(Thematic Study - V)

Water Conservation and Harvesting Strategies

A Study of Indian Himalayan Region (IHR)

assigned by

सत्यमेव जयते

NITI AAYOG, New Delhi

funded by

ज्ञान–विज्ञान विमुक्तये

UGC, New Delhi

February, 2022

Submitted by

Indian Himalayan Central Universities Consortium (IHCUC)

NITI Aayog

Project Report

on

Water Conservation and Harvesting Strategies

(Theme – V)

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Indian Himalayan Central

Universities Consortium (IHCUC)

Consolidated and prepared by

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INDIAN HIMALAYAN

CENTRAL UNIVERSITIES CONSORTIUM

(IHCUC)

Himalaya is the youngest and most sensitive mountain chain, having more than 15 thousand glaciers spread over 12 thousand square kilometers. Himalaya is a unique gift of nature for its freshwater, range of medicinal plants and biodiversity for humanity. Though the Himalayas are strategically important and a natural tool for climatic control, the recent rise in extreme natural events, depletion of natural resources, loss of livelihood, increasing natural disasters, and excessive migration of people to plain regions for livelihood and safety have raised an alarming concern for future generations. The Himalaya itself has been bleeding over the years due to various natural and anthropogenic factors, but the inhabitants living in this large Indian Himalayan Region (IHR) are now also paying the price of this damage. These problems are getting more complex with time. Therefore, to find a more humanistic solution, the concept of Indian Himalayan Central Universities' Consortium (IHCUC) was propagated by the HNB Garhwal University, Srinagar, Garhwal, Uttarakhand, in 2019 in the presence of India's National Security Advisor, Shri AjitDoval, Kirti Chakra, Former Union Minister of Education, Shri Ramesh Pokhriyal "Nishank" and the Chancellor of the HNB Garhwal University, Dr. YogendraNarain. The aim was to form a multi-institutional forum to develop joint multidisciplinary research and share knowledge and experiences on migration, employment, agroecology, tourism, and other common problems and resolution. In December 2019, in a meeting of four Vice-Chancellors, Professor AvinashKhare, VC Sikkim University, Professor S.K. Srivastava, VC NEHU, Professor D.C. Nath, VC, Assam (Silchar) University and Professor Annpurna Nautiyal, VC, HNB Garhwal University with the

Vice Chairman of NITI Aayog Dr. Rajiv Kumar, the IHCUC formalized its aims and objectives by agreeing to work on five thematic studies on *'Enumeration and Valuation of the Economic Impact of Female Labour in the Hills'*, *'Agroecology in the Himalayan States with special emphasis on Marketing'*, *'Development of Eco-Friendly and Cost-Effective Tourism in Hills'*, *'Opportunities of Livelihood to check Migration from Hills'*, and *'Water Conservation and Harvesting Strategies*'. After a meeting with the Vice-Chancellors of 12 Central Universities of IHR and the Director of CSIR-IHBT in January 2020, under the chairmanship of Dr. Rajiv Kumar, Vice Chairman, NITI Aayog, the IHCUC was officially launched by the NITI Aayog. With the sponsorship of NITI Aayog and the Ministry of Education, Government of India a grant of Rs. 2 Cr was allocated by the University Grants Commission, New Delhi, to work on the above thematic areas under the coordinator ship of Professor Annpurna Nautiyal, Vice-Chancellor, HNB Garhwal University, Srinagar, Garhwal, Uttarakhand. Her vision, sharing thoughts on each report with the teams, constant interest, dialogue, leadership role and a good coordination with all the Vice Chancellors as institutional partners and their team coordinators and members as well as the officials of the NITI Aayog and UGC helped immensely in the finalization of these reports. The inputs and suggestions provided from Dr. V.K. Saraswat, member NITI Aayog, CEO Shri Amitabh Kant and senior advisors Dr. Neelam Patel and Shri Avinash Mishra and others were very helpful in preparing the final report. The COVID-19 Pandemic hampered the pace of work, but now the five reports on the five thematic areas which have been consolidated and compiled by the team members of the HNB Garhwal University, are being presented to the NITI Aayog. This marathon exercise of submission of productive reports in each area became possible only with the support and inputs of the team members of the partner institutions representing their institutions and also on account of their Vice Chancellors' active interest in motivating their team members in the capacity of the main institutional Coordinator for each institution of the IHCUC.

