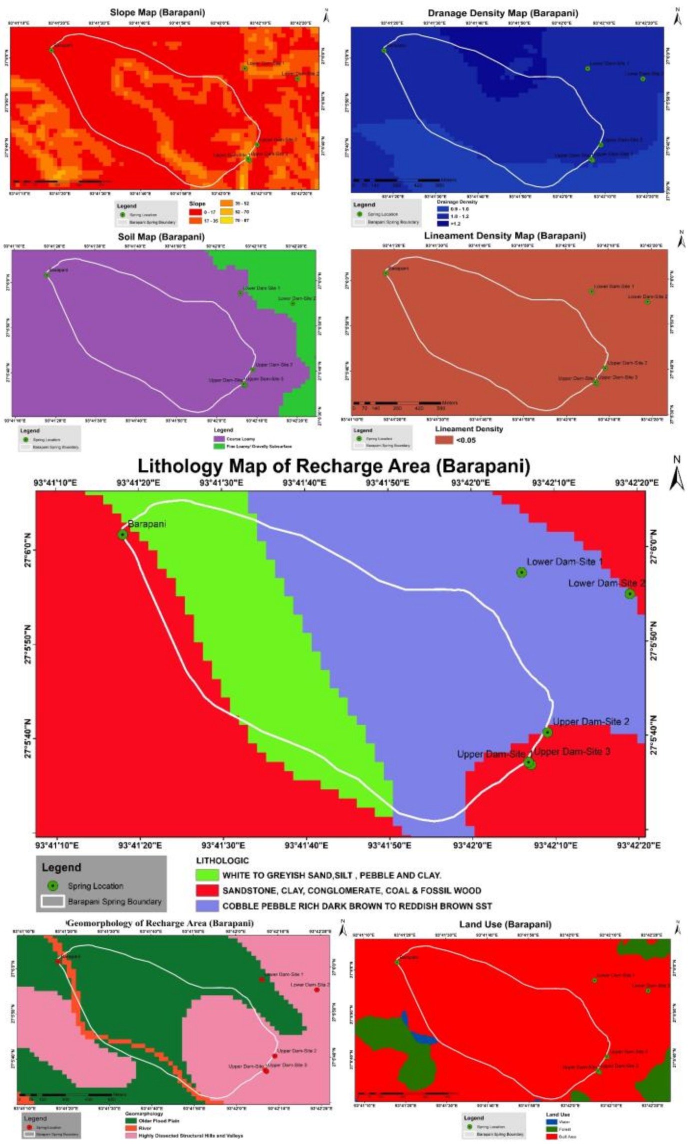


Fig. 13 Slope, drainage density, lineament density, soil texture, lithology, geomorphology, and land use map of the Gumto springshed

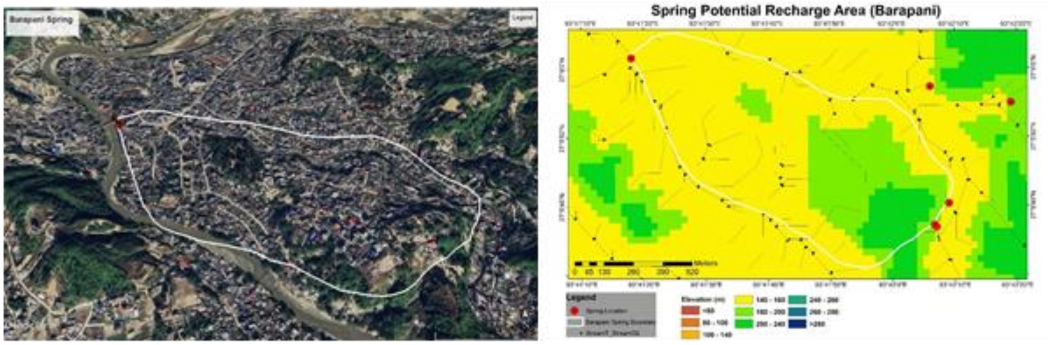


Fig. 14 Barapani springshed

Upper Dam Site Springshed: As per the map, the elevation range between 180 to >280 has the spring's recharge area in the developed map, and the elevation range between 240 to >280 has a more significant impact on the spring (**Fig 18**). The view of the springshed, elevation profile, and recharge area characteristics are shown in **Fig 16** and **17**, respectively.

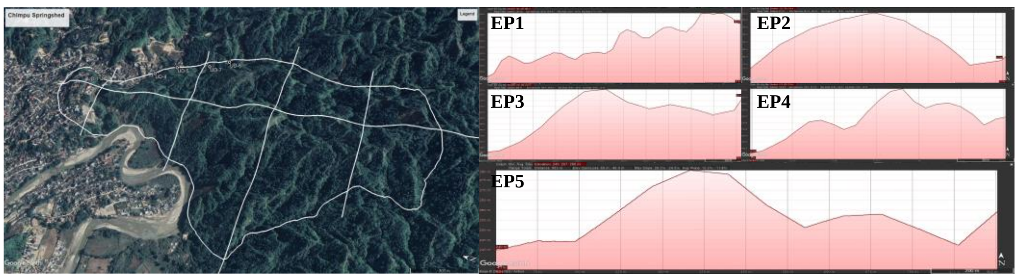


Fig. 16 Elevation Profile of upper dam Site Springshed (lines 1-5)

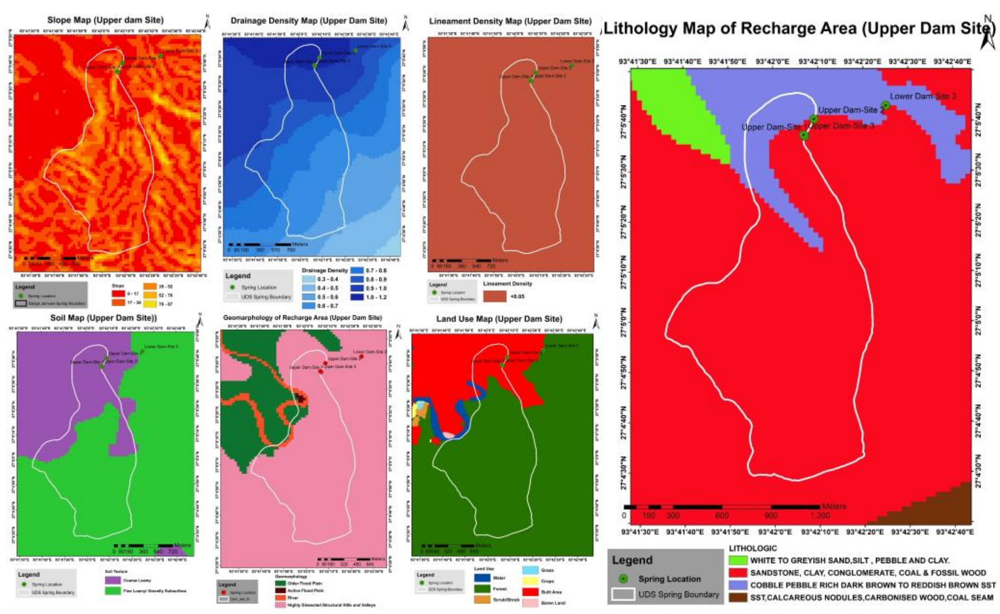


Fig. 17 Slope, drainage density, lineament density, soil texture, lithology, geomorphology, and land use map.

Fig. 18 Upper dam site springshed map

Lower Dam Site Springshed: As per the map, the elevation range between 180 to >280 has the spring's recharge area in the developed map, and the elevation range between 240 to >280 has a more significant impact on the spring (**Fig 21**). The view of the springshed, elevation profile, and recharge area characteristics are shown in **Fig. 19** and **20**, respectively.

