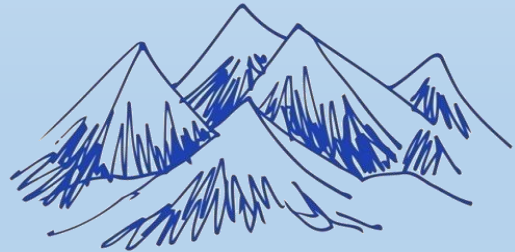


Source Sustainability for Water Supply Schemes Challenges and options in the Indian Himalayan Terrain



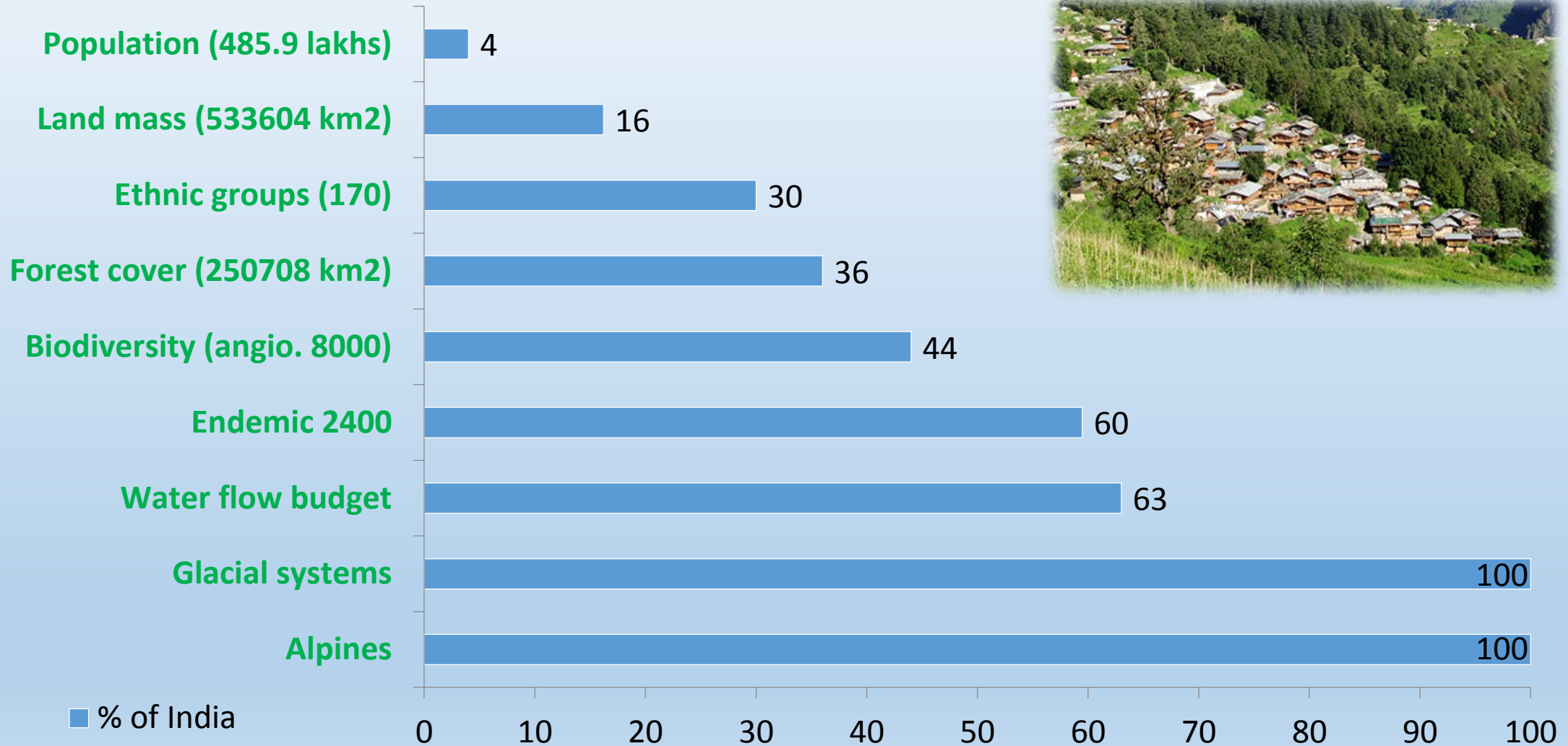
Kireet Kumar

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- **Water** supply systems in IHR- **Regional Scale**
 - Himalayan Terrain and people
 - Rural water supply sources
 - Springs and shallow ground water systems
- **Source** sustainability – **Regional assessment**
 - Index based
 - IWRM
- **Options** for **source** sustainability – **Local Action**
 - Water Sanctuary (Jal Abhyaranya)
 - Resource sharing (case studies)

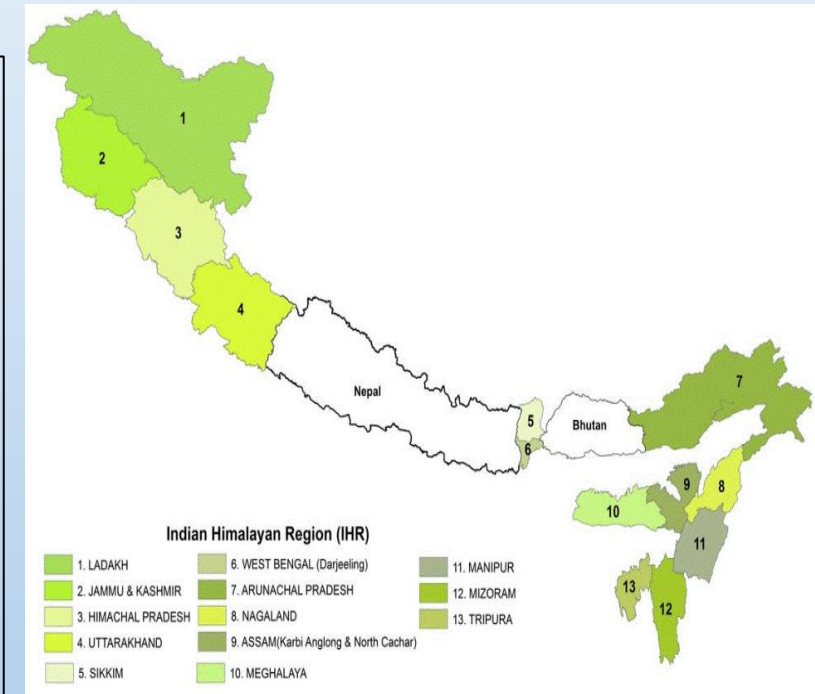
Indian Himalayan Region: Young and dynamic Terrain



Himalayan Water systems

- Indian Himalaya Region (IHR), a part of Himalayan Ranges, has huge no. of water resources, yet is under threat of water shortage in changing world.
- **Terrain specific challenges:** Changing rainfall pattern; protracted droughts; fluctuating temperatures; more frequent and severe weather events, including floods; **Springs Extinction & Drying up;** Loosing potential for hydropower generation; Huge sedimentation and other Anthropogenic activities.

- The Himalayan mountain springs act as the lifeline for both rural and urban communities.
- Out of the 5 million springs across India, 3 million, i.e., more than 60%, are in the Indian Himalayan region (IHR) alone (NITI Aayog, 2018).
- Over 200 million people in India depend on springs; out of these, 50 million people are in the 11 States and 2 UTs of the IHR.
- About 18,681 (21%) villages have springs out of 89,712 villages in the Indian Himalayan Region
- The Himalayas are having more than 33,000 km² of glaciated basins that store approximately 12,000 Km³ of fresh water (Hua et al., 2009)

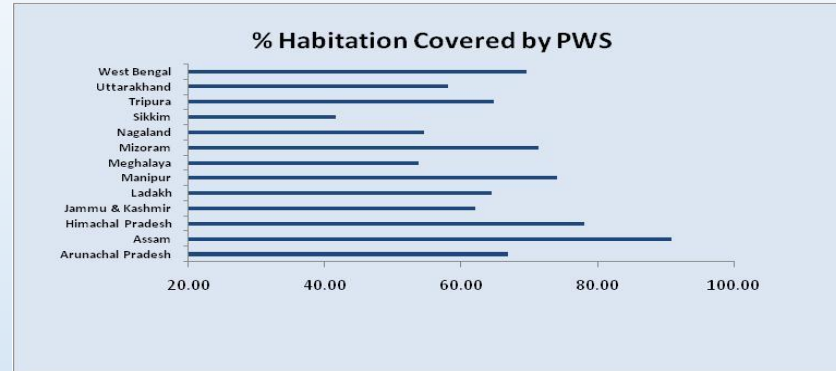


Total States/UTs: 11 States and 2 UTs



Himalayan Water: Key Challenges

- Providing year-round uninterrupted availability of fresh potable water through piped government schemes to every household of IHR by 2024



Present coverage of piped supply to homes is below 65% in IHR (NRDWP)

- Protection of natural springs and streams of the IHR needed on an urgency basis for long-term sustainable availability of fresh water (Niti Aayog, 2018)
- Key Challenges for sustaining water supply:
 - I. Continuous **extinction** of springs and spring fed sources
 - II. Reduction in stream flow and **water quality**
 - III. Increased threat to Water Security with growing **demand**

❑ **Data gap** - Lack of baseline information for springs and spring fed systems leads to poor planning

❑ Institutional conflicts and lack of community participation in rural water supply also affects source sustainability

Support to **SDG 6-**
Clean Water and Sanitation



Rural Water Supply in IHR

DOMINANT WATER SOURCES- BLOCK WISE (Source :<http://www.indiawater.gov.in/>)

STATE	DEEP TUBEWELL	OPEN WELL/ SHALLOW TUBEWELL	RIVULET/ NAULA/ GADHERA	SPRING	STREAM	OTHERS	NO DATA	TOTAL BLOCKS
HIMACHAL PRADESH	42	1	-	34	-	-	-	77
UTTARAKHAND	18	-	57	9	-	11	-	95
SIKKIM	-	-	-	24	-	-	1	25
WEST BENGAL	3	-	-	5	-	-	3	11
ARUNACHAL PRADESH	2	3	-	-	78	-	16	99
ASSAM	-	22	-	-	-	-	4	26
MANIPUR	-	1	7	1	14	4	11	38
MIZORAM	-	-	1	27	-	-	1	29
MEGHALAYA	-	6	-	2	20	1	10	39
NAGALAND	-	12	9	-	79	14	-	114
TRIPURA	9	30	-	-	-	-	1	40

- **Springs** (locally named *Naula, Dhara, shrota* etc.) and **Spring-fed streams** are life line for communities in mountains – often used for various **designated uses** i.e. drinking, domestic, agriculture as well as **economical purpose** such as running flour mills and generating electricity.