Structure and Main Institutional Coordinators of IHCUC

<table>
<tr><th>Name</th><th>(IHCUC)</th><th>Designation</th><th>Institution Represented</th></tr>
<tr><td>Professor Annpurna Nautiyal</td><td>Convener &Chief Coordinator of IHCUC</td><td>Vice Chancellor</td><td>H.N.B. Garhwal University, Uttarakhand</td></tr>
<tr><td>Professor Avinash Khare</td><td>Coordinator</td><td>Vice Chancellor</td><td>Sikkim University, Sikkim</td></tr>
<tr><td>Professor V. K. Jain</td><td>Coordinator</td><td>Vice Chancellor</td><td>Tezpur University</td></tr>
<tr><td>Professor Saket Kushwaha</td><td>Coordinator</td><td>Vice Chancellor</td><td>Rajiv Gandhi University Arunachal Pradesh</td></tr>
<tr><td>Professor Pardeshi Lal</td><td>Coordinator</td><td>Vice Chancellor</td><td>Nagaland University</td></tr>
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<tr><td>Professor K.R.S. Sambasiva Rao</td><td>Coordinator</td><td>Vice Chancellor</td><td>Mizoram University</td></tr>
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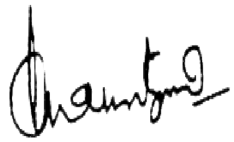
<tr><td>Professor Prabha Shankar Shukla</td><td>Present Vice Chancellor</td></tr>
<tr><td>Professor Mehraj-ud-Din Mir</td><td rowspan="2">Coordinator</td><td>Former Vice Chancellor</td><td rowspan="2">Central University of Kashmir</td></tr>
<tr><td>Professor Farooq A. Shah</td><td>Present Vice Chancellor</td></tr>
<tr><td>Professor Ashok Aima</td><td rowspan="2">Coordinator</td><td>Former Vice Chancellor</td><td rowspan="2">Central University of Jammu</td></tr>
<tr><td>Professor Sanjiv Jain</td><td>Present Vice Chancellor</td></tr>
<tr><td>Prof. Kuldeep Agnihotri</td><td rowspan="2">Coordinator</td><td>Former Vice Chancellor</td><td rowspan="2">Central University of Himachal Pradesh, Dharmshala</td></tr>
<tr><td>Professor Sat Prakash Bansal</td><td>Present Vice Chancellor</td></tr>
<tr><td>Professor D.C Nath</td><td rowspan="2">Coordinator</td><td>Former Vice Chancellor</td><td rowspan="2">Assam University Silchar</td></tr>
<tr><td>Professor R.M. Pant</td><td>Present Vice Chancellor</td></tr>
<tr><td>Shri Jarnail Singh</td><td rowspan="2">Coordinator</td><td>Former Vice Chancellor</td><td rowspan="2">Manipur University</td></tr>
<tr><td>Professor N. Lokendra Singh</td><td>Present Vice Chancellor</td></tr>
<tr><td>Dr. Sanjay Kumar</td><td>Coordinator</td><td>Director</td><td>CSIR-IHBT- Palampur, Himachal Pradesh</td></tr>
</table>

Foreword

Water is such an essential commodity for humans, plants and animals, without which life cannot be imagined. Himalaya has thousands of glaciers and glacial lakes, which are the sources of all perennial rivers for sustaining more than a billion humans in their foreland basins by providing water for their domestic use, food production, and energy generation. Nature has blessed the Himalayan region with millions of springs, which form the primary and sole source of drinking water supply for many households. Most of the Himalayan villages are located at the mid-slope of the hills, and the rivers flow at the bottom of the hill slopes; therefore, hill people are primarily dependent on meeting their water requirements through government schemes. With the retreating glaciers, exploited rivers, drying up of springs, lakes and wetlands due to climatic changes, and the vanishing traditional water resource management strategies, such areas also face water scarcity. When water scarcity in regions like the Himalayas, considered a water Tower of the world, is felt, it becomes essential to probe the factors responsible for it, either natural or man, and provide suggestions for a viable water-centric approach for developmental and conservational activities.

The impact of climate change in the last few years has added to the woes of sensitive ecosystems; as a result, the problem of water stress in the Indian Himalayan Region has aggravated. Though the government schemes have successfully provided relief to the inhabitants of IHR up to some extent, in the absence of a comprehensive action plan and cooperation of all the stakeholders, the problem of water scarcity has increased over the years. To resolve the water-related issues, appropriate policies, plans, actions and regional cooperation is required, along with the capacity building for conserving and harnessing the Himalayan water resources. NITI Aayog's Report on 'Inventory and Revival of Springs in the Himalayas for Water Security' strongly advocates implementing a spring rejuvenation programme, developed on a scientific basis, across the Himalayan States in a mission mode. The Indian Himalayan Central Universities' Consortium (IHCUC), with the sponsorship of NITI Aayog, New Delhi, Ministry of Education, and University Grants Commission (UGC), has made an effort to find out appropriate strategies and priority actions to bridge the gaps to overcome the water woes in IHR. The present report contains the primary data collected by the partner institutions of IHCUC, suggested possible water conservation strategies, and state-specific recommendations. I hope the findings of this report which is being submitted to Niti Aayog will give some new insights for future planning of the developmental schemes for water conservation and harvesting to address the water scarcity in the IHR. I would like to extend my heartfelt thanks and gratitude to the Vice Chairman of Niti Aayog, Dr. Rajiv Kumar, who has been instrumental in guiding us to work in this direction.

I also wish to thank the team members for contributing to this timely and relevant study.