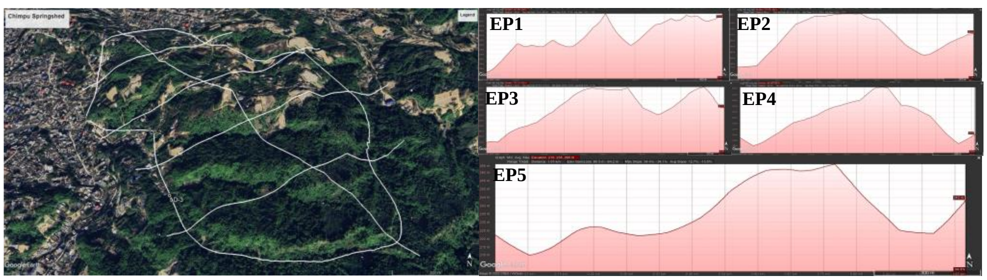


Fig. 19 Elevation Profile of Lower dam Site Springshed (line 1-5)

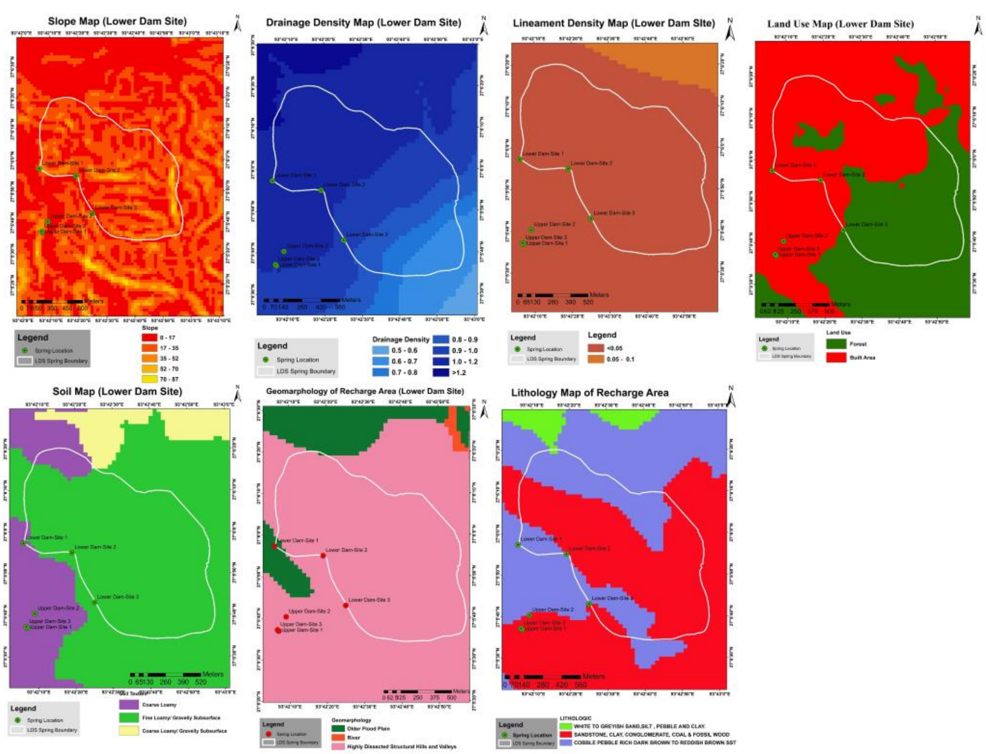


Fig. 20 Slope, drainage density, lineament density, soil texture, lithology, geomorphology, and land use map.

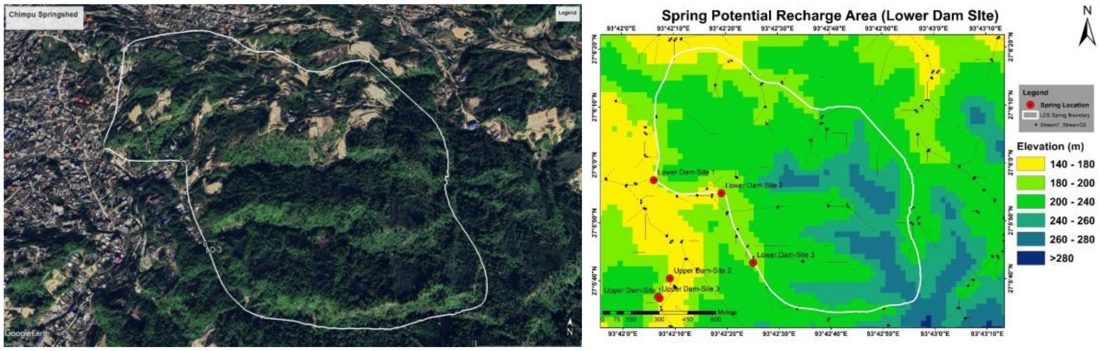


Fig. 21 Lower dam site springshed map

Chimpu Springshed: As per the map, the elevation range between 200 to >280 has the spring's recharge area in the developed map, and the elevation range between 240 to >280 has a more significant impact on the spring (**Fig 24**). The view of the springshed, elevation profile, and recharge area characteristics are shown in **Fig 22** and **23**, respectively

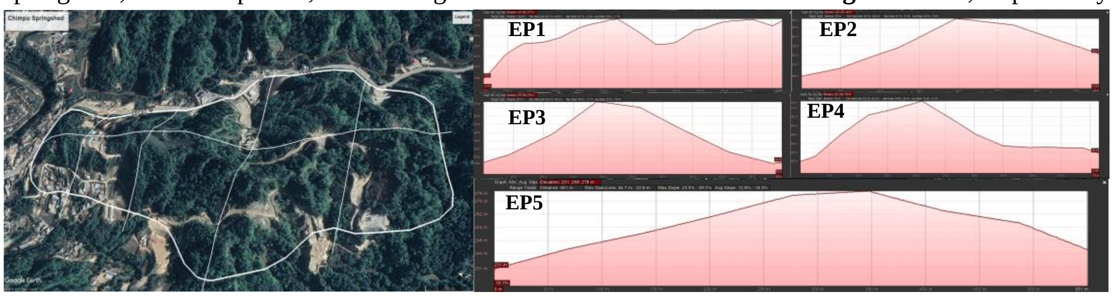


Fig. 22 Elevation Profile of Chimpu Springshed (lines 1-5)

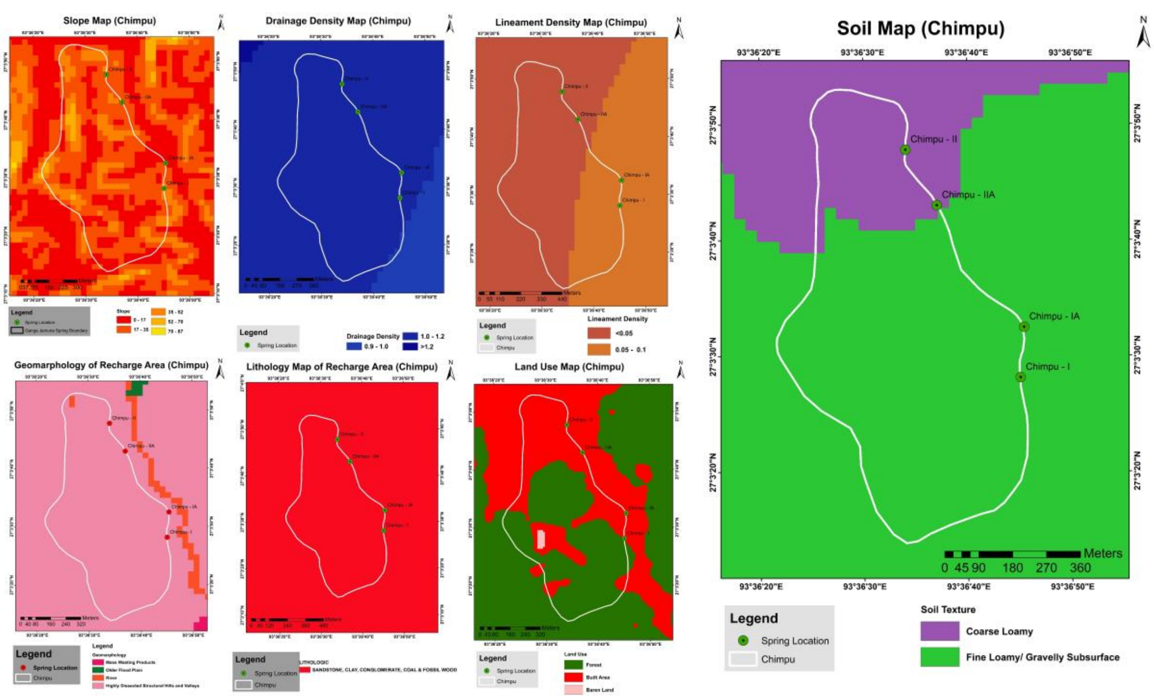


Fig. **23** Slope, drainage density, lineament density, soil texture, lithology, geomorphology, and land use map.

Fig. 24 Chimpu springshed map

Karsingsa Springshed: As per the map, the elevation range between 200 to >280 has the spring's recharge area in the developed map, and the elevation range between 240 to >280 has a more significant impact on the spring (**Fig 27**). The view of the springshed, elevation profile, and recharge area characteristics are shown in **Fig 25** and **26**, respectively.