Total Blocks in 11 IHR states (Excluding J&K and Ladakh): 593
 Block mapped for water supply sources in 11 States: 546
 Blocks largely dependent on Springs and spring fed streams: **254**
 Total dependence on shallow ground water : 329

Rural Water Supply in IHR

Thresholds used for Calculating Water scarcity Indices...

S.N.	Vegetation Cover (%)	E_Ind. Value
1	0 - 25	0.25
2	25 – 50	0.5
3	50 – 75	0.75
4	> 75	1

S.N.	Rainfall (mm)	R_Ind. Value
1	< 1000	0.25
2	1000 – 1250	0.5
3	1250 – 1500	0.75
4	> 1500	1

S.N.	Pop. Density (Person/Km ²)	L_Ind. Value
1	< 100	1
2	100 – 250	0.75
3	250 - 400	0.5
4	> 400	0.25

S.N.	Mean Elevation (m)	Pr_Ind. Value
1	< 1000	1
2	1000 – 1500	0.75
3	1500 – 2000	0.5
4	> 2000	0.25

S.N.	Water Avail/Demand	H_Ind. Value
1	< 2	0.25
2	2 – 6	0.5
3	6 – 10	0.75
4	> 10	1

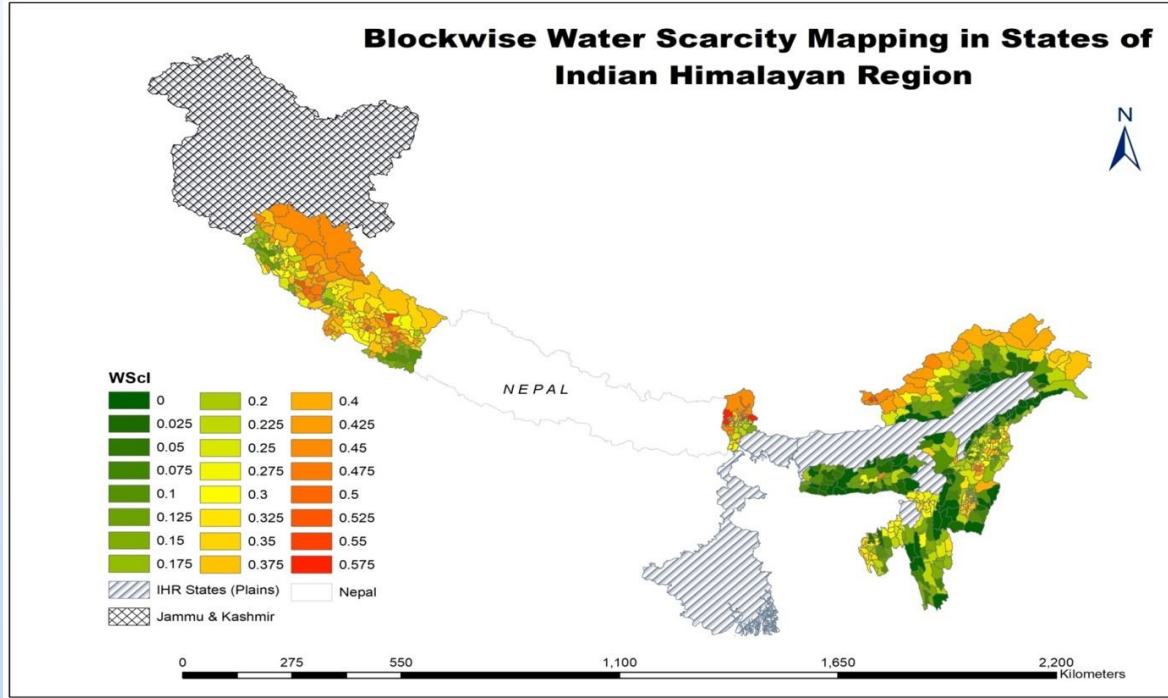
$$WSI = 0.4 * Pr_{-i} + 0.3 * H_i + 0.1 * (E_i + L_i + R_i)$$

$$WScI = 1 - WSI$$

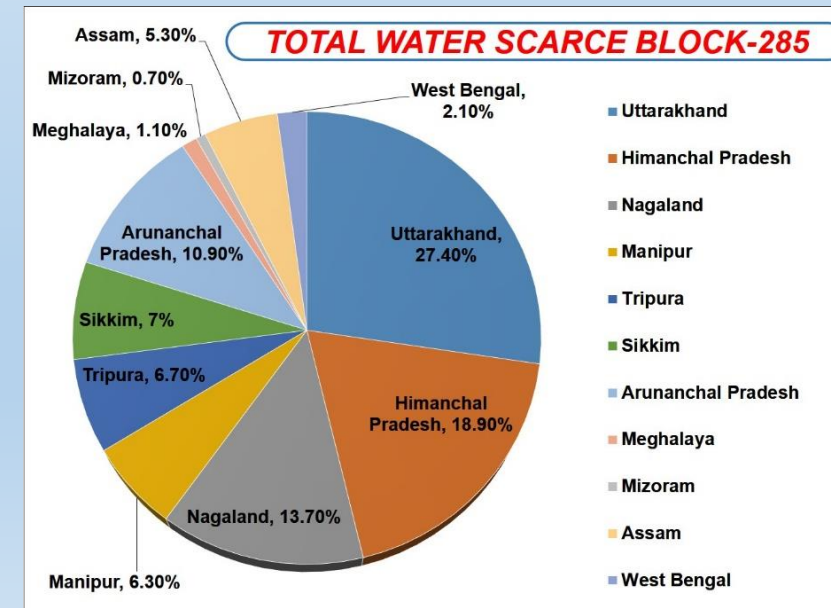
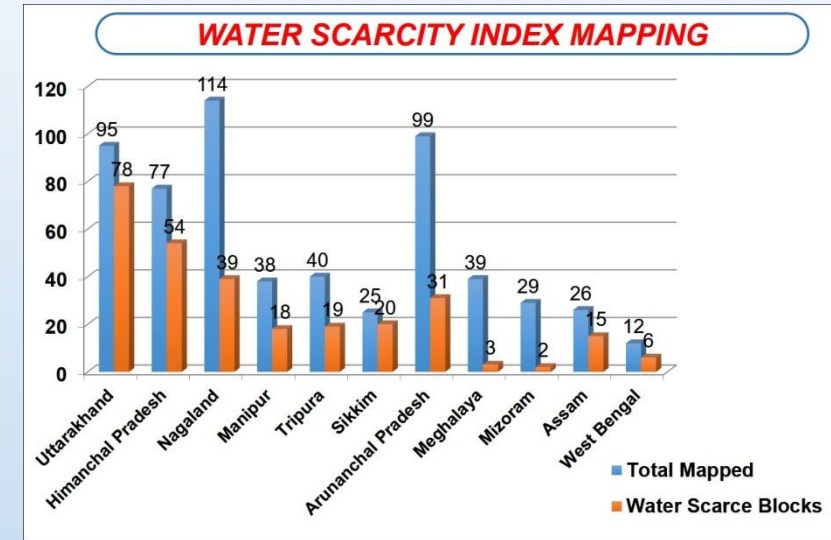
*WSI = Water Sustainability Index

WScI= Water Scarcity Index

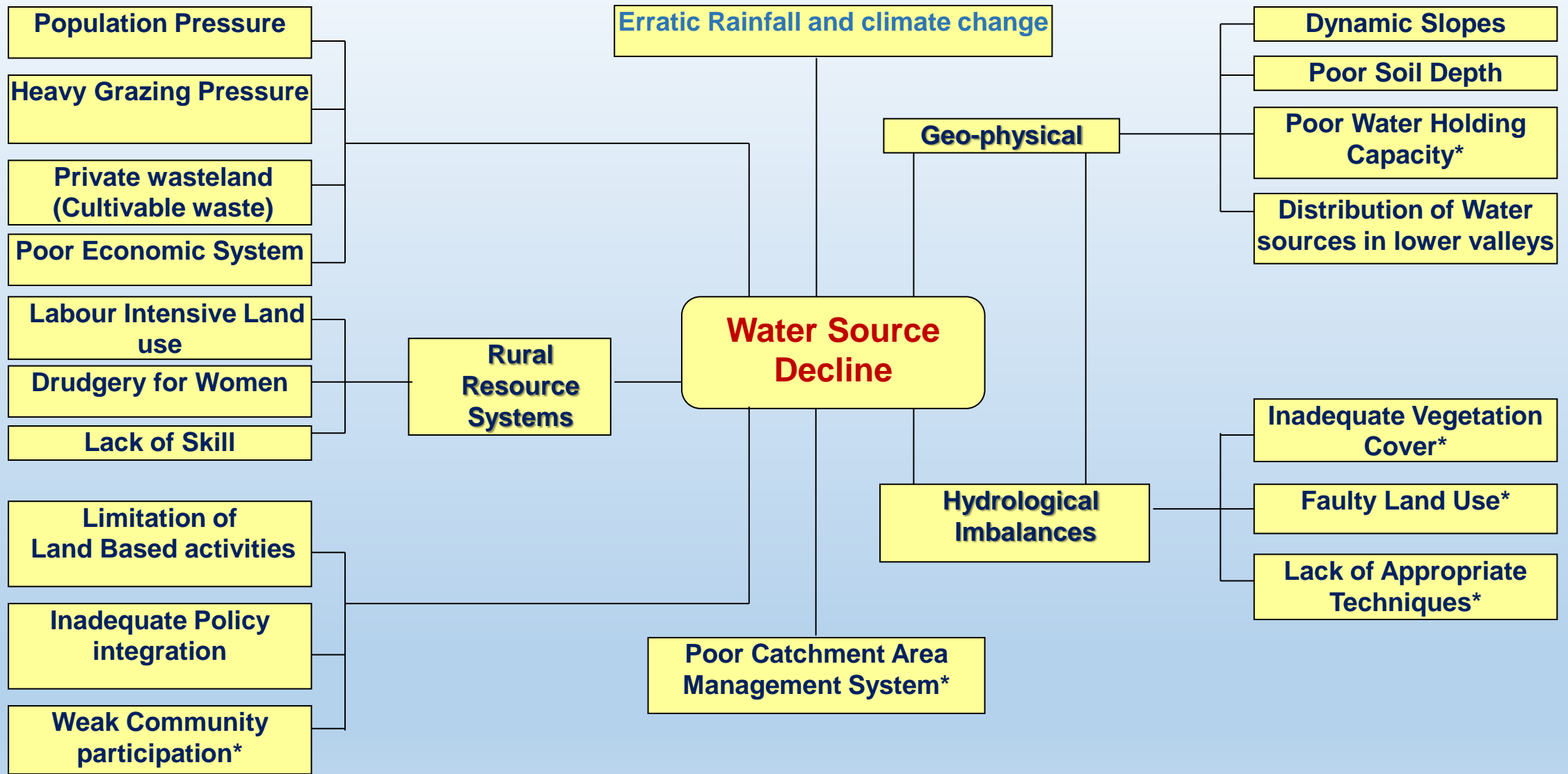
Water Scarcity in Himalayan States



- **285 blocks** out of total 593 blocks are found to be water scarce in 11 states
- Blocks having **mid-elevation villages** face highest order of scarcity
- With this rate sustaining water source is must to ensure water security