Professor Annpurna Nautiyal,

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Coordinator IHCUC

Acknowledgements

We express our sincere gratitude to Dr. Rajeev Kumar, Vice Chairman, Niti Aayog, Dr. V.K. Saraswat, member, Niti Aayog, and other experts and advisors of Niti Aayog who critically evaluated our progress and their valuable suggestions helped us to address the critical issue of "Water conservation and harvesting strategies." We are thankful to Sri Ramesh Pokhriyal 'Nishank' former union Education Minister and Sri Ajit Doval, Kirti Chakra, NSA of India, who were initially involved in forming the Indian Himalayan Central Universities' Consortium (IHCUC). We are incredibly grateful to Professor Annpurna Nautiyal, Vice-Chancellor of Hemvati Nandan Bahuguna Garhwal University and IHCUC coordinator, for her full cooperation and direction throughout the project's work. We acknowledge the services of all field investigators who carried out survey work and collected the required data from different parts of IHR during the difficult period.

This work would not have been possible without the cooperation of the Principal Investigators of all the partner Central Universities of the consortium. Thanks to Dr. Sanjeev Kumar and his colleagues at HNBGU for their help with data handling. Thanks to Professor Gibji Nimasow (Rajiv Gandhi University, Arunachal Pradesh) and Dr. Masroor Ahmed (Central University of Kashmir) for providing valuable inputs that helped in report writing. We also acknowledge Mr. Vargish Bamola of the People’s Science Institute for sharing his experience on spring revival. Experts from NITI Aayog and the Vice-Chancellor of HNB Garhwal University played an important role in evaluating the project's progress from time to time. We are also grateful to the Vice-Chancellors of the partner Central Universities of IHR (IHCUC) for their guidance and support. We are grateful to the University Grants Commission for providing financial support. We would also like to express our gratitude to all the Block, Tehsil and District level employees and officers who have provided the required data. We are extremely thankful to the respondents for taking the time to respond to our questions despite their busy domestic schedules.

Perfection in any task is challenging, but the present work is an honest effort based on the data provided by the partner institutions and their team members. We hope that this study will provide some ground data for dealing with the impending water crisis in IHR.

Yaspal Sundriyal

28 February, 2022 **Naresh Rana**

Contents

Executive Summary

- Water is an essential requirement for life, and its access is a human right. Water is essential for survival, directly related to health (hygiene and sanitation), and adds quality to life. Recent studies reveal that the water resources of the Himalaya are under threat of drying up, mainly due to climate change, population growth, and changing socio-economic practices. Declining water resources of the Himalaya will also adversely affect the population of the Ganga plain. The near future prediction models suggest a severe climate-change impact on the Himalayan ecology. And the effect of climate change on the water resources of the Himalayan region is evident—and more adverse than in other regions. The springs are the primary water source for millions of people in the Himalayan region. Half of the mountain springs have dried up completely, and the remaining are facing a steady decline in discharge. All the climate and water-related socio-political figures indicate severe water scarcity in the Himalaya.
- The Indian Himalayan Region (IHR) is endowed with thousands of glaciers and millions of springs, as well as a vast network of several mighty rivers and their tributaries. The rainfall in the region is mainly contributed by the Indian Summer Monsoon and Western Disturbances. Despite the plentiful resources and rain, the IHR is facing water scarcity. As a result, water infrastructure was encouraged and cooperative-social-volunteer management of water resources was transformed into government-supplied water systems. With this shift, the traditional expertise of creating and conserving water sources has virtually vanished—but the tapped water supply failed to fulfil the water requirement that has expanded manifold due to changing lifestyle. This has increasingly exacerbated the difficulty of maintaining a healthy lifestyle. Meanwhile, climate change has altered rainfall patterns dramatically, having a direct influence on agriculture and livelihood. Additionally, potable water derived from IHR's natural resources is becoming increasingly polluted, mainly by human activities, which has been identified as a serious upcoming threat.
- Under this project, a random social survey of nearly 18,000 households in 53 districts of IHR was conducted through personal interviews to measure water use and deficits, as well as the role of various elements (physical, social concerns, disputes, etc.) as water security constraints. The effectiveness of both modern and traditional water supply and conservation practises in dealing with water shortages was also evaluated in this study. Most crucially, the public's perspective was taken into account in the output in order to bridge the gap between policy formulation and field execution.
- This study identified a low water consumption (per capita) at most places in the IHR. We estimated water consumption of 37 litres per capita per day (lpcpd) that indicate a deficit of about 18 lpcpd from the benchmark of 55 lpcpd (suggested by *Jal Jeevan Mission*). The shortage represents the ‘physical’ scarcity of water and also amalgamates the socio-economic factors that limit water consumption. The causes of physical absence of water at the regional level are well-known, but socio-economic characteristics at the local scale often aggravate them. According to

this assessment, people walk around 1 kilometer (on average) to gather water—which frequently places an additional load on the health of women and children. Additionally, the family composition, health, and occupation can influence the household's water fetching capacity—and, ultimately, water consumption. As a result, water consumption is constrained by shortage.