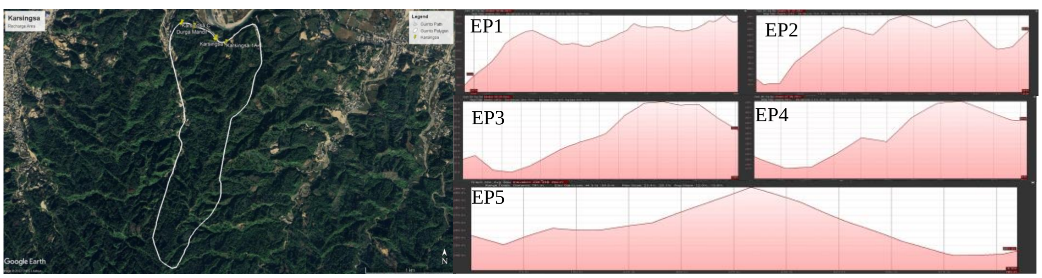


Fig. 25 Elevation Profile of Karsingsa Springshed (lines 1-5)

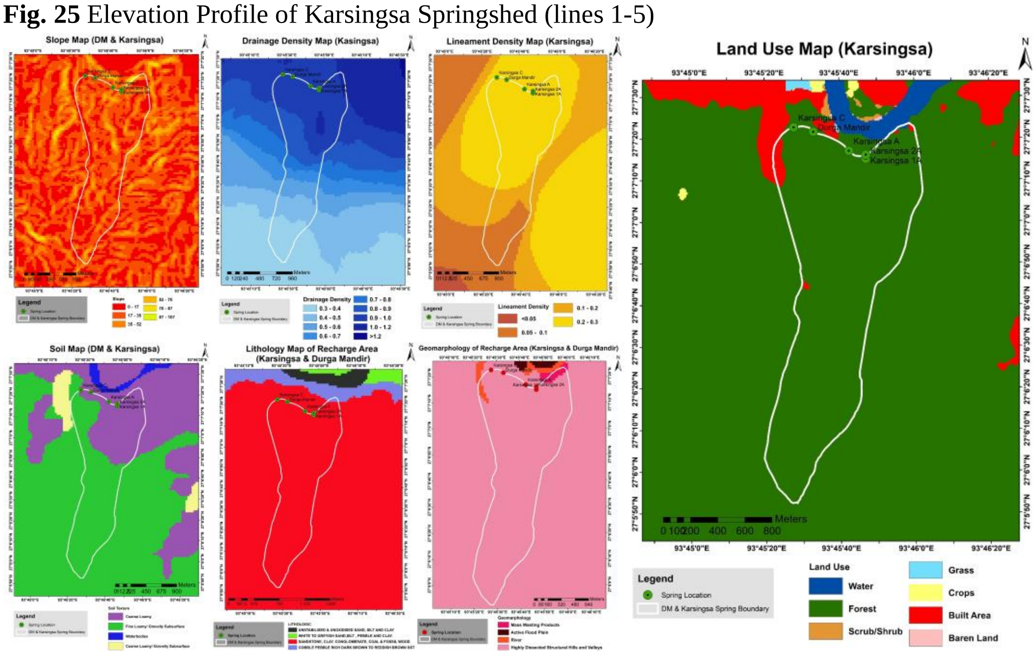


Fig. 26 Slope, drainage density, lineament density, soil texture, lithology, geomorphology, and land use map.

Fig. 27 Karsingsa springshed map

Ganga-Yamuna Springshed map: As per the map, the elevation range between 200 to >280 has the spring's recharge area in the developed map, and the elevation range between 240 to >280 has a more significant impact on the spring (**Fig 30**). The view of the springshed, elevation profile, and recharge area characteristics are shown in **Fig 28** and **29**, respectively.

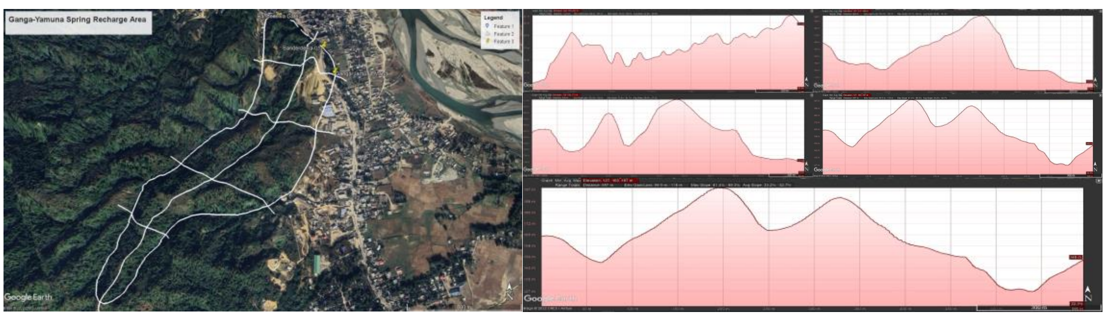


Fig. 28 Elevation Profile of Karsingsa Springshed (lines 1-5)

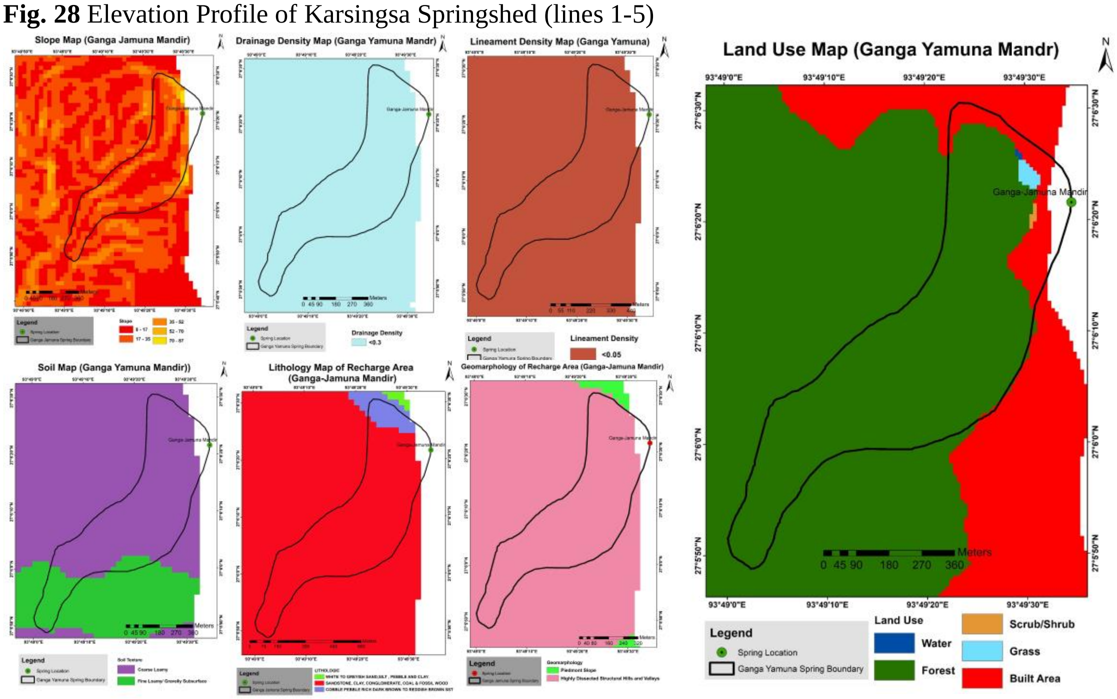


Fig. **29** Slope, drainage density, lineament density, soil texture, lithology, geomorphology, and land use map.

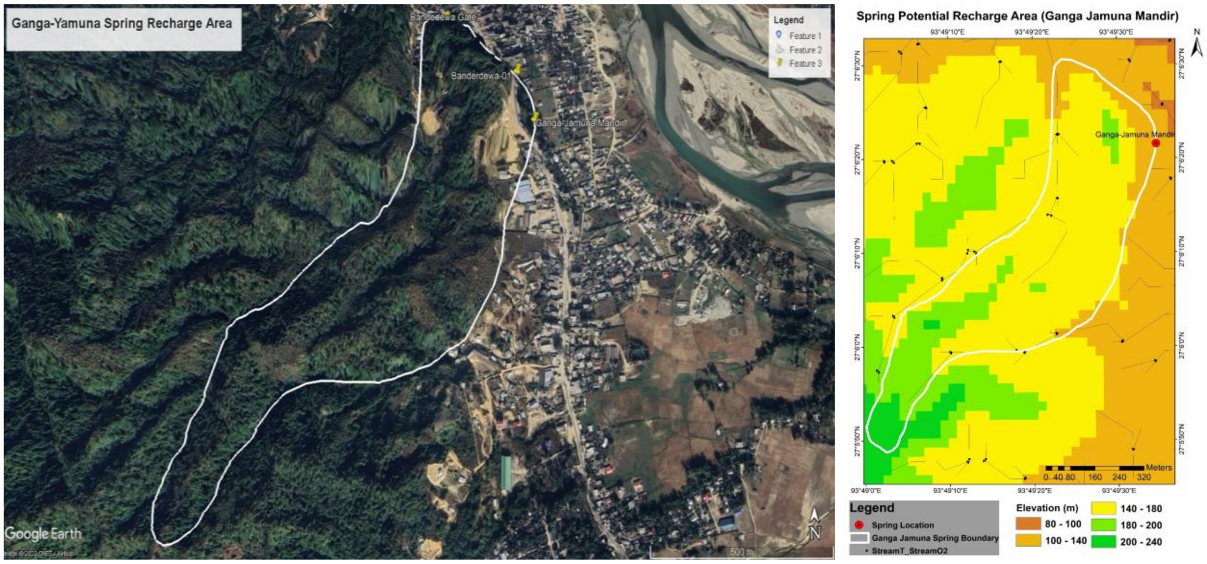


Fig. **30** Ganga-Yamuna springshed map

Spring Reliability: Spring discharge data collection was started from January 2019 to May 2022. The discharge data of 11 springs of Papum Pare district were collected, of which Gumto spring shows the maximum discharge rate of 518.40 m3/d, followed by Barapani spring with a discharge rate of 93.41 m3/d and the springs with minimum discharge rate is Chimpu II with a discharge rate of 0.09 m3/d followed by Karsingsa 2A with 0.372 m3/d. Recently, some springs are dried due to the hill cutting for new constructions, such as new buildings (upper dam site spring and Chimpu springs).at the spring head and in the springshed. The two springs hydrograph and recession curve are shown below.