Factors affecting Water Source Sustainability



← Socioeconomic

* Items where intervention can be made

→ Bio-geophysical

Overview and Need for Source Sustainability

- Over the north-western Himalaya, dependency of fresh water through *Rivulets*, *Streams* and *Springs* is higher in Uttarakhand (~62%) than Himachal Pradesh (~40%). One administrative block of Himachal Pradesh is noted to be 100 % dependent on Springs.
- Over the eastern Himalaya, dependency of fresh water through *Streams* and *Springs* is highest in Mizoram. A total of 27 blocks in Mizoram is noted to be 100% dependent on *Springs*.
- The [water scarcity mapping](#) of Indian Himalayan indicates that a total of 285 administrative blocks of 11 IHR states are having water scarcity. Subsequently, more than 27000 villages, within the water scarce blocks, having population of around 13.5 million might be experiencing current water scarcity.
- About 7946 villages having a population of about 3.7 million are facing severe water scarcity and need urgent interventions.
- Several examples of spring rejuvenations, traditional catchment based approaches of participatory water management have shown promising results.
- Considering this, a source centred approach of [Water Sanctuaries \(Jal Abhyaranya\)](#) incorporating integrated bio-physical and social measures for rain water harvesting, can provide viable solutions to water sustainability of the region.
- Precise selection/identification of recharge area/springshed and systematic designing of recharge structures can be effective way of rejuvenating the drying springs and spring-fed systems.
- Reviving springs through spring sanctuary makes sense. Controlling a spring from its source of water to its point of release requires some planning and management. With the use of hydrogeology, a more effective strategy for revitalizing springs may be crafted by taking into account the aquifers that supply water to them

Integrated Water Resources Management (IWRM) to cope with water scarcity

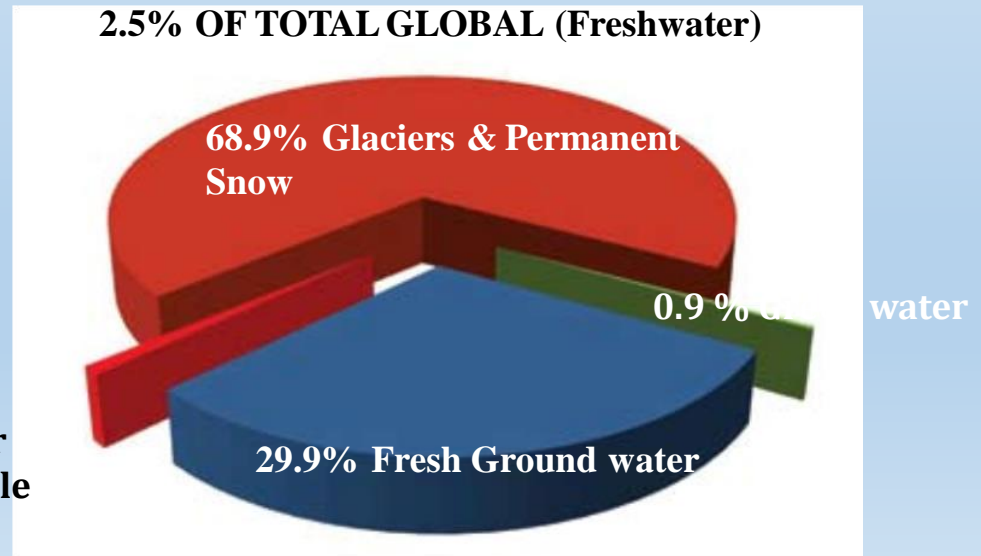
Includes more coordinated development and management of:

- Land and water,
- Surface water and groundwater,
- The river basins and its adjacent environment,
- Upstream and downstream interests (including human systems).

IWRM is therefore a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives. IWRM can provide solution to growing problem of water scarcity

- **Freshwater is limited and not evenly distributed**
- **Climate change, growing demand and management uncertainties causing **water scarcity** in different areas at different levels**

0.3% Freshwater Lakes and River Storage (Renewable in manageable time scale)



Addressing water scarcity with Integrated Water Management (IWRM)

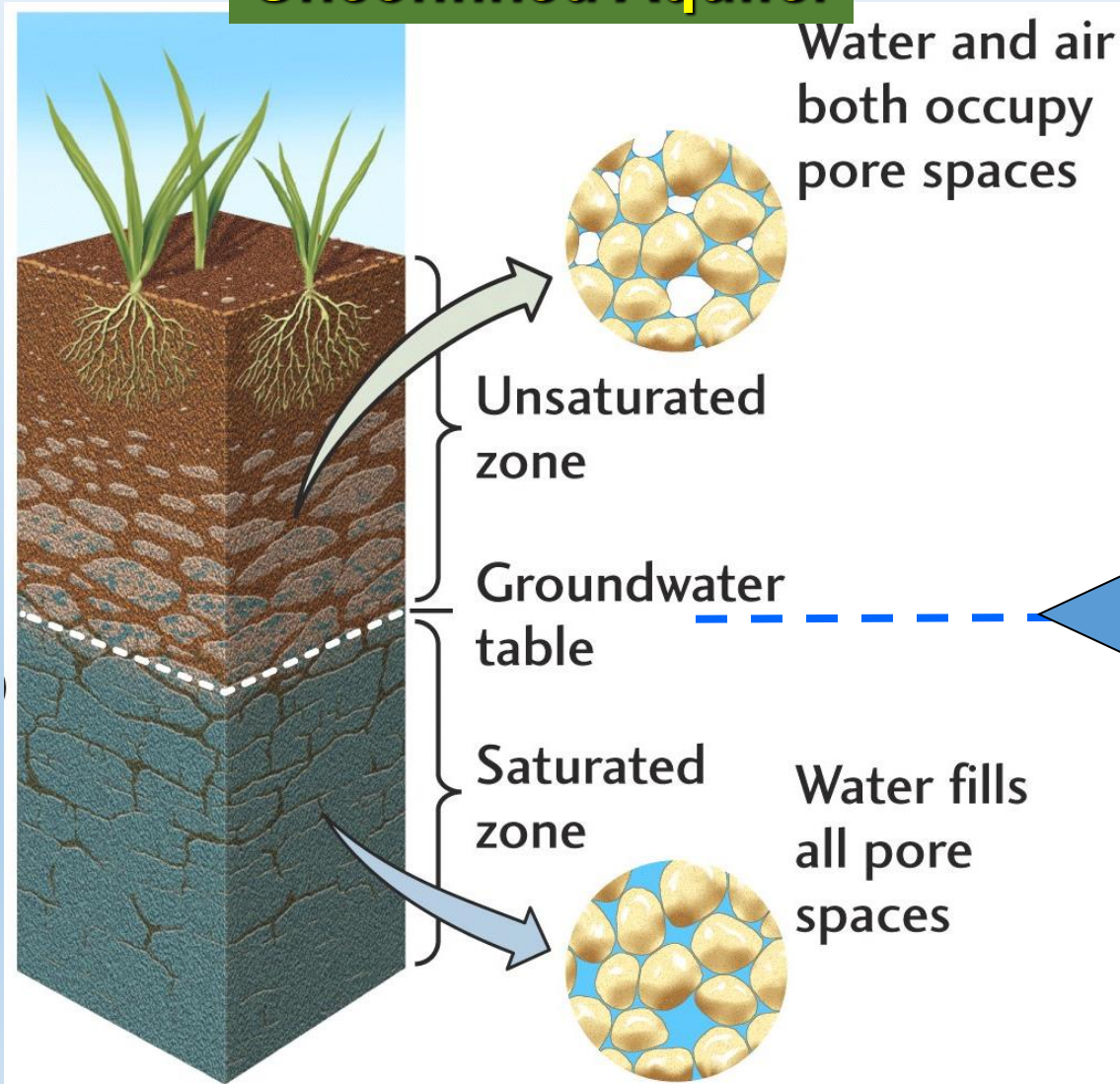
IWRM approach recognizes that:

- **Water is a finite and vulnerable resource;**
- **Water is an economic good;**
- **Women play a central part in the management of water;**
- **Water development and management should be based on a participatory approach**

Ground Water Management: Characterization of Aquifers

An aquifer is defined as a geologic formation (single layer or group of layers) that can store and yield a significant quantity of water.

Unconfined Aquifer



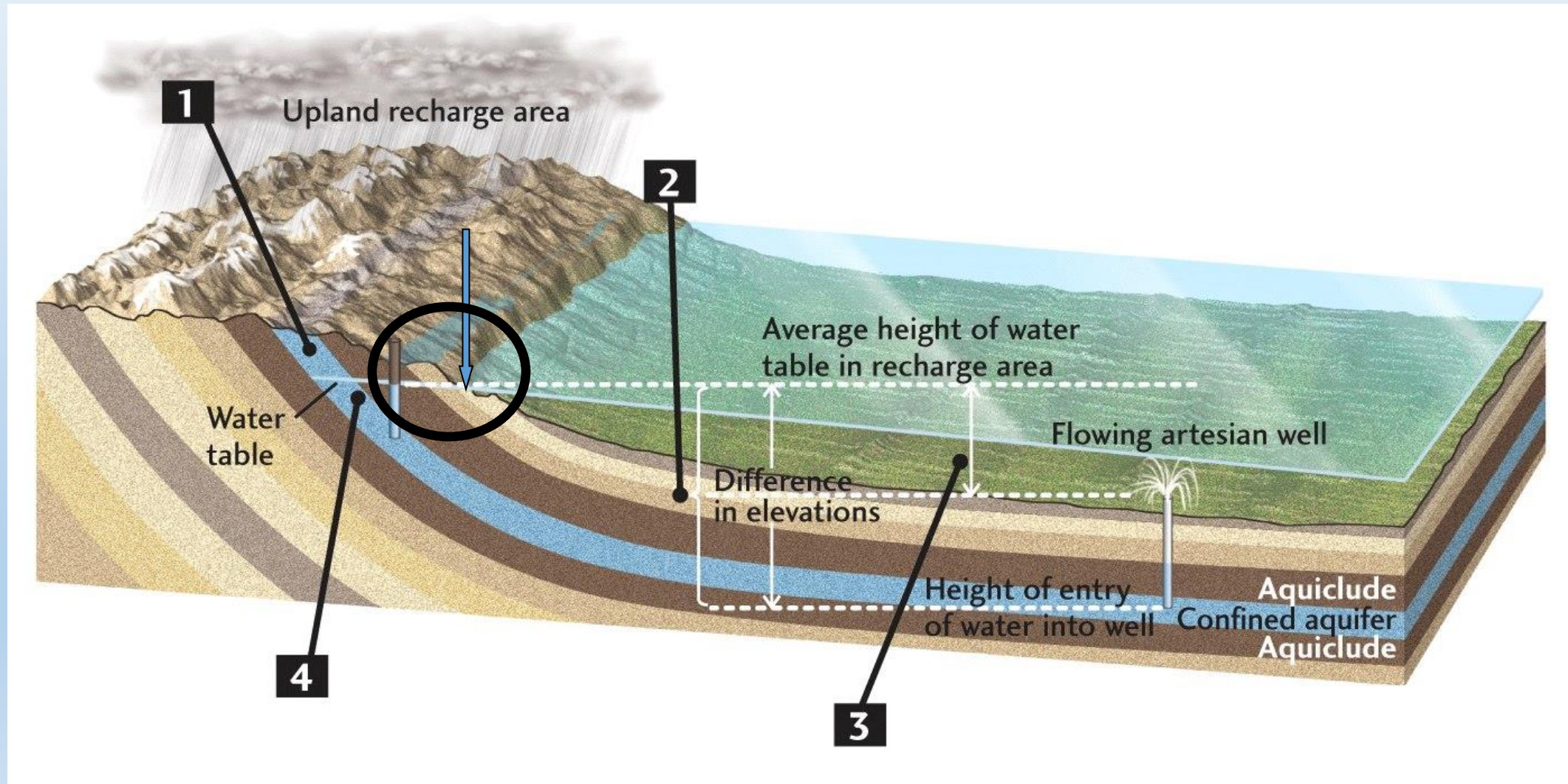
Good aquifers are those with high permeability such as sands, gravels, and sandstones or highly fractured rock; they can be excellent sources of water for human usage.