- Studies clearly indicate that water scarcity will increase in the coming years, which will also raise many socio-economic problems. Water scarcity will severely impact agriculture production—and indirectly affect the economically lower and marginal reaches of society. Water-related conflicts and health-related issues will also increase. The women and children will shoulder the maximum burden of water scarcity. These conditions will lead to several secondary problems such as out-migration at a higher pace.
- In IHR, the overall quantity of (green and blue) water is abundant, though it cannot be utilized for human needs. Since the erratic rainfall also has limitations for sustained agricultural use, storage must be encouraged and promoted. Presently, the trend of making water harvesting and recharge structure through government schemes is increasing, but they are functional only when constructed under the guidance of experts. Public awareness, education and participation have to be raised through the concept of citizen science—specifically for the construction of water harvesting and recharge structure. This is also necessary to improve the demand control measures such as diversification of crops and the introduction of water-saving irrigation methods.
- Climate change and its adverse impact on water resources are inevitable. However, the increasing demand requires substantial investment intervention to construct water infrastructure. Presently, the water supply schemes in the rural parts of IHR are not functioning as per the expectations and requirements of the people. Primarily due to the inefficient water supply infrastructure—inaccurate planning—and secondly, due to the limited carrying capacity of the resources.
- Currently, only a limited amount of information regarding the nature of Himalayan aquifers is available, which can be expanded through action-oriented research. In totality, initiatives need to be taken in all directions like environment conservation, education, awareness, research and action for water harvesting and recharging, and, most importantly, water infrastructure.

Background

The Himalaya is the source of fresh water for millions of Asian populations, which makes it the water tower of Asia (Immerzeel et al., 2010). Many mighty rivers originate from the Indian Himalaya Region (IHR) and flow through the highly populated and fertile plains of South Asia, directly connecting with people's livelihood and playing an essential role in the socio-economic and socio-political affairs of the region. Over the last few decades, the Himalayan glaciers have experienced a significant loss due to global warming—and this has been the focus of concern for scientists, environmentalists, and policymakers. In addition to this, the water from natural springs, which is a significant contributor to the renewable water of the Himalaya, has also been significantly reduced (Niti Ayog, 2018).

The springs have an extensive network throughout the region compared to the valley-confined large (glacial-fed) rivers. They are a source of freshwater for the majority of the mountain population (60%) and their agriculture (64%). According to an estimate, the IHR is the home of about 3 million of India's total 5 million springs (Niti Ayog, 2018). Thus, the springs have a much broader role in the mountain ecosystem and socio-economic development. But the growing population and socio-economic changes have adversely changed traditional resource management practices (ICIMOD, 2007) and led to the exploitation of natural resources beyond their carrying capacity.

Moreover, climate change has amplified this impact on the ecology of natural resources. The impending water crisis in the Himalayas has been recognised long ago and has activated policymakers to invest in water infrastructure development. In recent years, the government of India has made an investment of about Rs. 90,000 crore to provide drinking water to the rural population through the *National Rural Drinking Water Programme* (NRDWP). The NRDWP was focused mainly on the tap water supply to rural households. Unfortunately, due to some discrepancies in planning and execution, this programme could not achieve the objectives (CAG Report, 2018). This indicates a gap between the perception of policymakers and ordinary people. Thus, the identification of water-scarce areas, causes, and quantification of severity are essential for formulating policies to combat the adverse impact of climate change on the socio-economy of IHR.

The IHR has thousands of glaciers, millions of springs, and several rivers and their tributaries. The Indian summer monsoon mainly contributes to the rainfall in the region, but the western disturbances also provide a significant contribution in the NW Himalaya. Despite the plentiful resources and rain, the IHR is facing water scarcity. And it was felt that water infrastructure needs to be strengthened to cope up with the scarcity of water and increasing demand. Consequently, in the last few decades, traditional water conservation practices and sanitation have changed from cooperative-social-volunteer management to government supply systems. The conventional wisdom of making and conserving water-wells and spout springs has almost disappeared, but the (per capita) water requirement has increased manifolds. The awareness of personal hygiene has improved—and the use of toilets has reached nearly 100%.