Barapani Spring: Geographic location: 27°6'01.5876"N, 93°41'18.0960"E. Barapani spring (**Fig 31**) is a perennial spring with a minimum discharge yield of 19.20 m^3/d (January 2019), 12.5 m^3/d (April 2020), 12.80 m^3/d (April 2021), 11.52 m^3/d (March 2022) and a maximum discharge rate of 93.41 m^3/d (August 2019), 86.40 m^3/d (July 2020), 90.95 m^3/d (July 2021), 62.84 m^3/d (up to collected). Settlements dominate this spring's recharge area; a total of 40 families depend on this spring for their daily water requirements. The hydrograph and rainfall vs. spring discharge response are shown in **Fig 32**. The recession curve of 3 years was plotted, showing the recession period in days and best fit models shown in **Fig. 33**.

Fig. 31 Barapani spring

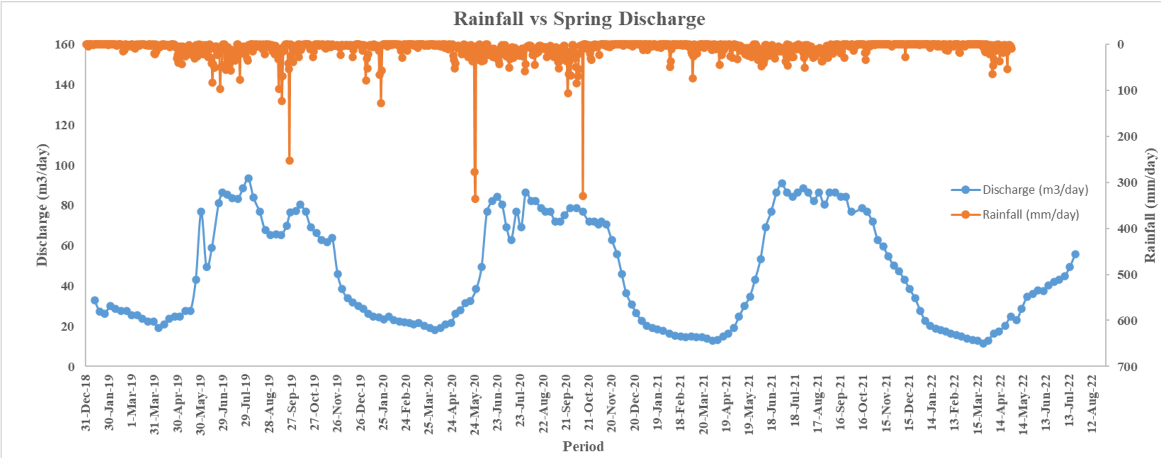


Fig. **32** Barapani Spring hydrograph

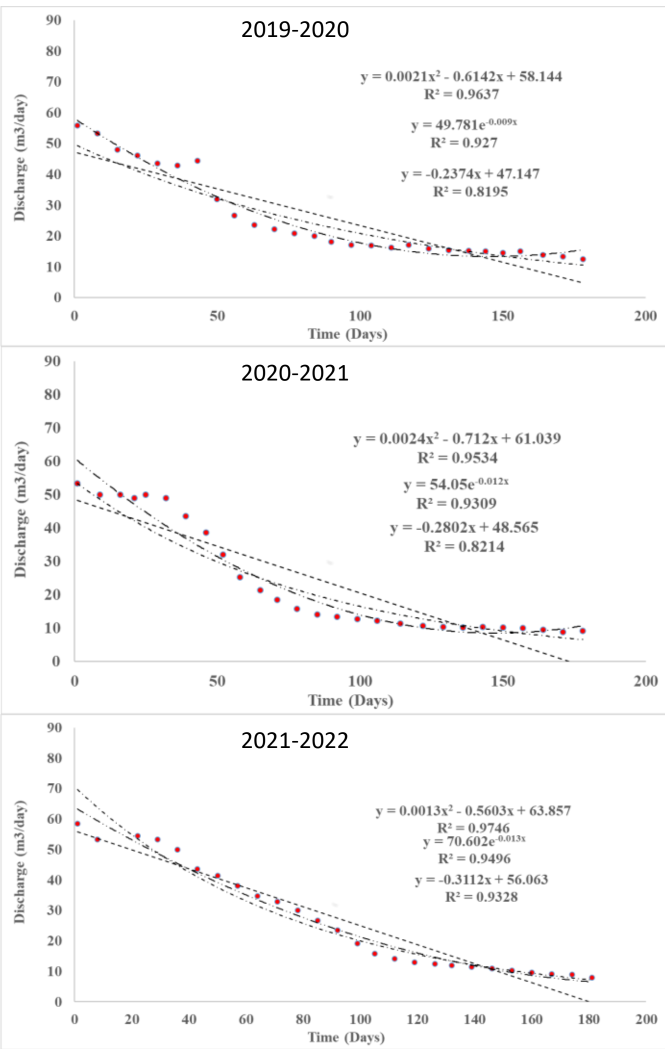


Fig. 33 Recession curve of the session (2019-2020, 2020-2021, 2021-2022).

Gumto Spring: Geographic location: 27°08'22.3"N, 93°48'08.5"E. Gumto spring (**Fig. 34**) is a perennial spring with a minimum discharge rate of 50.84 m3/d and a maximum discharge rate of 518.40 m3/d. Forested areas and a few settlements dominate the recharge area of this spring. The hydrograph and rainfall vs.

spring discharge response are shown in **Fig 35**. The recession curve of 3 years was plotted, showing the recession period in days and best fit models shown in **Fig. 36**.