Groundwater Table

Two types of aquifers are Unconfined and Confined.

Recharge in a Confined Aquifer

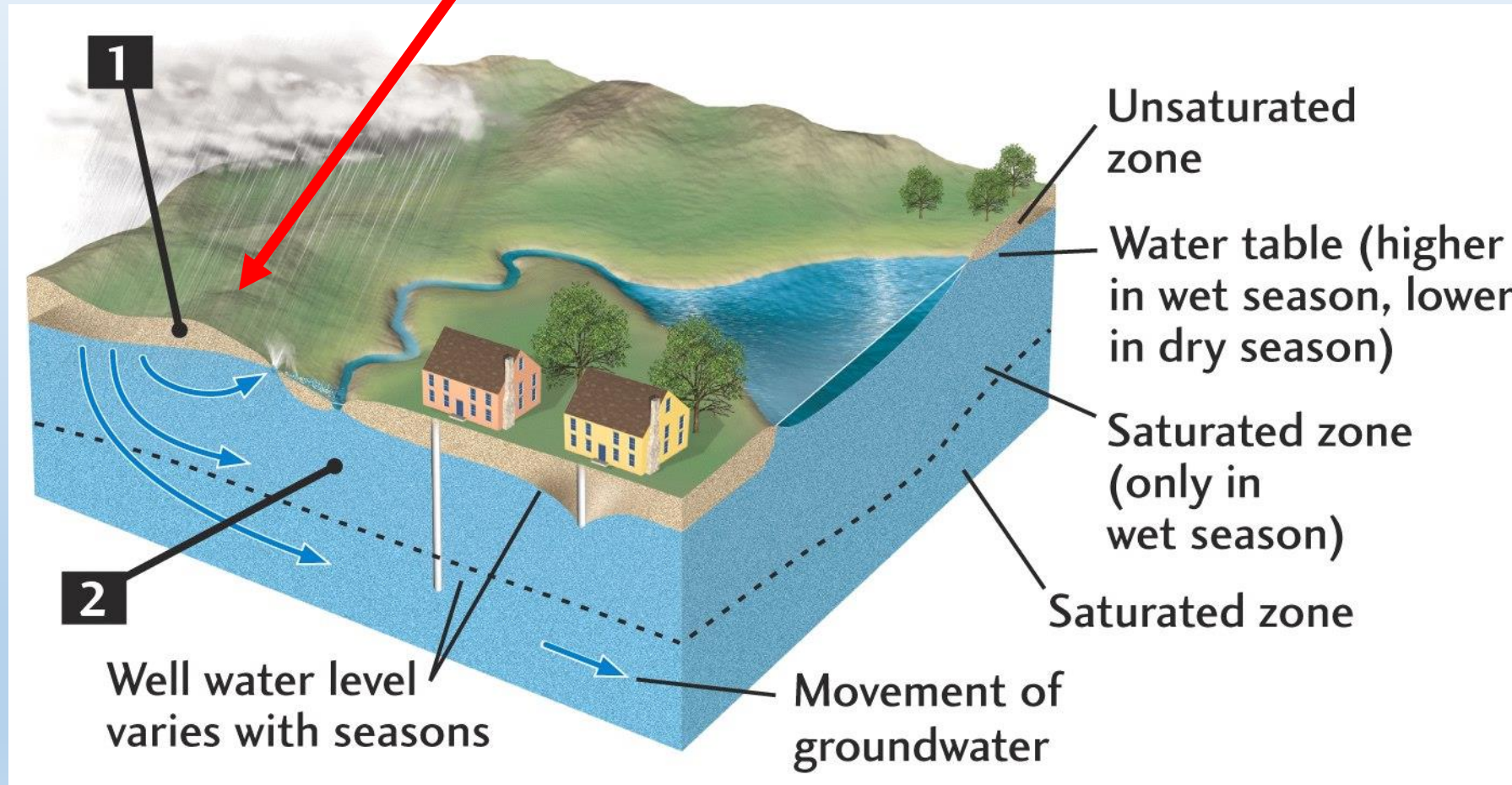
Recharge Area: where the confined aquifer is recharged by infiltration



Dynamics of an Unconfined Aquifer

Aquifers are typically recharged by natural rainfall entering the soil profile and leaching into deeper soil layers.

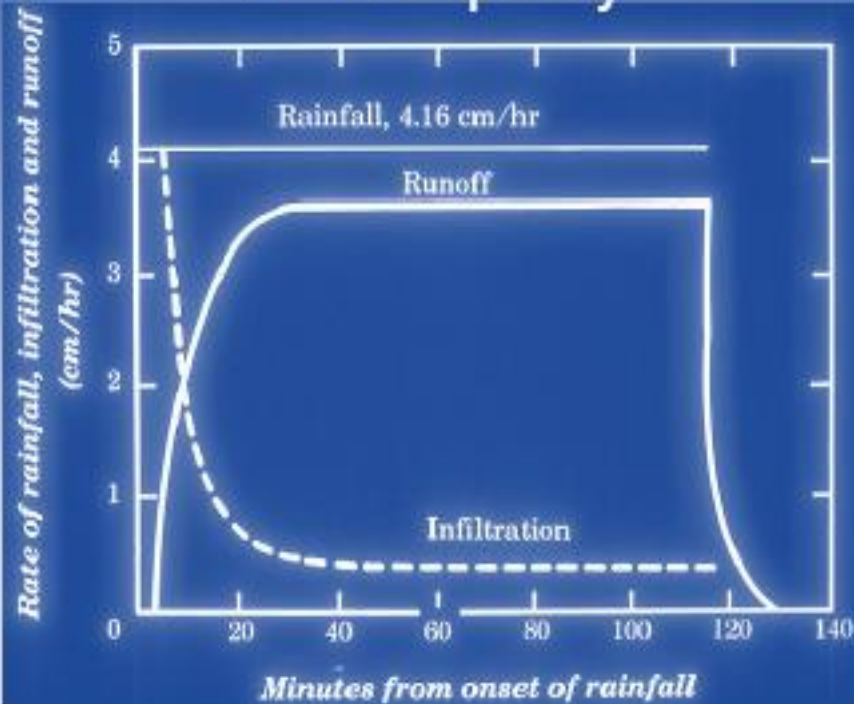
Rainwater infiltrates porous soil & rocks



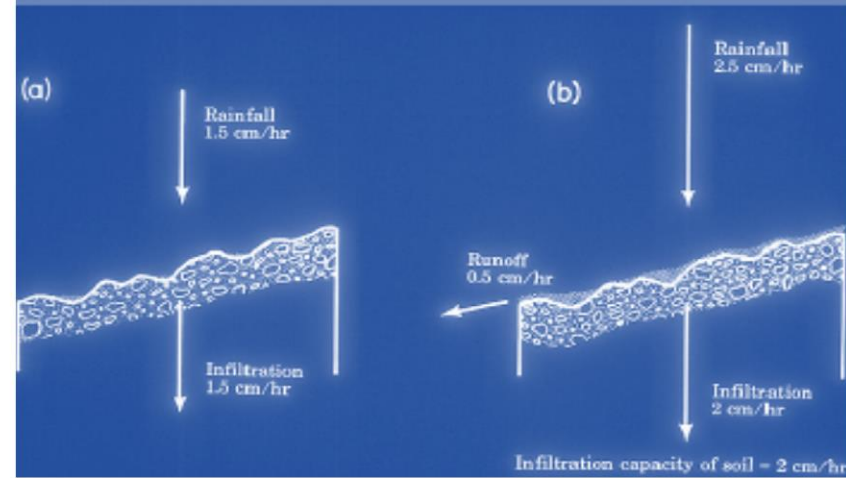
... and flows underground towards lakes and streams.