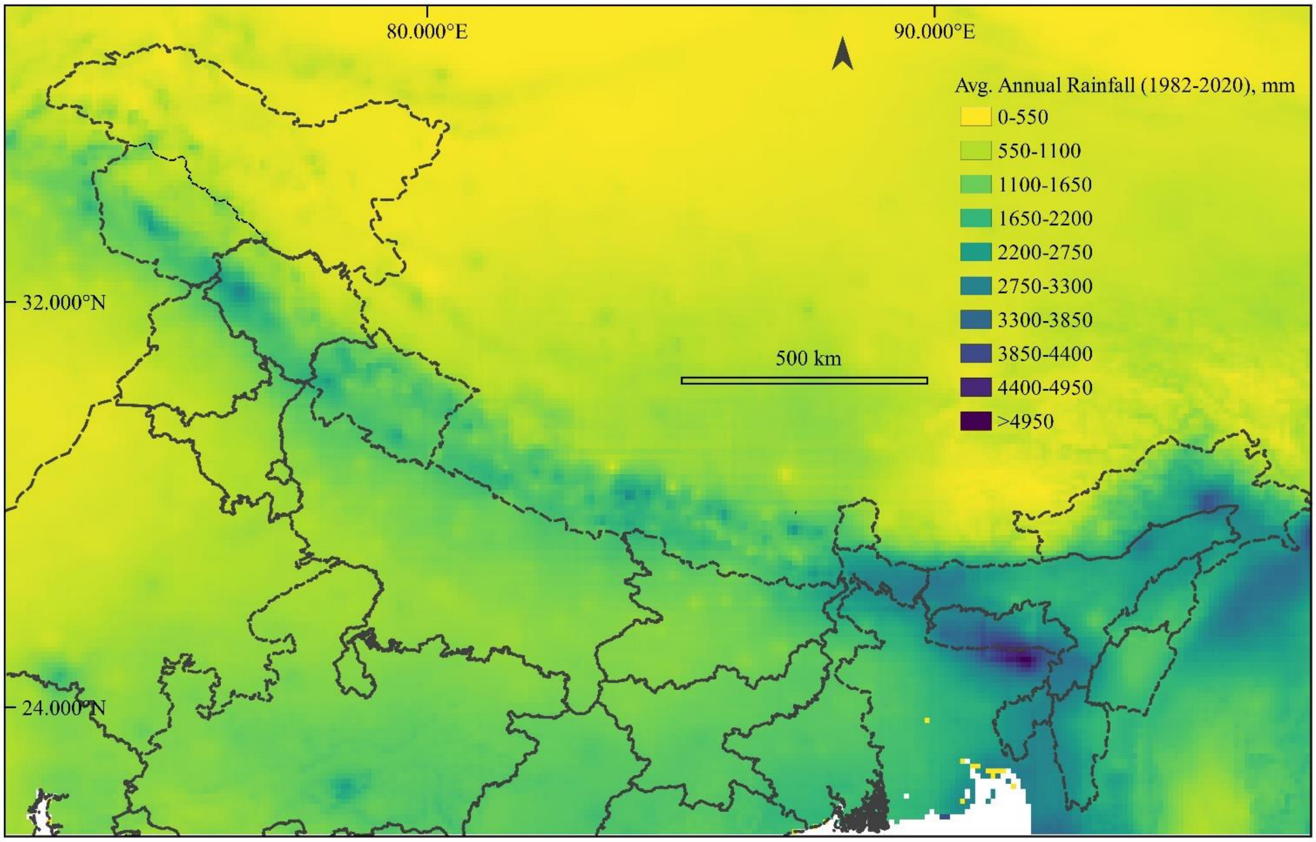
Despite huge investments such as the *National Rural Drinking Water Programme*, tapped water has yet to become a viable alternative due to inadequate infrastructure and planning. As a result, people are forced to compromise on their necessary water requirements to live a healthy lifestyle. The scarcity is further causing a systemic risk to agriculture and livelihood.

In the Himalayas, many traditional systems, like the simple shallow wells, spout springs, Kuhuls, Chal and Khal (artificial ponds on hilltops), Zings, and complex systems like the Apatani system, Zabo arrangement, and Dongs (ponds), have been used to supply and store water. All these sources were managed by the social and volunteer efforts of villagers. Interestingly, many of these sources have been considered equivalent to gods and have been worshipped on many occasions. Although there were reports of discrimination associated with the rights to the water resources based on class, but the clashes were limited due to available alternatives. The rural lifestyle was very much aligned to the water availability. The settlement, agriculture, and livestock locations were chosen according to the availability of natural resources such as water, fodder, forest, etc. There has been a significant shift in the lifestyles of people from this traditional natural resource-dependent (sustainable) lifestyle to a new market-controlled lifestyle. Unfortunately, some practices that are important for good health and making life more decent also require more water, like toilets and more hygiene procedures. Further, population growth and climate change have adversely affected the water resources. Changing forest types, forest fires, natural hazards, and anthropogenic activities (developmental work) also enhance this scarcity. People have highlighted ‘mismanagement of the water resources’ as one of the important factors behind the water scarcity. Though the role of climate change in reducing spring discharge is not easy to evaluate as it is a slow and steady process to notice, the climate projection suggests about a 20% increase in water scarcity in the near future.

Many approaches for assessing water scarcity have been developed, and each has its own set of limitations (Rijsberman, 2006). Falkenmark (1989) started this process by examining the countries' renewable-water resources, but water shortage is influenced by a variety of socio-economic issues at the local level (Ohlsson, 2000). Because the prevailing Indian summer monsoon feeds the Himalayan glaciers, rivers, and springs, causing considerable flooding during the monsoon, the ratio of resource availability to population does not provide any useful input in dealing with water scarcity. We suppose that in a water-scarce location, access to freshwater regulates the water consumption rate (per capita liters). As a result, the shortfall in water use is the best indicator of water scarcity in terms of practical solutions.