Fig. 34 Gumto spring

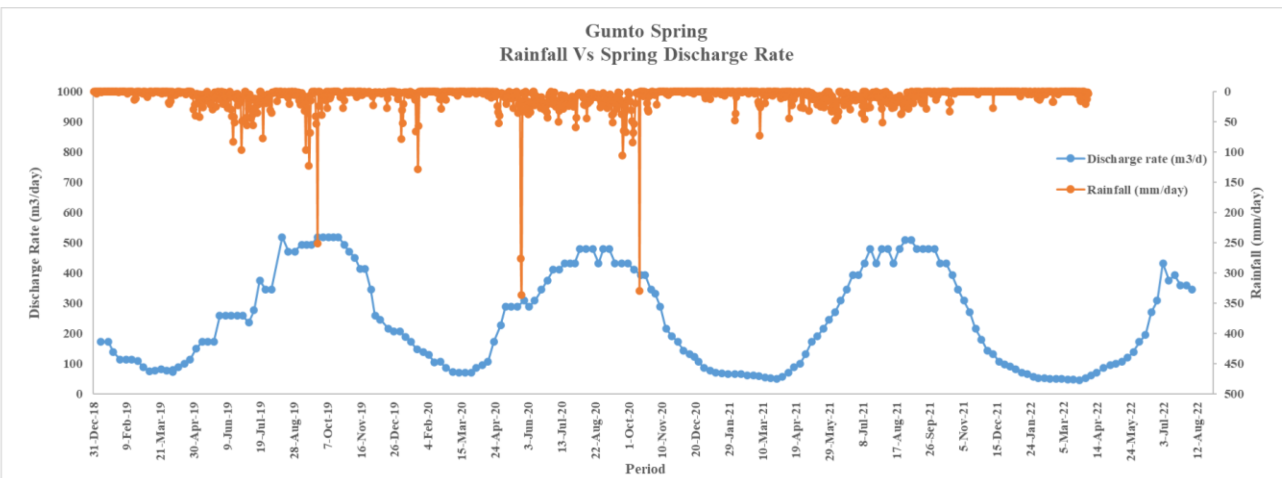


Fig. **35** Gumto Spring hydrograph

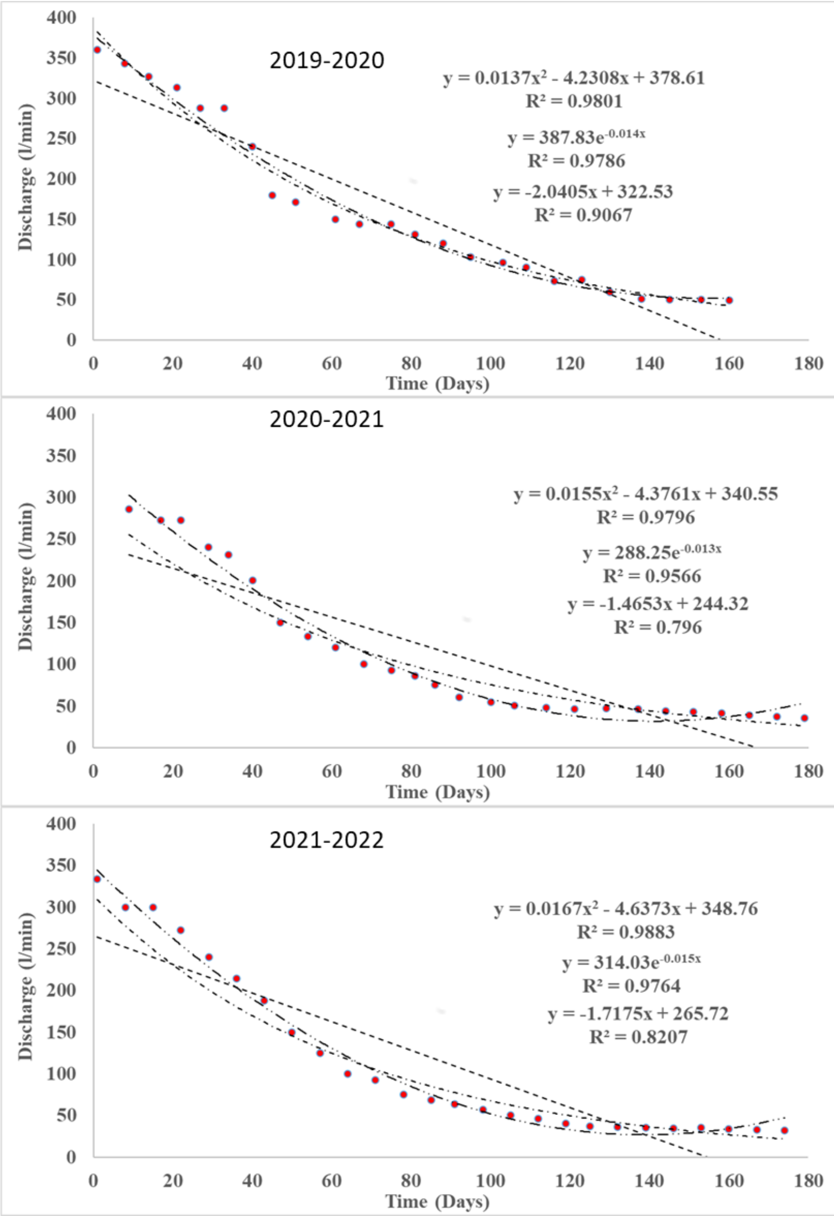


Fig. 36 Recession curve of the session (2019-2020, 2020-2021, 2021-2022).

Physico-chemical properties of spring water:

Some water properties are measured at spring sites as temperature, pH, EC, DO, and TDS (shown in **Table 7**). The observed data shows that most of spring's EC, DO, and TDS are under acceptable or permissible limits as per WHO. The pH of the six springs is acidic, and the EC and TDS of the Barapani spring are above the permissible limit.

Table 7 On-site measured spring water quality data

Spring Name	Spring Code	Temp. [°C]	pH	EC [µS/cm]	D.O. [%]	TDS [ppm]
Ganga-Yamuna Mandir-1	AR/PP/GJM1/SP	21.71	6.97	95	78.6	48
Ganga-Yamuna Mandir-2	AR/PP/GJM2/SP	19.04	7.57	105	87.7	53
Lower RGU	AR/PP/LRGU/SP	20.89	8.07	79	15.9	39
Gumto	AR/PP/GU/SP	23.84	**5.77**	43	14.0	21
Karsingsa Durga Mandir	AR/PP/DM/SP	16.14	7.59	59	104.3	30

Karsingsa 1A	AR/PP/KAR-1A/SP	16.23	**6.46**	149	105.0	75
Karsingsa 2A	AR/PP/KAR-2A/SP	16.20	6.91	173	106.0	86
Barapani	AR/PP/BP/SP	23.91	**6.26**	419	36.1	**209**
Prem Nagar	AR/PP/PN/SP	22.82	**6.41**	223	23.5	111
Lower Dam Site-1	AR/PP/LD1/SP	22.58	**6.13**	73	13.5	36
Upper Dam Site-1	AR/PP/UD1/SP	22.82	**6.24**	57	30.2	28
Upper Dam Site-2	AR/PP/UD2/SP	20.17	7.82	52	46.0	26
Chimpu-1	AR/PP/HL1/SP	14.40	8.08	114	52.6	57
Holanagi-1	AR/PP/CH1/SP	15.52	7.77	39	49.8	19

The metal analysis of spring water indicated that most of the springs' water is below detectable or under acceptable or permissible limits for the analyzed parameters (**shown in Table 8**). Some results of metal analysis and chemical water analysis have not been received yet. After getting the results, it will be incorporated.

Spring Name	Spring Code	Li (Mg/l)	Na (Mg/l)	NH_4 (Mg/l)	K (Mg/l)	Mg (Mg/l)	Ca (Mg/l)	Zn (Mg/l)	Ni (Mg/l)	Cd (Mg/l)	Co (Mg/l)	Cu (Mg/l)	Mn (Mg/l)	Fe (Mg/l)
Ganga-Yamuna Mandir-1	AR/PP/GJM1/SP	BDL	11.2	BDL	3.38	3.09	6.55	BDL	BDL	BDL	BDL	BDL	0.003	BDL
Ganga-Yamuna Mandir-2	AR/PP/GJM2/SP	BDL	9.94	BDL	3.27	3.26	9.39	BDL	BDL	0.001	0.01	BDL	0.004	BDL
Lower RGU	AR/PP/LRGU/SP	BDL	11.6	BDL	2.80	2.62	7.37	BDL	BDL	BDL	0.004	BDL	0.002	BDL
Gumto	AR/PP/GU/SP	BDL	5.59	BDL	2.96	1.39	3.03	BDL	BDL	BDL	0.005	BDL	BDL	BDL
Karsingsa Durga Mandir	AR/PP/DM/SP	BDL	6.13	BDL	2.81	2.42	4.61	BDL	BDL	BDL	BDL	BDL	0.002	BDL
Karsingsa 1A	AR/PP/KAR-1A/SP	BDL	10.0	BDL	1.02	6.68	11.5	BDL	BDL	0.002	0.007	BDL	0.066	BDL
Karsingsa 2A	AR/PP/KAR-2A/SP	BDL	10.9	BDL	4.69	8.76	12.7	BDL	BDL	BDL	0.02	BDL	0.16	BDL
Barapani	AR/PP/BP/SP	BDL	25.0	BDL	9.80	5.63	41.8	BDL	BDL	BDL	0.013	BDL	0.009	BDL
Prem Nagar	AR/PP/PN/SP	BDL	19.0	BDL	7.16	4.85	21.6	BDL	BDL	BDL	0.016	BDL	0.003	BDL
Lower Dam Site-1	AR/PP/LD1/SP	BDL	10.0	BDL	3.14	2.75	5.93	BDL	BDL	0.001	0.005	BDL	0.001	BDL
Upper Dam Site-1	AR/PP/UD1/SP	BDL	9.43	BDL	2.86	2.21	4.26	BDL	BDL	0.001	0.02	BDL	0.016	BDL
Upper Dam Site-2	AR/PP/UD2/SP	BDL	9.54	BDL	2.52	1.94	3.84	BDL	BDL	0.001	0.02	BDL	0.021	BDL
Chimpu-1	AR/PP/HL1/SP	BDL	9.56	BDL	3.62	5.64	10.2	BDL	BDL	0.001	0.014	BDL	0.006	BDL
Holanagi-1	AR/PP/CH1/SP	BDL	6.81	BDL	2.29	1.95	4.36	BDL	BDL	0.001	0.009	BDL	0.006	BDL

Recommendation of storage structures: Once we know the available water supply in the upcoming lean season, stakeholders and water managers may implement appropriate water management policies to cope with water scarcity.