Water transport and storage in Unconfined Aquifers

Field Capacity



Infiltration

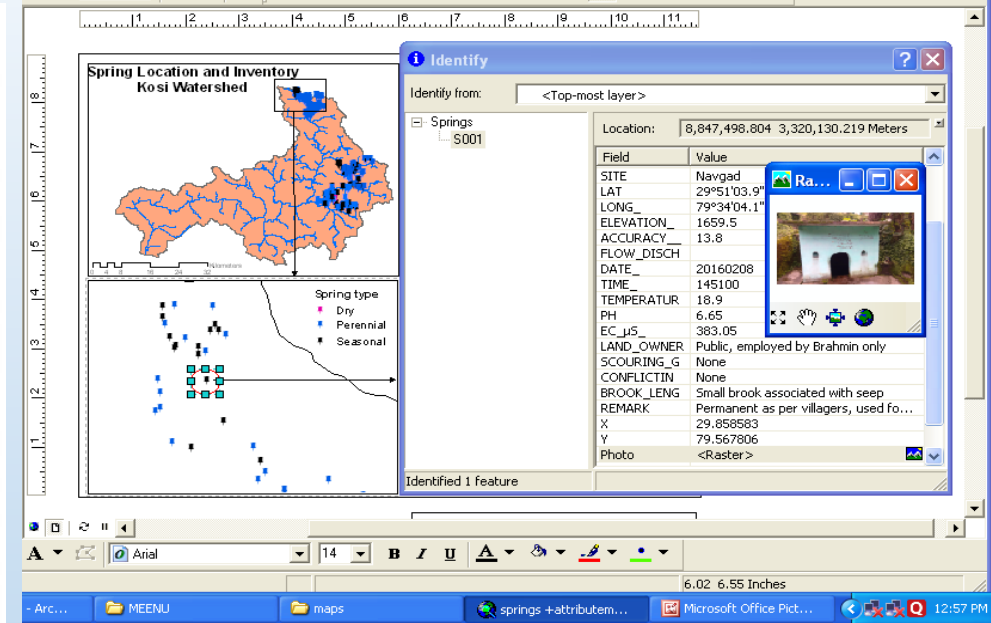
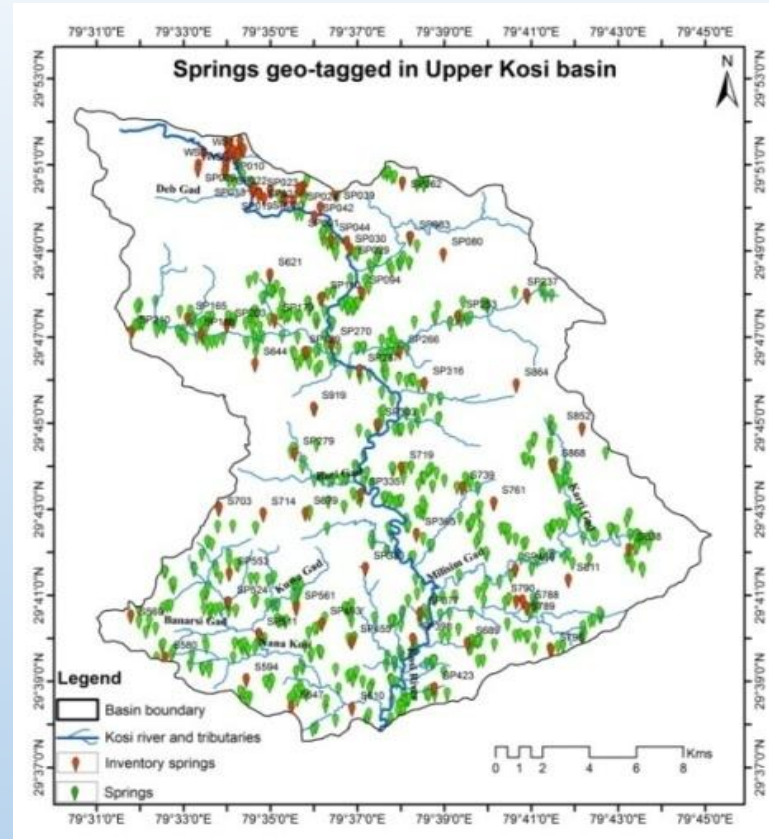
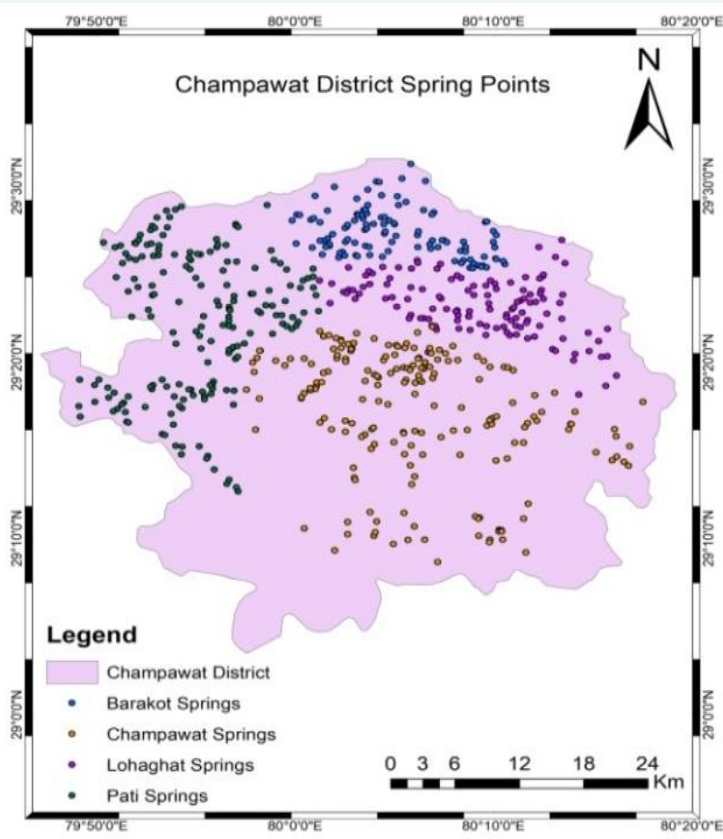


Infiltration

Entry is the result of gravity & capillary action

- Rate limited by pore diameters (soil type)
- Capillary action may move water up or down

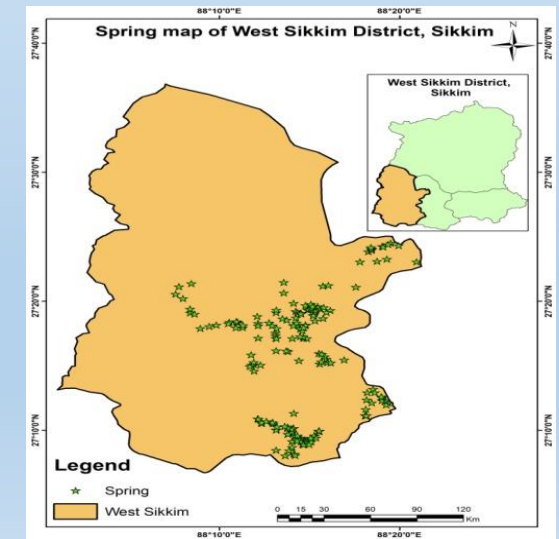
Baseline data: Creation of Springs Inventory under NMHS



Spring Inventory and geo-tagging in Uttarakhand

Outputs:

- ✓ Status of **4000+** springs inventoried and geo-tagged in 11 IHR states & 01 UT
 - **1500+** springs geo-tagged and inventoried in the Uttarakhand.
 - **944** and **668** springs in Sikkim and Himachal Pradesh, respectively.
- ✓ **120+** Spring sanctuary models developed for revival of critical springs in the IHR



Spring Inventory and geo-tagging in Sikkim

Options: Source Selection Criteria for Treatment

- Sources having extreme fluctuations (i.e. discharge falling by more than 25 % in summer in last 3-5 years)
- Discharge fluctuations with respect to monsoon rainfall exceeding mean \pm SD values
- Spring should have scope (large area with favorable geology and slope) for catchment area conservation and management for its sustenance.
- Villagers should be willing for participation for catchment area conservation and management



Identification of Recharge Area for Treatment

1. Identification of catchment area to draw subwatershed and micro-catchment maps
 - Use of Toposheet/Remote sensing data/available maps (1:25000 scale)

1-2 days per source

2. Geological mapping of the catchment area to delineate recharge zone /treatment zone
 - a. Types of rocks using existing geological maps (1:25000 scale) - Igneous/Sedimentary/Metamorphic

 - b. Type of structures

Bedding Plane:	Inclination of bedding plane	←	2- 3 days per catchment
Fault/thrust	: Presence of major structure		
Joint	: Network/type/pattern of joint plane		
Porosity/Permeability:	Presence of porosity/permeability		
Lineaments	: Type of lineament		
Aquifer condition:	Confined/ unconfined		

3. Type of spring to decide the interventions

Seasonal :	Colluvial/ fluvial
Perennial :	Structurally controlled

4. Identification of feasible location of recharge zone based on the detail mapping to decide net area for treatment

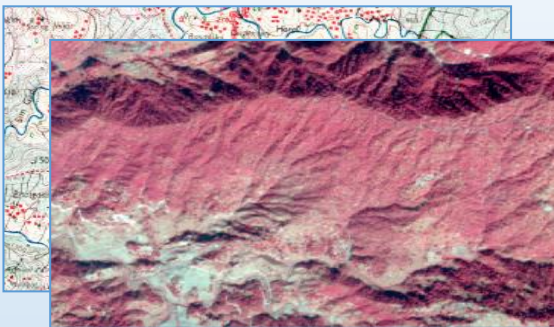
1-2 days per catchment

5. Hydrogeomorphic conditions (fine resolution 1:10000 or higher) to design interventions

Slope	: Slope condition	Using GPS surveys	2-3 days per catchment
Drainage	: Drainage network		
Terrain	: Terrain condition		
Soil erosion/Landslide:	Present status of erosion/landslide in the catchment		
Soil map	: Soil thickness/texture/type (qualitative		

Approach for Groundwater Recharge Potential & Recharge Structure Suitability

Input data



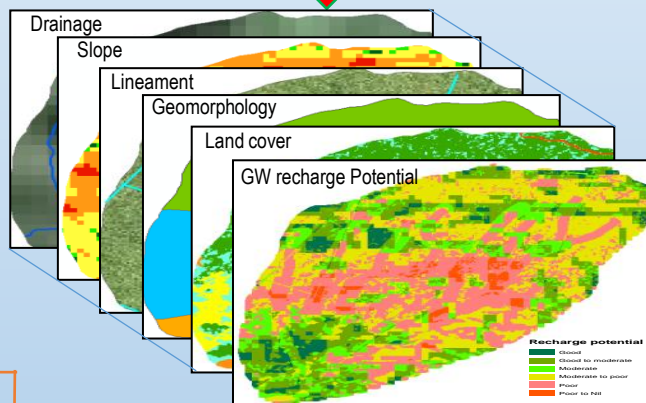
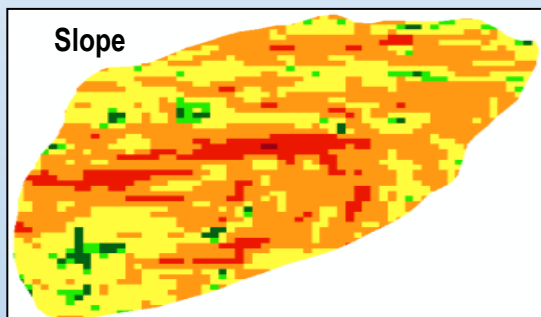
Ranking, scoring and weightage