STUDY AREA

Indian Himalayan Region



(Figure: Spatial variability in rainfall. Source: FLDAS_NOAH01_C_GL_M model (McNally, 2018). Spatial resolution of dataset: 0.1°)

The study area comprises of ten states and two Union Territories (UT) from the (IHR) Indian Himalayan Region, located in the latitudinal/longitudinal range of 21.93° N - 36.80° N/ 72.27° E - 97.36° E. The states are Himachal Pradesh, Uttarakhand, Sikkim, Darjeeling (West Bengal), Assam, Arunachal Pradesh, Nagaland, Meghalaya, Manipur, Tripura, and Mizoram, and union territories are Jammu-Kashmir and Ladakh. Among all these states, Arunachal Pradesh consists of a maximum land area (83,743 km^2), whereas Sikkim occupies a minimum area (7096 km^2). In the context of hilly area percentage, Jammu-Kashmir and Ladakh UTs cover the maximum hilly area (41.65 %) of the Indian Himalayan Region (IHR), whereas Darjeeling in West Bengal has the least (0.59 percent). Details* of Individual states/UTs are as follows:

Jammu-Kashmir (J-K) and Ladakh UTs (or the erstwhile state of Jammu and Kashmir) are located along with the northernmost Indian Himalayan range between 32.27° N - 36.80° N and 72.27° E - 80.39° E. The region covers a total geographical area of 222,236 km^2 in which Ladakh covers about 117,000 km^2. The elevation in these UTs varies from 2,000 ft to 20,000 ft. With a combined population of 12.54 million, the two UTs account for just over one percent of the country's total. About 72 % of the total population live in rural areas. The average annual rainfall in J&K is between 100 and 3850 mm, while it is between 0 and 550 mm in Ladakh. In J-K, the yearly average temperature ranges from -5 to 19°C, while in Ladakh, it ranges from -15 to 15°C. The densely populated Kashmir valley is a lake basin, which is 140 km long and 32 km wide. In addition, the area comprises snow-covered mountains, steep river gorges, glaciers, lush green meadows and valleys full of Chinar trees, attractive silvery lakes, and diverse flora and wildlife, making it "Paradise on Earth." Lakes, streams, and glaciers are plentiful throughout the valley. At least 1230 lakes and streams may be located in Jammu & Kashmir (ref). Jhelum, Chenab, Indus, and Tawi are some of the important Himalayan rivers flowing through the region. Dal Lake, Manasbal Lake, Nigeen Lake, and Wular Lake are Kashmir's most notable lakes. Despite abundant water supplies, unequal distribution of water resources over time and space places further restrictions on the amount of water that can be used.

Himachal Pradesh is located between 30.38° N - 33.21° N and 75.61° E - 78.75° E, and covers a total area of 55,673 km^2 with elevation ranging from 350m to 7000m. There are 6,864,602 people living in the state, with 3,481,873 of them being men and 3,382,729 of them being women (Census of India 2011). Around 90% of the state's population lives in rural areas. The state receives an average annual rainfall of 1111mm, varies spatially from 550-2750 mm, and decreases from west to east and south to north. The temperature also drops from west to east. In the winter nights, temperatures can drop to -3 to 4° C. The state is privileged with a mountainous landscape that is home to the Satluj, Beas, Ravi, and Chenab rivers' catchment basins. Glaciers and rivers provide abundant water resources, but the state's groundwater supplies are restricted. Himachal Pradesh is classified as a wet, hilly climate region. Because of the various aspects and altitudes, the distribution of rainfall and temperature varies significantly.

Uttarakhand has an area of 53,483 km^2 and is located between 28.72° N-31.28° N, and 77.70° E-80.88° E. It has an 86.6% hilly area and a 14% plain area. The state's elevation ranges from about 210 m at Haridwar to 7818 ft at the Nanda Devi summit, which is the highest point in the state. The total population of Uttarakhand is 10,086,292, out of which 5,137,773 are male and 4,948,519 are female (963 women per 1000 men). Out of this population, 61.33% of people live in rural areas and 38.67% live in urban areas. The average annual rainfall in Uttarakhand varies between 550 and 3300 mm, which decreases from east to west. The Indian summer monsoon contributes about 78% of the total annual rainfall in the state from June to September.

The winter months (December to February) receive 9 percent, the pre-monsoon months (March to May) receive 10 percent, and the post-monsoon months receive 3 percent (October to November). Through the western disturbances, snowfall occurs mainly in the winter months of December to February. The annual average temperature in Uttarakhand ranges from 20–25°C in the southern part to 6–2°C in the northern mountain ranges. Yamuna, Ganga, Kali rivers and their tributaries originates from Uttarakhand and constitute the surface water resources of the area. The total high-altitude wetlands in the state cover an area of about 1040 km^2, whereas some of the middle-to-low altitude lakes include Nainital, Devariya Tal, and Benital. In addition to the major river systems and lakes, natural springs are a significant water source.