Barapani springs: About 30 to 40 families depend on spring for every water requirement. The families living at this place are mostly daily wage labuors, settled here from other states. The other tap/pipe water supply services are unavailable at this location. Thus, they entirely depend on this spring for every water requirement. As per the questionnaire survey, the ratio of family members is 3-5. The standard daily water requirement per person for lower income groups is 135 lit/head/day. So, the daily water demand is 10.8 m3/day, and the lowest water yield in the lean period is 11.52 m3/day. The daily water yield is higher than the daily water demand. So, the open circuit storage structure is the best option for the spring. The peak water demand was noticed in the morning session from 6:00 AM to 12:00 PM (6hrs), including latrine, washing utensils, cooking, drinking, bathing, and washing clothes. It covers 70% total daily water demand, about 7.56 m3/day. Another peak water demand is from 05:00 PM to 09:00 PM (4hrs), which includes (drinking, cooking, and washing utensils). As per the 6hr peak demand storage structure should be designed. The structures should be open circuits with a capacity greater than 7.56 m3/day.

Gumto Springs: About 10 families depend on spring; sometimes, the nearest families also use water. The families living in this place is local peoples. The tap/pipe water supply by communities' services is available at some points in this location. As per the questionnaire survey, the ratio of family members is 5-7. The standard daily water requirement per person for 150 lit/head/per day. So, the daily water demand is 10.5 m3/day, and the lowest water yield in the lean period is 46.403 m3/day. The daily water yield is higher than the daily water demand. So, the open circuit storage structure is the best option for the spring. The peak water demand was noticed in the morning session from 6:00 AM to 12:00 PM (6hrs), including latrine, washing utensils, cooking, drinking, bathing, and washing clothes. It covers 70% total daily water demand, 7.35 m3/day. Another peak water demand is from 05:00 PM to 09:00 PM (4hrs), which includes (drinking, cooking, and washing utensils). The discharge yield during peak 6hr is 11.60 m3/day, which is much higher than the peak 6hr demand. So, as per the 6hr peak demand, an open circuit storage structure should be designed. Near spring locations, agricultural lands are also available, where groundwater is used for irrigation during non-monsoon periods. The construction of spring-fed ponds is suitable for providing water for irrigation and fish farming.

4.2 Key Results (max 1000 words in bullets covering all activities)

- About 102 spring locations were recorded, and the district's geotag map was prepared.
- The purpose of water uses, and community dependability on springs was recorded to estimate the water demand and supply.
- A spring potential zonation map was generated and validated for future regional water management practices.
- Springshed delineation and recharge area identification were conducted to implement the spring rejuvenation and protection practices.
- The approx. 3 years of discharge data were recorded for 11 springs to estimate the spring yield and recession period.
- The recession period was estimated at 140 to 180 days in the year.
- The water yield of 11 springs was estimated, in which the highest yield was recorded by Gumto spring at 518 m^3/day and the lowest in Chimpu-I spring at 0.13 m^3/day.
- The water quality of the springs was measured, and it was found that in most springs, the pH is lesser than the (6.5) permissible limit. Other parameters are also above the permissible level in spring water, where the recharge area is dominated by population and agricultural activities. So, the recharge area's springhead development and protection are recommended.
- It was recommended that the region's most suitable spring water harvesting structures are open circuit type (except in very low discharge). Also, it was recommended the construction of spring-fed ponds.

4.3 Conclusion of the study (maximum 500 words in bullets)

- Springs are the primary drinking and irrigation water source in most of the district. But it was noticed that springs have been drying in the last few decades due to climate change (especially rainfall "too little and too much water") and anthropogenic regions. The major anthropogenic activities of hill cutting (mostly noticed in the district) for new construction, forest burning for Jhum cultivation, and deforestation reduce the aquifer recharge. Springs tend to have a continuous natural flow. It recharges and discharges in every monsoon and non-monsoon period. Thus, the recharge area is susceptible; hence, any disturbance in the recharge area dramatically affects the discharge pattern and increases the water scarcity scenario in the region. The area has no spring-related data available. So, primary data must be collected before implementing any water management projects. In the current project, a field survey was conducted to identify the spring location and its related information, and geotag map was prepared. Based on recorded data and collected maps from the different agencies, a spring potential zone map, springshed delineation, and recharge area of the region were prepared. Based on the discharge recorded of 11 springs hydrograph, the recession curve and spring yield were estimated. The recession period started from mid-October to March (140 to 180 or 190 days), but most water scarcity was noticed during January to March. The spring's water quality was monitored, and it was noticed that most parameters are under acceptable or permissible limit, except the pH of most spring water is below the acceptable limit (6.5). Primarily, water quality parameters are above the permissible limit in springs recharge areas dominated by population. Based on spring yield, the water harvesting structure recommended for low (very low & low), medium, and high discharge are closed circuits for very low discharge, open circuits for low to high discharge, and spring-fed ponds for high discharge springs. Spring rejuvenation and protection are required to achieve the region's future water scarcity. Due to less care, springs are drying or vanishing; hence spring protection is more required in the region. Therefore, train or educate the local communities to protect the spring head and recharge area.

5 OVERALL ACHIEVEMENTS

5.1 Achievement on Project Objectives [Defining contribution of deliverables in overall Mission (max. 1000 words)]

- A geotagged map of the district was created after 102 spring locations were registered. The purpose of water uses and community reliance on springs was documented to assess water demand and supply. A prospective zonation map for spring was created and validated for the area's future water management strategies. To put spring rejuvenation and protection procedures into place, springshed delineation and recharge area identification were made. To estimate the spring yield and recession duration, discharge data from 11 springs spanning approximately 3 years was collected. It was estimated that the recession would last between 140 and 180 days per year. Estimated water yields from 11 springs showed that Gumto spring had the most significant production (518 m^3/day), while Chimpu-I spring had the lowest yield (0.13 m^3/day). When springs' water quality was evaluated, it was discovered that most had pH levels below the acceptable range of (6.5pH). Other factors are also above the allowable limit in spring water, where agriculture and human activity dominate the recharge region. Therefore, developing the spring head and safeguarding the recharge region is advised. It was suggested that open circuit-type spring water harvesting facilities would be the most appropriate in the area (except in shallow discharge). Additionally, it was advised to build spring-fed ponds.

5.2 Establishing New Database/Appending new data over the Baseline Data (max. 1500 words, in bullet points)

- The locations of around 102 springs were documented, and a geotagged district map was created. The reasons for using water and the degree to which the community depends on springs were documented to estimate water demand and supply. A map of the spring potential zonation was developed and then confirmed in preparation for future water management methods in the region. Delineation of the springshed and identification of the recharge area were the first steps in putting the spring rejuvenation and protection practices into action. 11 springs had their discharge data recorded over approximately three years to determine the spring yield and recession period. According to the estimates, the recession lasted anywhere from 140 to 180 days yearly. We determined the water yield of 11 springs, and the Gumto spring was found to have the most significant yield at 518 m3/day, while the Chimpu-I spring had the lowest yield at 0.13 m3/day. After conducting tests to determine the water quality in springs, it was discovered that the water's pH in most springs is lower than the allowable maximum of 6.5. In spring water, where people and agricultural activities dominate the recharge area, other criteria are also over the allowed threshold. Therefore, the spring head's development and the recharge region's protection are advocated. It was suggested that the open-circuit spring water harvesting facilities would be the most appropriate location (except in shallow discharge). Additionally, the creation of ponds supplied by springs was suggested.

5.3 Generating Model Predictions for different variables (if any) (max 1000 words in bullets)

- Remote sensing and GIS-based study were used to predict the spring potential zones and most suitable spring areas.
- Remote sensing, GIS, and isotope techniques were used to identify the potential recharge.
- Regression analysis of the recession curve was used to estimate the best-fit models.
- The water quality of the springs was measured, and identified the major contamination activities to avoid activities.

5.4 Technological Intervention (max 1000 words)

- **Comprehensive mapping of springs**:

  Remote sensing and GIS: It is widely used in hydrological studies and watershed management. This technique is also used in spring inventory and springshed mapping, potential zonation, and springshed delineation. Because of how quickly things change, GIS is one of the most important tools for integrating spatial data and managing natural resources. Planners and decision-makers use GIS and remote sensing technology for many different tasks. It takes lesser time than other traditional techniques and is cheaper than conventional methods.

  Isotope techniques: There are different ways to do this kind of investigation, but environmental isotopes of oxygen and hydrogen are often used to find the source and the path groundwater takes to refill. Oxygen and hydrogen, the building blocks of water molecules and the hydrological cycle leave behind a unique pattern of isotopes in water that can be used to track groundwater recharge. Other biosphere factors, such as the interaction between water and rocks, do not change this pattern.

- **Data monitoring system**: Set-up up data monitoring systems such as automatic weather stations, flumes for discharge recording, and water testing kits.