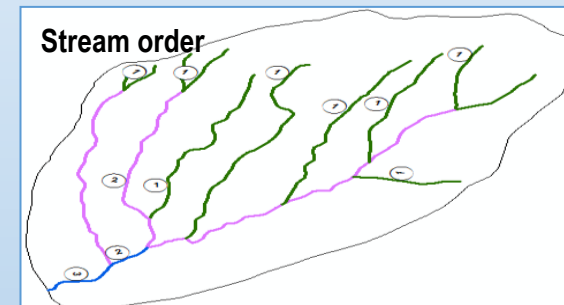
Expert discussion and decision



Slope

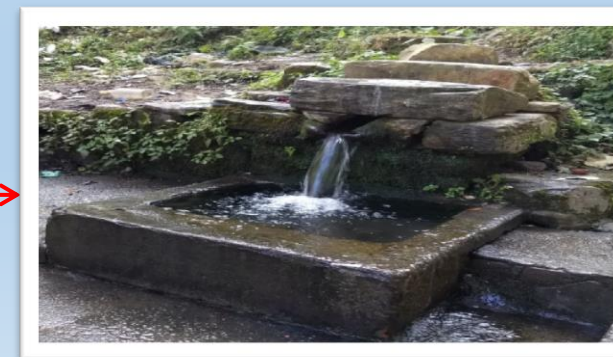
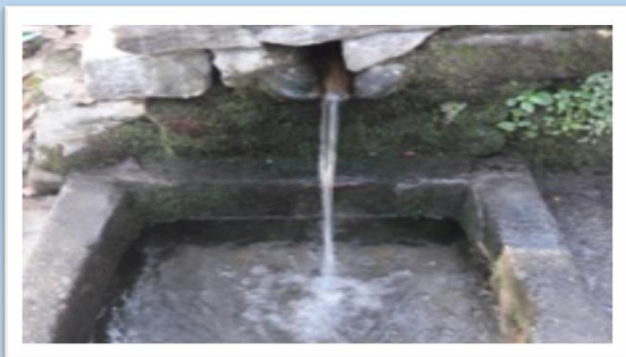


Stream order



Recharge and Conservation Site Suitability Tool (RCSST)

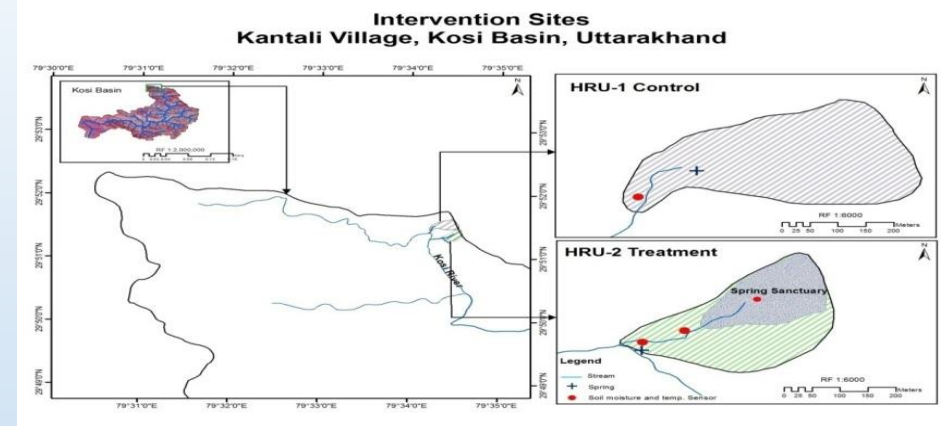
Groundwater Augmentation Structure



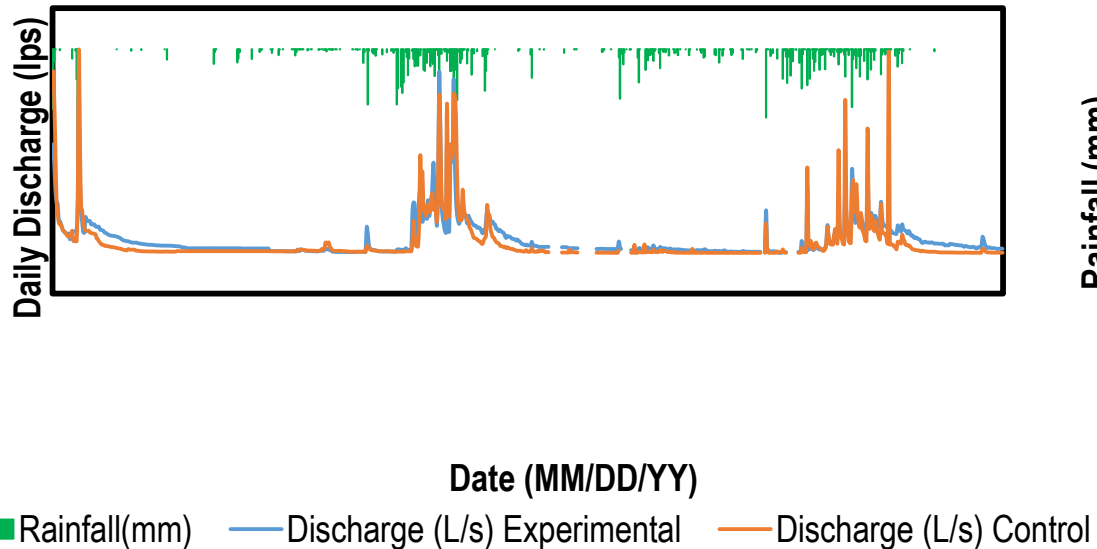
Intervention and Outputs in Kantali Site, Almora, Uttarakhand

Site details and interventions taken for spring sanctuary development

Site name	Coordinates	Interventions taken (in Nos.)	Intervention area
Kantali (Uttarakhand)	29°51'19.0"N 79°34'13.7"E	Contour Trenches = 600 Recharge Pits = 4 Conical Ponds = 6 Bioengineering structures (Live check dams)	0.05 km ² (5 ha)



Variation of Daily Discharge of Control and Experimental Spring with Rainfall
Intervention Site: Kantali, Kausani
Period: 01 Sept.-17 to 31 Dec.-19



Rainfall (mm)



Figure: Kantali site and Contour trenches as a part of spring sanctuary in the catchment

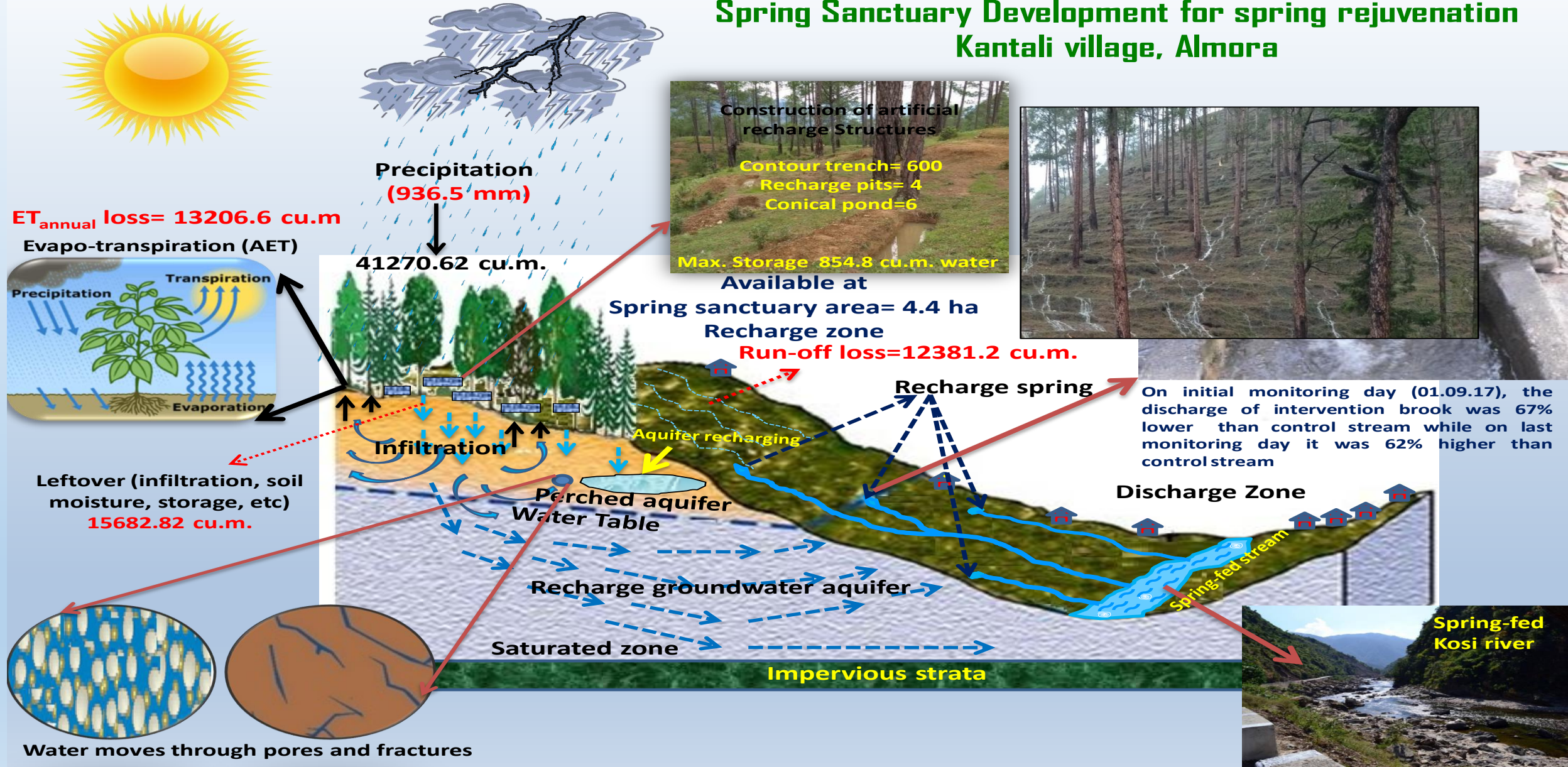
Impact:

- Initially, the discharge of the control and experimental spring was 5346 and 3192 lpm, respectively.
- During the lean month of march 2018, discharge at the control spring was 4.8 lpm, which was lower than the discharge at the experimental spring (7.4 lpm).
- Slower recession rate was observed after the groundwater augmentation measures were taken at the experimental site, highlighting groundwater recharge success.