Sikkim is located between 27.07° N - 28.13° N and 88.01° E - 88.92° E, beneath the world's third-highest peak, Kangchendzonga (8598 m). The state covers a total geographical area of 7,096 sq km. The state is hilly, with an elevation varying from 280 m in the southern part at the border with West Bengal to 8,586 m in northern high mountainous area near Nepal and Tibet. With 610,577 residents, Sikkim is India's least populated state, with 321,661 males and 286,027 females. The rural population in Sikkim is about 75 % of the total. The average annual rainfall in the state is 2376 mm, and the precipitation decreases from south to north. The average number of rainy days are 161. The annual average temperature in Sikkim is 19.5°C.

The state is dissected by numerous valleys, high peaks and rippling rivers draining into the Brahmaputra River. Together with its primary tributary River Rangeet and Rammam, River Teesta is the most important river in the region. These rivers are nourished by numerous glaciers and hundreds of jhoras (streams, rivulets, and nallas). Small streams and natural springs are the primary drinking and domestic water sources in both Sikkim and the adjacent Darjeeling region of West Bengal.

DArjeeling is the northernmost mountainous region (district) in the West Bengal state that shares its geographic and hydrological boundary with Sikkim, Bhutan and Nepal. It is located at an elevation of around 2,000 m and comprises a land area of 3149 km^2. It is located between 26.44° N-27.21° N and 87.98° E - 88.87° E. Darjeeling has a population of 18, 46, 823 and about 60% of them live in rural areas. The region experiences an annual mean temperature of 13.40°C, 3608 mm of rainfall and 126 days of average rainy days. The western part of the district drains into the Mahananda river basin while the eastern part drains into the Teesta River system.

Assam is situated from 24.15° N- 27.96° N/89.73° E - 95.96° E, and covers a total area of 78,438 km^2 ranging from 450 to 1000 m. The state has a total population of 31,205,576 with 15,939,443 males and 15,266,133 females (Census of India 2011). Around 86 percent of the total population lives in rural areas. The state receives an average annual rainfall between 1100 and 3300 mm, with rainfall decreasing east to west. The annual average temperature decreases from east to west and is between 16 and 30 °C. Two main river systems flow through the Brahmaputra and the Barak. Karbi Anglong, West Karbi-Anglong (previously part of Karbi-Anglong), and Dima Hasao are the two hill districts that make up the state.

Arunachal Pradesh is the easternmost region, covering an area of 83, 743 km^2. The state is situated between 26.30° N - 29.31° N latitudes and 91.30° E - 97.30° E longitudes in the Indian Himalayan Region. The elevation ranges from less than 300 meters in the plains to above 7,000 meters in the mountains. The state has a population of 1,383,727 with about 77% living in rural areas. The state receives heavy mean annual rainfall of about 2000 to 5000 mm and thereafter rapidly decreases towards the northern parts. The yearly average temperature ranges between 0-18°C. The adequate monsoon precipitation and distribution of springs, glaciers and lakes are the life sustaining water resources that play an essential role in the hydrological cycle and varieties of ecosystem services. The glacier-fed streams and natural springs/ lakes are important sources of livelihood for drinking water supply, livestock, and agricultural activities. However, due to remoteness, harsh climatic conditions, and inaccessibility, the current status of wetlands in the Arunachal Himalayan Region is limited to a geographical extent only. The total area covered by wetlands in Arunachal Pradesh is estimated to be 155,728 hectares (ha.), with the maximum concentration of roughly 45,719 ha. in the Lohit district, owing to the vast number of rivers and streams. Dibang Valley (37,602 ha.) and East Siang (25,512 ha.) are the other two districts with the most wetlands, while Tirap district (1,262 ha.) has the least (Space Applications Centre, ISRO, 2009).

Nagaland State covers a geographical area of 16,579 sq km spreading along with the Arakan range between 25.17° N-28.26° N and 93.34° E-97.14° E. The state includes elevated ridges and intermountain valleys that range in elevation from 160 to 3841 m. The Naga Hills rises from 610 m in the western part to 1,800 m in the southeast. The state had a population of 1,980,602 inhabitants in 2011, of which 71% is living in rural regions. Nagaland receives heavy rainfall during monsoon and experiences water scarcity during post-monsoon (November to April). The average annual rainfall varies between 1650 and 2200 mm and annual average temperature ranges from 10 to 29°C. About 61%

of precipitation is received during monsoon, and 27% is received during pre-monsoon. In the post-monsoon, rainfall contributes only 12.17% of the total. The state can be classified into five rainfall zones: very high rainfall (1817-2123 mm), moderately high rainfall (1634-1817 mm), high rainfall (1438-1634 mm), increased rainfall (1634-1817 mm), medium rainfall (1233-1438 mm) Zone, and Low rainfall zone (860-1233 mm). Water is a crucial natural resource in Nagaland. Surface water in natural springs, streams, and rivers is the primary source of drinking, domestic, and agricultural water. Several seasonal and perennial rivers and rivulets cut through the topography of Nagaland. Dhansiri, Doyang, and Dikhu are three rivers that flow westward into the Brahmaputra, whereas the Tizu River flows eastward and join the Chindwin River in Myanmar. Due to the high runoff, the monsoon rainfall has a very insignificant contribution in the groundwater.