5.5 Field Demonstration and Value-addition of Products (max. 1000 words, in bullet points)

- Development of seepage springs techniques,
- Construction of spring boxes to head protection and recommendation of other protection measures to avoid contamination.
- Discharge measuring methods for continuous monitoring
- Demonstration of water quality test kits.

5.6 Promoting Entrepreneurship in IHR

- The availability of sufficient water throughout the year facilitated the communities' sustainable development and decreased the drudgery of water fetching for household use, transferring for irrigation, and other small-scale businesses. Sufficient water increases agricultural production, such as rice, tea, spices, and fruits. Tea, orange, apple, kiwi, and large cardamom have greater demand worldwide. So, the increase in production will increase the many startups. Also, traditional food products, arts and crafts have demand in India and worldwide

5.7 Developing Green Skills in IHR

-----NA------

5.8 Addressing Cross-cutting Issues (max. 500 words, in bullet points)

- The delineation of the springshed is currently predicated on the stable behaviors of the input parameters. However, input drivers may display non-stationary behavior in a changing climatic scenario, resulting in increased complexity in understanding and modeling. As a result, more point-based input driver data is required for mapping, modeling, and managing springshed at the landscape level. The study will provide a better understanding through the detailed database on spring drying, seasonality, water stress in the winter season, water quality status, causes of pollution, reviving status, threatened households, conservation measures, awareness, and education, along with factors influencing it. The study will also provide information on the factors that influence it. Publication in both national and international publications will be used to spread the word about the most important discoveries. As a result, this kind of research has a greater chance of being sustainable and reproducible, which can lead to a better knowledge of and approach to managing springshed in the vulnerable Himalayan region.

6 PROJECT'S IMPACTS IN IHR

6.1 Socio-Economic Development (max. 500 words, in bullet points)

- This study was the first research to be conducted in the district; now, many agencies are working on inventory and rejuvenation of springs. This investigation will be strengthened by taking a collaborative, multidisciplinary approach from specialists from various institutes and fields of study. The database generated because of the study will be useful to scientists who are active in springshed management and the conservation of spring water, as well as to engineers and technocrats who are involved in water conservation projects. In addition to that, during the field visit and data collection, friendly talks gave residents the impression of preserving land use in springshed, water harvesting, and protection as part of the initiative. The most important discoveries will be made public through presentations at conferences and publications in scholarly journals on a global scale. This suggested (ST-dominated) activity impacted the rural community more broadly.

The findings of the study will be helpful in convincing policymakers, water managers, local governments, and finally, the community around the study sites about the deteriorating status of the land, which may, in the long run, help in conserving this valuable resource. This will be accomplished by making them aware of the deteriorating status of the land, which will make them aware of the deteriorating status of the land. There is a greater need for educating them because springs are the lifeline of the communities that live around them and because they are responsible directly and indirectly for the deterioration of these valuable resources, and since they are responsible directly and indirectly for the deterioration of these valuable resources.

6.2 Scientific Management of Natural Resources In IHR (max. 500 words, in bullet points)

- Conduct a field study to identify all springs (small and large) and seepage springs in the region, then geo-tag the map.
- Define each spring's recharge area for management.
- Check the spring's discharge and water quality regularly.
- Build a spring-fed water harvesting structure to store excess water.
- Rejuvenation and protection are long-term springshed management practices.
- Reduce catchment soil erosion and boost plant cover and organic matter.
- Increase soil infiltration to recharge the aquifer.
- Protect the land to allow ecological regeneration and keep the catchment region clean to prevent water pollution.
- Effective rainwater gathering strategies should enhance natural infiltration and recharge. Build a lake to collect spring water.
- Springshed management involves protecting spring points from contaminants and rehabilitating springshed areas using the best management techniques based on protection zones and land cover. Create the "spring front" by building a spring box, temple, park, etc.
- Encourage community members to learn about spring water and share this information with other local institutions so they can monitor and regulate springs after receiving training.
- All key stakeholders must collaborate to conserve the spring.

6.3 Conservation of Biodiversity in IHR (max. 500 words, in bullet points)

- Both people and trees have a thirst for water. Biodiversity and springs have a more significant impact on each other such as the local biodiversity influencing the water recharge in aquifers and the availability of water enhancing the growth of trees/plants and shrubs. In identifying springs, it was considered that the greenery area in the hillside or valley shows the springs or seeps. Springs also feed rivers to maintain the baseflow. Besides humans, biodiversity, and rivers, it also provides water to birds and wild animals. Therefore, it is vital to our long-term well-being to handle the forest's water-people-climate linkages sensibly, extensively, and swiftly.

6.4 Protection of Environment (max. 500 words, in bullet points)

- Reduce the amount of soil erosion in the catchment region and increase the amount of vegetation cover and soil organic matter. The natural infiltration of water into the soil should be increased to recharge the aquifer. Protect the land to make it possible for ecological restoration and keep the catchment area clean so that pollution of the groundwater and surface runoff can be avoided. Rainwater harvesting techniques that are the most effective should be used to supplement natural processes of infiltration and recharging. Construct a little manufactured lake to capture spring water. Create the "spring front," also known as a beautification project, by constructing features such as a park. Encourage people of the community to become knowledgeable about groundwater and share this information with other local institutions so that they may take over the monitoring and management of springs once they have received significant training and management.

6.5 Developing Mountain Infrastructures (max. 500 words, in bullet points)

- We all know that the effects of water scarcity on men and women are distinct. Because women are expected to take charge of water management, they often must travel great distances to replenish their supplies, which can be physically taxing. Rural women's participation in economic development projects has been a major driving force, opening opportunities for more equitable representation of women. The availability of reliable freshwater sources in the region boosts the sustainable growth of communities. Such as it reduces the drudgery on women and children and saving time fetching water from distant sources. It improves health, education, and women's empowerment. It also generates opportunities for many small-scale businesses in the region.

6.6 Strengthening Networking in IHR (max. 700 words, in bullet points)

- Locals, especially those who rely on the springs directly, should get hydrogeology education to better monitor local springs and grasp the scientific principles underpinning spring recharge and outflow. When the mechanism to keep tabs on things for the long haul is finally put up, the training should begin. By providing training to locals, we can ensure that monitoring of spring discharge and related factors will continue long after the research has concluded.

- Communities have been guarding springs for a long time, but their knowledge of springshed management hasn't necessarily expanded to cover the recharge/catchment area. Furthermore, self-sufficient communities are better able to control demand, which is especially important during the lean months. The science is de-mystified through an iterative process of experiential learning that imparts an understanding of the behavior of water through rocks and its consequences for the total water supply to local populations. Incorporating this information into one's worldview typically encourages communities to create bonds to the resource and guides the creation of management guidelines based on the consensus of those involved. In most instances, the cause is a shortage of available water. Realizing that doing nothing would cost more in the long run than working together will motivate people to get things done faster.

7 EXIT STRATEGY AND SUSTAINABILITY

7.1 How effectively the project findings could be utilized for the sustainable development of IHR (max. 1000 words)

- Based on the literature, there have been many pragmatic gaps in our understanding; we are constantly improving knowledge; not many qualitative and quantitative detail studies are available about mountain ecosystems' susceptibility to climate change. The high-elevation region of Arunachal Pradesh faces water scarcity while receiving extensive orographic rainfall for both physical and manmade reasons. The communities have never focused on water management, spring protection, and rejuvenation, which was the availability of abundant water and natural resources. The communities were highly involved in the hill cuttings, new construction, deforestation, and burning of the forest at the local level. Springs are greatly affected, and now it is drying or becoming seasonal. Also, increasing contamination activities such as poor management of wastes, construction of latrines, animal wastes, and use of fertilizers in recharge areas impacted the water quality. Thus, these activities in the springshed area trigger the drying and water quality of the springs. But in the last few decades, they noticed the drying water. In this project, research staff and students have often interacted with stakeholders and were acquainted with the what do? and what not do to not-do? in the springshed. Also, data collection was never prioritized in the region; hence a negligible amount of spring data (such as location, discharge, and water quality) is available in the region. In the present data, spring location and springshed were delineated, and recharge area characteristics, discharge data, water quality, water demand, and availability were identified, collected, and estimated. These data were helpful for the communities, research communities, and policymakers in planning and implementing water management projects in the region. But there is a need for an intense investigation into climate change's impact on spring discharge fluctuation and which climatic causes significant effects.

7.2 Efficient ways to replicate the outcomes of the project in other parts of IHR (Max 1000 words)

- While current springshed models are predicated on input parameters' stationary behaviors, input drivers' non-stationary behaviors in a changing climate setting could complicate the understanding and modeling of the system. Springshed mapping, modeling, and management at the landscape scale need additional point-based input driving data. The study's extensive database on spring drying, seasonality, water stress in the winter season, water quality status, causes of pollution, reviving status, threatened households, conservation measures, awareness, education, and variables influencing it will shed light on these topics and more. Findings will be disseminated by publication in both international and national publications. Thus, such research has a higher potential for long-term sustainability and reproducibility, allowing for improved knowledge and management of springshed in the vulnerable Himalayan region.