Figure: Spring discharge of experimental and control spring in Kantali Site, Almora

Intervention and Outputs in Kantali Site, Almora, Uttarakhand

Spring Sanctuary Development for spring rejuvenation Kantali village, Almora



Intervention and Outputs in Silangiya Site, Almora, Uttarakhand

Site details and interventions taken for spring sanctuary development

Site name	Coordinates	Interventions taken (in Nos.)	Intervention area
Silangiya (Uttarkhand)	29°43'28.2"N 79°39'24.5"E	Contour Trenches = 500 Bioengineering structures (live check dams)	0.05 km ² (5 ha)

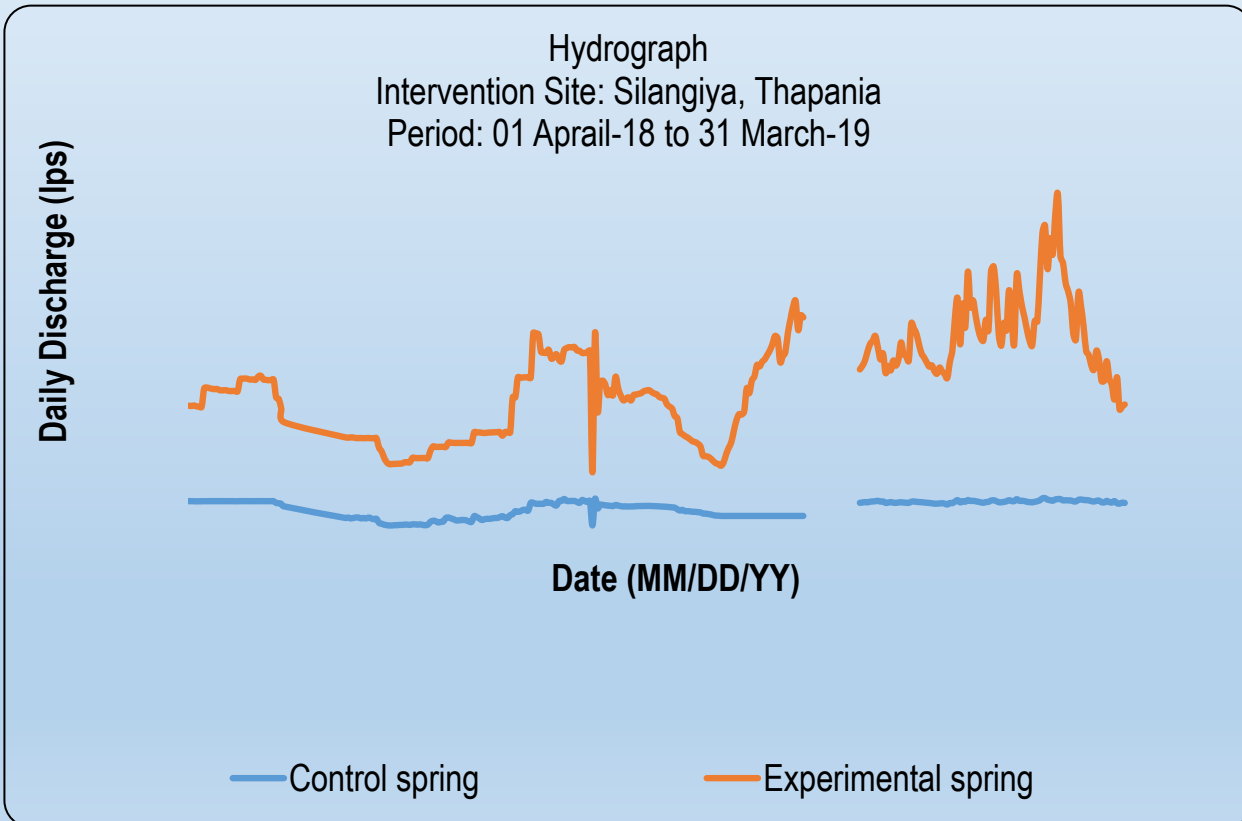
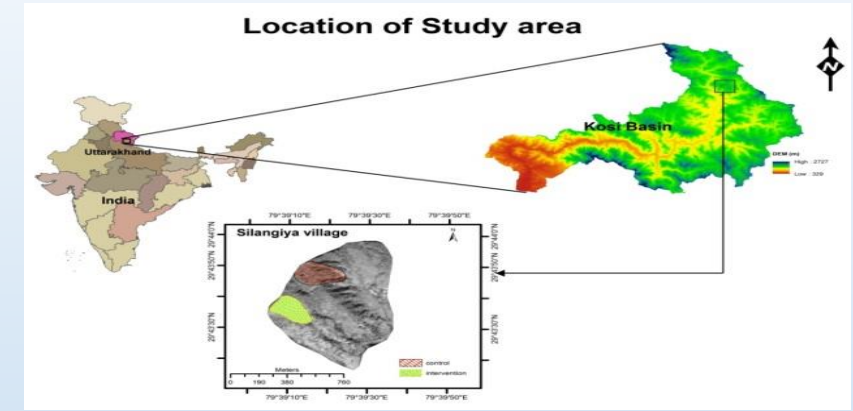


Figure: Spring discharge of experimental and control spring in Silangiya Site, Almora



Figure: Control and Experimental spring at Silangiya, Almora

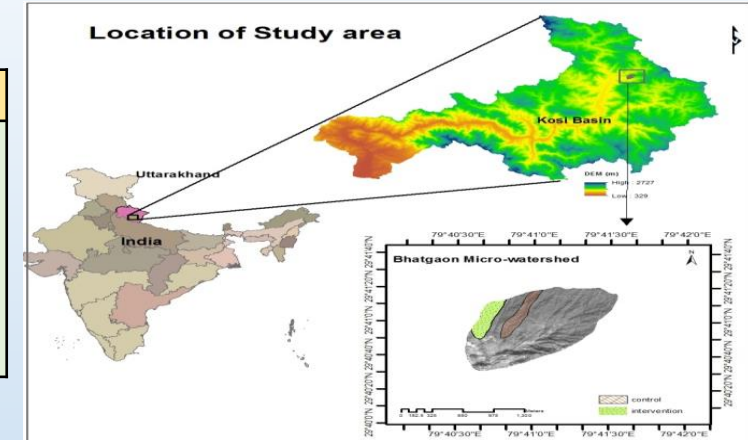
Impact:

- The difference between the experimental and control spring discharge on the initial monitoring days in lean month was 0.87 lpm which increased to 3.402 lpm on 31 Mar 2018.
- The tremendous increase in water discharge at the experimental spring (average 3.06 lpm before monsoon to 4.44 lpm after monsoon) as compared to the control spring (average 1.03 lpm before monsoon to 1.04 lpm after monsoon) reflects the success of the model.

Intervention and Outputs in Bhatgaon Site, Almora, Uttarakhand

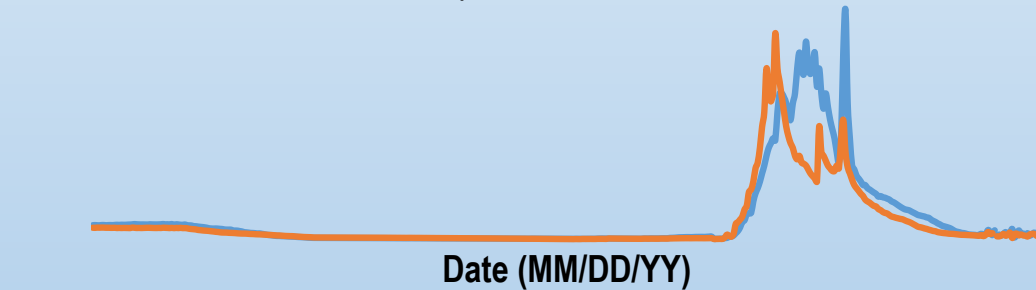
Site details and interventions taken for spring sanctuary development

Site name	Coordinates	Interventions taken (in Nos.)	Intervention area
Bhatgaon (Uttarakhand)	29°40'84.5"N 79°40'64.9"E	Contour Trenches = 500 Recharge Pits = 4 Permanent Check Dam = 1 Bioengineering Measures Plantations = 700	0.06 km ² (6 ha)



Hydrograph: Experimental and Control Spring
Intervention Site: Bhatgaon (Takula)
Period: 21 Sep-17 to 30 Nov-18

Daily Discharge (lps)



— Discharge-Experimental (L/s)

— Discharge-Control (L/s)

Figure: Spring discharge of experimental and control spring in Bhatgaon Site, Almora

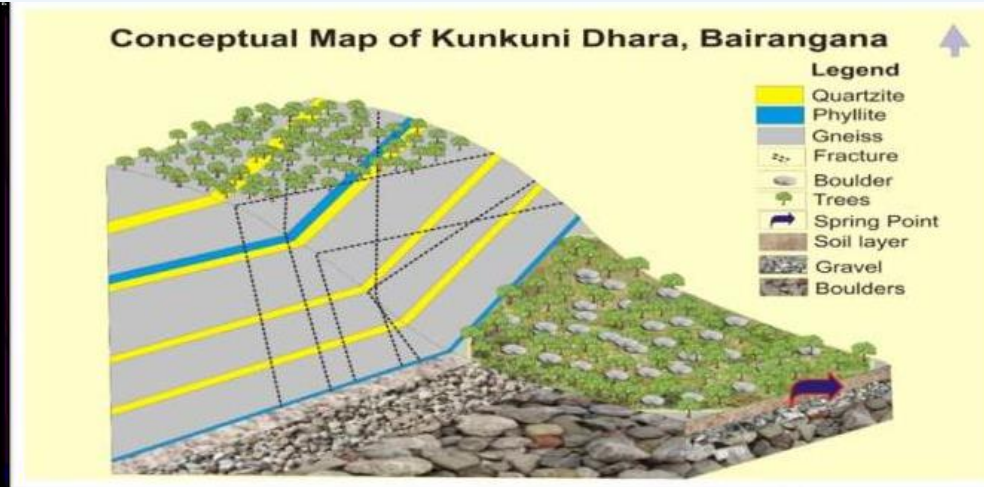
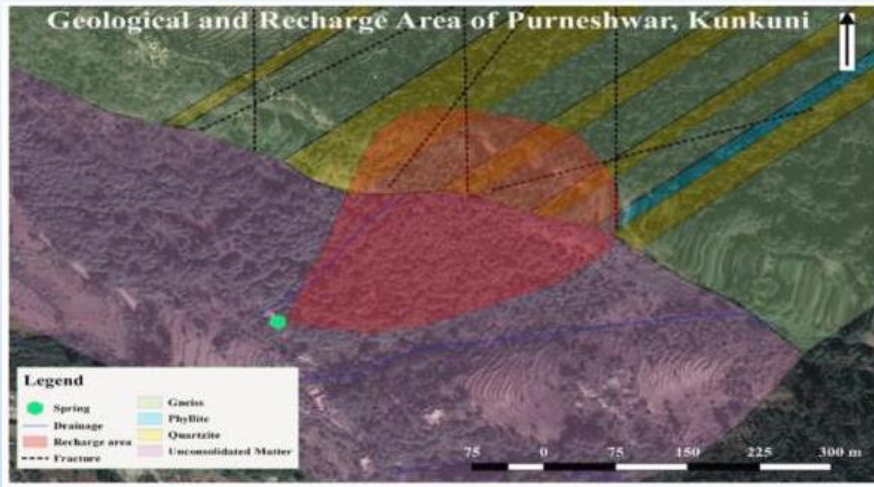


Figure: Control and Experimental spring at Bhatgaon, Almora

Impact:

- Average discharge data of the experimental and control springs was 1.44 lpm and 1.14 lpm, respectively during post-monsoon 2017, 0.54 lpm at both springs during winter 2018, 0.36 lpm in summer 2018.
- Clear evidence of less recession in experimental spring since discharge difference was observed as zero(0).
- During the 2018 monsoon season average discharge of exp. spring was more as compared to control spring.