7.3 Identify other important areas not covered under this study needs further attention (max 1000 words)

- Implement spring rejuvenation and protection practices to tackle the future water crisis, especially protecting spring heads and springshed. It is vital to preserving the land use of the recharge region to increase the aquifer recharge, and it is also required to place restrictions on the activities that can be carried out in the recharge area by either humans or animals. Examples include recently built structures, cleared land for agricultural use, and other similar endeavors. Local users or communities will create rules to restrict activities and protect the spring after analyzing the situation and determining the most appropriate steps to perform locally. Planting trees and other vegetation in the recharge area will help bind the soil and decrease erosion (except eucalyptus plant or other plants competing for water). Recharging aquifers and preventing soil erosion are two essential functions that pine trees and other native species plants provide. Conflicts between communities are another issue that must be addressed when protecting springs.

- Additionally, secure the area around the spring by erecting a fence with barbed wire or another type of barrier, with a minimum radius of fifty meters, as agreed by the community. In addition, human activities such as farming, grazing, and hunting should be prohibited in this area. A secondary goal would be to restore springs or other freshwater water sources if they have dried up, water scarcity is observed throughout the year, or the community is forced to relocate outside the village. Implement augmentation of ponds, lakes, and challs, and construct check dams and trenches to boost the natural infiltration rate. In addition to this, the ecological function should be restored by planting native kinds of plants to improve the soil cover. Participation from the neighborhood residents is essential at every stage of the spring development practices.

7.4 Significant recommendations for sustaining the outcome of the projects in the future (500 words in bullets)

- Conduct an intensive field survey to identify all springs (small and large), including seepage springs in the region, and prepare the geo-tag map with its local information. Delineate the recharge area of every spring to implement any management practices. Monitor the discharge and water quality pattern regularly to understand the spring's health. Construct the water harvesting structure and spring-fed to store the water when it is in excess. For long-term sustainability, implement the springshed management practices such as rejuvenation and protection activities. The springshed management can be accomplished by protecting spring points from contaminates and rehabilitating springshed areas using best management practices in accordance with the protection zones and the type of land cover. All relevant stakeholders must participate in the conservation actions taking place in the spring through the utilization of collaborative management. One alternate technique for minimizing the effects of drought and adjusting to the effects of climate change will be the management of springs and springshed.

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9 ACKNOWLEDGEMENT

APPENDICES

Appendix 1 – Details of Technical Activities
Appendix 2 – Copies of Publications duly Acknowledging the Grant/ Fund Support of NMHS
Appendix 3 – List of Trainings/ Workshops/ Seminars with details of trained resources and dissemination material and Proceedings
Appendix 4 – List of New Products (utilizing the local produce like NTFPs, wild edibles, bamboo, etc.)
Appendix 5 – Copies of the Manual of Standard Operating Procedures (SOPs) developed
Appendix 6 – Details of Technology Developed/ Patents filled
Appendix 7 – Any other (specify)

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Annexure-I

Consolidated and Audited Utilization Certificate (UC) and Statement of Expenditure (SE)

For the Period: ……………………………………..

1.	Title of the project/Scheme/Programme:	**Assessment of natural spring reliability for rural water security in the lesser Himalayan region-Arunachal Pradesh**
2.	Name of the Principle Investigator & Organization:	**Dr. Pankaj Pandey** **North Eastern Regional Institute of Science and Technology (NERIST) Nirjuli, Itanagar, Arunachal Pradesh-791109**
3.	NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand Letter No. and Sanction Date of the Project:	Ref. No.: GBPNI/NMHS-2018-19/SG Date: 21-12-2018
4.	Amount received from NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand during the project period (Please give number and dates of Sanction Letter showing the amount paid):	
5.	Total amount that was available for expenditure (Including commitments) incurred during the project period:	
6.	Actual expenditure (excluding commitments) incurred during the project period:	
7.	Unspent Balance amount refunded, if any (Please give details of Cheque no. etc.):	
8.	Balance amount available at the end of the project:	
9.	Balance Amount:	
10.	Accrued bank Interest:	

Certified that the expenditure of **Rs.______________________ (Rupees ____________________________)** mentioned against Sr. No. 6 was actually incurred on the project/scheme for the purpose it was sanctioned.

Date:

(Signature of Principal Investigator) (Signature of Registrar/ Finance Officer) (Signature of Head of the Institution)

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALAYAN STUDIES (GBP NIHE)

Statement of Consolidated Expenditure

[Institution Name here]

Statement showing the expenditure of the period from
Sanction No. and Date :

1. Total outlay of the project :

2. Date of Start of the Project :

3. Duration :

4. Date of Completion :

a) Amount received during the project period :

b) Total amount available for Expenditure :

S. No.	Budget head	Amount received	Expenditure	Amount Balance/ excess expenditure
1	Salaries			
2	Permanent Equipment Purchased (Item-wise			
3				
4				
5				
6				
7				
8				
9				
10	Institutional charges			
11	Accrued bank Interest			
12	**Total**			

Certified that the expenditure of **Rs.___________________ (Rupees:______________________________)** mentioned against Sr. No.12 was actually incurred on the project/ scheme for the purpose it was sanctioned.

Date:

(Signature of Principal Investigator)	(Signature of Registrar/ Finance Officer)	(Signature of Head of the Institution)

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALYAN STUDIES (GBP NIHE)

Annexure-II

Consolidated Interest Earned Certificate

Please provide the detailed interest earned certificate on the letterhead of the grantee/ Institution and duly signed.

Annexure-III

Consolidated Assets Certificate

Assets Acquired Wholly/ Substantially out of Government Grants

(Register to be maintained by Grantee Institution)

Name of the Sanctioning Authority: ____

1. Sl. No. ____
2. Name of Grantee Institution: ____
3. No. & Date of sanction order: ____
4. Amount of the Sanctioned Grant: ____
5. Brief Purpose of the Grant: ____
6. Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant-in-aid Sanction Order: ______________________________
7. Particulars of assets actually credited _____________________________________ or acquired________
8. Value of the assets as on ____
9. Purpose for which utilised at present ____
10. Encumbered or not ____
11. Reasons, if encumbered ____
12. Disposed of or not ____
13. Reasons and authority, if any, for disposal____
14. Amount realised on disposal ____

Any Other Remarks: ____

____

(PROJECT INVESTIGATOR) **(FINANCE OFFICER)**

(Signed and Stamped) **(Signed and Stamped)**

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Annexure-IV

List or Inventory of Assets/ Equipment/ Peripherals

S. No.	Name of Equipment	Quantity	Sanctioned Cost	Actual Purchased Cost	Purchase Details

(PROJECT INVESTIGATOR)

(Signed and Stamped)

(FINANCE OFFICER)

(Signed and Stamped)

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Annexure-V

Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department

To,

The Convener, Mountain Division
Ministry of Environment, Forest & Climate Change (MoEF&CC)
Indira Paryavaran Bhawan
Jor Bagh, New Delhi-110003

Sub.: Transfer of Permanent Equipment purchased under Research Project titled "...." funded under the NMHS Scheme of MoEF&CC – reg.

Sir/ Madam,

This is hereby certified that the following permanent equipment purchased under the aforesaid project have been transferred to the Implementing Organization/ Nodal Institute after completion of the project:

1. pH/EC/TDS Meter
2. Multiparameter Photometers
3. Rain gauges and H-flume
4. Mini disk infiltrometer
5. GPS
6. Electronic Balance
7. LCD projector with display
8. Computer & Printer
9. Camera

Head of Implementing Organization:
Name of the Implementing Organization:
Stamp/ Seal:
Date:

Copy to:

1. The Nodal Officer, NMHS-PMU, National Mission on Himalayan Studies (NMHS), G.B. Pant National Institute of Himalayan Environment (NIHE), Kosi-Katarmal, Almora, Uttarakhand-263643

Annexure-VI

Details, Declaration and Refund of Any Unspent Balance

Please provide the details of refund of any unspent balance and transfer the balance amount through RTGS (Real-Time Gross System) in favor of **NMHS GIA General** and declaration on the official letterhead duly signed by the Head of the Institution.

Kindly note the further Bank A/c Details as follows:

Name of NMHS A/c:	NMHS GIA General
Bank Name & Branch:	Central Bank of India (CBI), Kosi Bazar, Almora, Uttarakhand 263643
IFSC Code:	CBIN0281528
Account No.:	3530505520 (Saving A/c)

In case of any queries/ clarifications, please contact the NMHS-PMU at e-mail: nmhspmu2016@gmail.com