Intervention and Outputs in Purneshwar Spring, Kunkali, Chamoli, Uttarakhand



Geological & recharge map of Purneshwar Spring, Kunkali

Conceptual layout map of Purneshwar Spring, Kunkali

Site details and interventions taken for spring sanctuary development

Site name	Coordinates	Interventions taken (in Nos.)	Intervention area
Purneshwar Spring, Kunkali (Uttarakhand)	30°27'14.832"N 79°17'24.036"E	Khals (Village ponds) = 2 Drainage of Khals = 2 Percolation Pits = 610 Plantation = 500 Source Repair Work = 1	0.084 km ² (8.4 ha)

Impact:

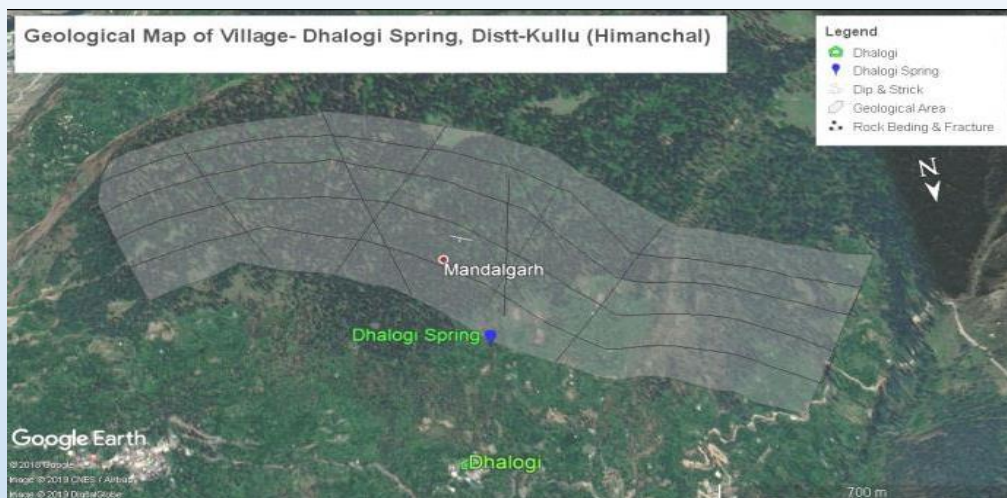
Average spring discharge (lpm) pre and post Implementation

Before intervention (pre implementation)	0 lpm, April 2019 (Dry Spring)
After intervention (post implementation)	10.5 lpm, March 2020

Impact:

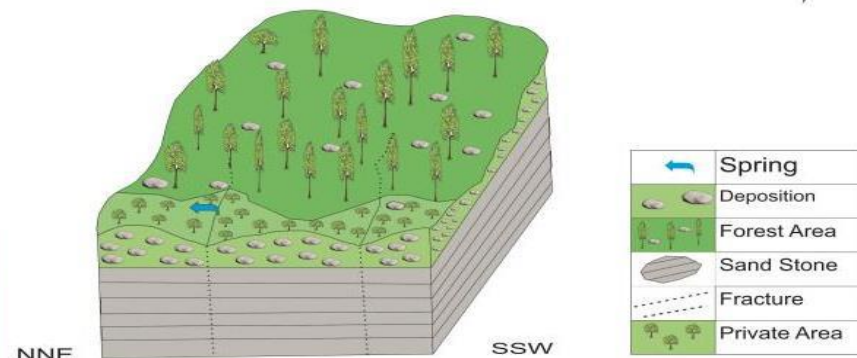
- Results in terms of spring discharge increase were very prominent and observable.
- Dry Spring in the lean month of April 2019, resulted in revitalized and free flowing spring after implementation of the spring sanctuary concept in the lean month March 2020 with the average discharge of 10.5 lpm

Intervention and Outputs in Dhalogi Spring, Himachal Pradesh



Geological & recharge map of Dhalogi village spring

Conceptual Layout of Dhalogi Village Spring



Conceptual layout map of Dhalogi village spring

Site details and interventions taken for spring sanctuary development

Site name	Coordinates	Interventions taken (in Nos.)	Intervention area
Dhalogi (Himachal Pradesh)	32°5'8.0556"N 77°5'44.322"E	Khals (Village ponds) = 5 Contour Trenches = 1000 Percolation Pits = 1038 Plantations = 1000 Deep Recharge Pits = 150	0.082 km ² (8.2 ha)

Impact:

Average spring discharge (lpm) pre and post Implementation

Before intervention (pre implementation)	5 lpm May 2019
After intervention (post implementation)	28.5 lpm, March 2020

Impact:

- Before the intervention, the average daily discharge was 5 lpm in may 2020 and increased to 28.5 lpm in april 2020 after the interventions were made.
- The spring sanctuary development was successful, and similar models are now being implemented in other water-scarce blocks of Himachal Pradesh under the Jal Abhyaranya program of the MoEF&CC.

Intervention and Outputs in Sumbuk Kamerey, Sikkim

Site details and interventions taken for spring sanctuary development

Site name	Coordinates	Interventions taken (in Nos.)	Intervention area
Sumbuk Kamerey (Sikkim)	27°10'01"N 88°21'56"E	Staggered contour trenches	0.13 km ² (13 ha)

Approach and Impact:

- Geo-hydrological methods and recharge structures applied to develop sanctuaries around the five springs in Sumbuk Kamerey, Sikkim.
- Sumbuk Malagiri Dhara catchment area of 13 hectares treated using staggered contour trenches as a spring sanctuary development plan.
- Increase in spring discharge in the lean season (March-April), from 4.4 to 14.4 lpm.
- Geo-hydrological approaches proved that artificial rainwater harvesting for recharging the local region can enhance the natural recharge of the spring aquifer.
- People in Lunchok Kameray also reported higher discharge rates from several springs in the area during the lean months, reducing the water issues in the region.



Malagiri spring, Sumbuk and agroforestry development in the spring catchments

Revival of Dried Lakes: Aaley-Gairi and Sherpatar, as a part of Spring Sanctuary Development in East Sikkim

Location: 27°13'4.629"N, 88°32'28.427"E



Dried lake, Aaley-Gairi, East Sikkim



During Intervention



Post Intervention

Impact post intervention:

- Total Capacity: 2073.54 m³
- Water Stored: 816.35 m³, July 2021
- Recharging Source: 21 springs downstream
- Beneficiaries: 935 households (4675 persons)

Location: 27°13'12.81"N, 88°31'15.030"E



Dried lake, Sherpatar, East Sikkim



During Intervention



Post Intervention

Impact Post Intervention:

- Total Capacity: 3584.79 m³
- Water Stored: 90 - 112.8 m³, July-Sep, 2021
- Recharging Source: 39 perennial springs
- Beneficiaries: 1118 households (5035 persons) and floating population around 200-450

Approx. Cost of Spring (Water) Sanctuary Developed in 5 Ha

S#	Particulars	Unit Rate (INR)	Number	Total Cost (INR)
A. Water Conservation Activities in Recharging Zone				
1	Plantation Works	21362 (250 Plants/ha)	1250 Plants (e.g. Baanj, Bamboo, and other suitable sp.)	106,810
2	Maintenance of plantations	9754/ha	5 times	48,770
3	Contour Trenching (Nos) (2.00*0.45*0.45 m)	108	1000	1,08,000
4	Percolation Tanks (nos) (2.00*1.00*1.00 m)	536.20	50	26,800
5	Impervious Check Dams (40 cum)	6232	40	2,49,280
6	R.R Dry Check Dams (75 Cum)	1890	75	1,41,750
7	Vegetation Check Dams (1m height)	735	300	2,20,500
8	Mud/Stone build bunds/Gully Plug (nos)	5000	25	1,25,000
9	Conical ponds (0.85m depth and 5 m radius)/ Trapezoidal Ponds (8*4.2/3*1.2m)	11,600	10	1,16,000
10	Barbed Wire Fencing (rm)	140	5 000meter	7,00,000
Total				18,42,910
B. Monitoring of Hydrological Parameters				
11	Rain Gauges	28000	3	84,000
12	Soil Moisture Sensors	120500	3	3,61,500
13	Water level recorder	90000	1	90,000
Total				5,35,500
C. Miscellaneous				
15	Miscellaneous activities (Awareness programme; Watch & Ward)			1,20,000
Grand Total (A+B+C)				24,98,410 (say 25 Lakh)

Conclusions and Way forward

- Watershed interventions can aid in augmenting spring discharge. However, site-specific data are needed to implement successful watershed interventions. In particular, interventions to combat decreases in spring recharge involve detailed field investigations with hydrogeological maps and conceptual and mathematical models. In the current analysis, all pilot studies urged the need for active community participation in spring protection and recommended interventions such as artificial rainwater harvesting measures, afforestation, and demarcation and protection of recharge zones from human activity.
- Sustainable water resource management and adaptation to climate change were achieved by the pilot-level implementation of the groundwater augmentation structures, demonstrating the efficacy of the concept in restoring the springshed and revitalizing the drying springs.
- Spring sanctuary development must be included in updated versions of previously established watershed management guidelines, plans, and policies. We must reevaluate and refocus our development priorities and efforts to make “springshed management” a top priority in the IHR.
- Synergizing with local and state social and scientific organizations is essential, as is guaranteeing gender equality and social involvement. Some examples of the recent effective techniques are the Spring Sanctuary Development in Uttarakhand, Sikkim, and Himachal Pradesh. These initiatives began in the few water-scarce blocks of the IHR and are now on a large-scale Aspirational District in each State/UT of the IHR have been selected for the replication and upscaling towards enhancing the socio-ecological resilience of mountain communities.
- Considering this, a source centred approach of Water Sanctuaries (Jal Abhyaranya) incorporating integrated bio-physical and social measures for rain water harvesting, can provide viable solutions to water sustainability of the region.
- The groundwater modelling under changing land use and climate change has proven very effective and useful for conservation and management of water resource.
- Precise selection/identification of recharge area/springshed and systematic designing of recharge structures can be effective way of rejuvenating the drying springs and spring-fed systems.



Thanks...

Methodology and approach for implementing the Spring sanctuary development in the IHR

- Under the National Mission on Himalayan Studies scheme, many pilot projects are being implemented focusing on water security issues and the rejuvenation of springs in the Indian Himalayan Region (IHR).
- Completed case studies under the NMHS scheme from the three IHR states, Uttarakhand, Sikkim, and Himachal Pradesh covered in this paper.
- In all the pilot studies, the project approach has entailed a village-by-village survey of springs, mapping, and developing a geo-database followed by hydrological modeling and impact assessment.
- The study area also performed the physiochemical features of spring water and isotope analysis and the selection of springs for long-term monitoring and seasonal change evaluation.
- Finally, an improved hydrological modeling technique were used to verify the feasibility of a land use model developed for the spring sanctuary.
- The concept of spring sanctuary development was tested by implementing groundwater augmentation measures at the intervention sites.
- The groundwater augmentation measures like contour trenches, recharge pits, conical-shaped ponds, masonry/live check dams, gabion structures, and plantations were implemented after identifying the recharge zone of the springs in the pilot sites in three IHR states viz. Uttarakhand, Himachal Pradesh and Sikkim.