Meghalaya state is located in Shillong Plateau between 25.0° N - 26.07° N and 89.87° E - 92.78° E. The elevation of this plateau ranges between 150 m to 1,961 m. The region receives the highest rainfall in the Indian Himalayan Region. The central part of the Khasi Hills plateau has the highest elevations, followed by the eastern section comprising the Jaintia Hills region. Total population of the state is 2,966,889, out of which 1,491,832 are male and 1,475,057 are female. Around 80% of this population live in rural areas. The state receives an average annual rainfall of 3300-4950 mm, decreasing from south to northeast. The annual average temperature ranges from 15-18°C.

The state's climate is moderate, subtropical, and humid, with maximum summer temperatures up to 27 °C and winter lows of 4 to 14 °C. There is a wet season from May to October, followed by a dry season from November to April. Four major watersheds exist in the area, with two rivers flowing into the Brahmaputra north and Bangladesh's Surma valley in the south. The Kopili, Myntang, and Mynriang rivers feed into the Brahmaputra, whilst the Myngngot (Umngot), Myntdu, Wah Prang, WahLukha, and WahSimlieng rivers flow into the Surma valley.

Manipur is situated from 23.92° N - 25.67° N to 93.10° E - 94.60° E spreading along with the Arakan range. It covers a total area of 22,327 km^2 with elevations between 1,500 and 1,800 metres in general, which in the north rise to 2,900 m. Manipur has a total population of 2,855,794, and around 71 % of this population live in rural areas. The state's annual rainfall is 1454mm, which varies spatially between 550-1650 mm, and decreases from west to east. The yearly average temperature ranges between 18-29° C. The state is separated physiographically into hills, intermontane valleys, and alluvial plains, drained primarily by the Meghna and Chindwin rivers and their tributaries.

Manipur has fifteen significant rivers that flow through four major river basins: the Barak River Basin in the west, the Manipur River Basin in the middle, the Yu River Basin in the east, and the Liyai River Basin in the north.

Tripura state has an elevation ranging between 780 m in the northeastern part to 15 m in the western part above mean sea level. It goes between 23.66° N - 23.97° N and 91.61° E - 92.23° E. Total population of Tripura is 36,71,032 (18,74,376 are male and 17,99,541 are female) out of, which 27, 12, 464 inhabitants live in the rural areas. The average annual rainfall in the state varies spatially between 2200 mm and 2750 mm, and the annual average temperature in Tripura Pradesh ranges from 25-29°C. The state covers an area of 10,491.69 km^{2,} out of which about 60% is covered by forest. The torrential monsoon rain is an integral feature of the state's weather. A total of eleven rivers originates from the mountains of Tripura i.e., Bijay, Deo, Dhalai, Feni, Gumti, Haora, Juri, Khowai, Longai, Manu, and Muhuri, but all are seasonal. Tripura's climate has a distinct seasonal pattern. Spring, summer, monsoon, autumn, and winter are the five distinct seasons that characterize the state's warm and humid tropical environment.

According to Koppen's climatic classification, Tripura's climate is classified as a 'Savanna climate'.

Mizoram is a land of undulating topography, with 21 major hill ranges of varying heights (up to 2065 m -Phawngpui peak) traversing the length and breadth of the state at an average elevation of about 1000m. The state is located in the Arakan range between 21.93° N-24.46° N and 92.27° E-93.37° E. Mizoram covers a total size of 21,081 sq.km. To the east, these increase substantially to 1,300 m. Some areas, however, have higher ranges which go up to a height of over 2,000 metres. Mizoram had a population of 1,091,014, with 52.11% living in urban areas. The average annual rainfall remains between 1100 and 3850 mm. The state has a pleasant climate, with summer temperatures ranging from 20 to 29°C, but winter temperatures range from 7 to 22°C. The region receives heavy rain from May to September and little rain during the dry (cold) season with an average annual rainfall of 254 mm, and the climate is wet tropical to moist sub-tropical.
Mizoram's largest river, Chhimtuipui, is known as Kaladan, emerges in Myanmar and flows through Mizoram's southernmost districts of Saiha and Lawngtlai before returning to Myanmar. Many more rivers and streams flow through the mountain ranges. However, the Tlawng, Tut, Tuirial, and Tuivawl rivers, which flow through the northern part of the district and eventually join the Barak River in Cachar, are the most important and valuable. Despite getting ample monsoon rain and a profound river network, the state faces water shortage, particularly during the dry months of November to May.

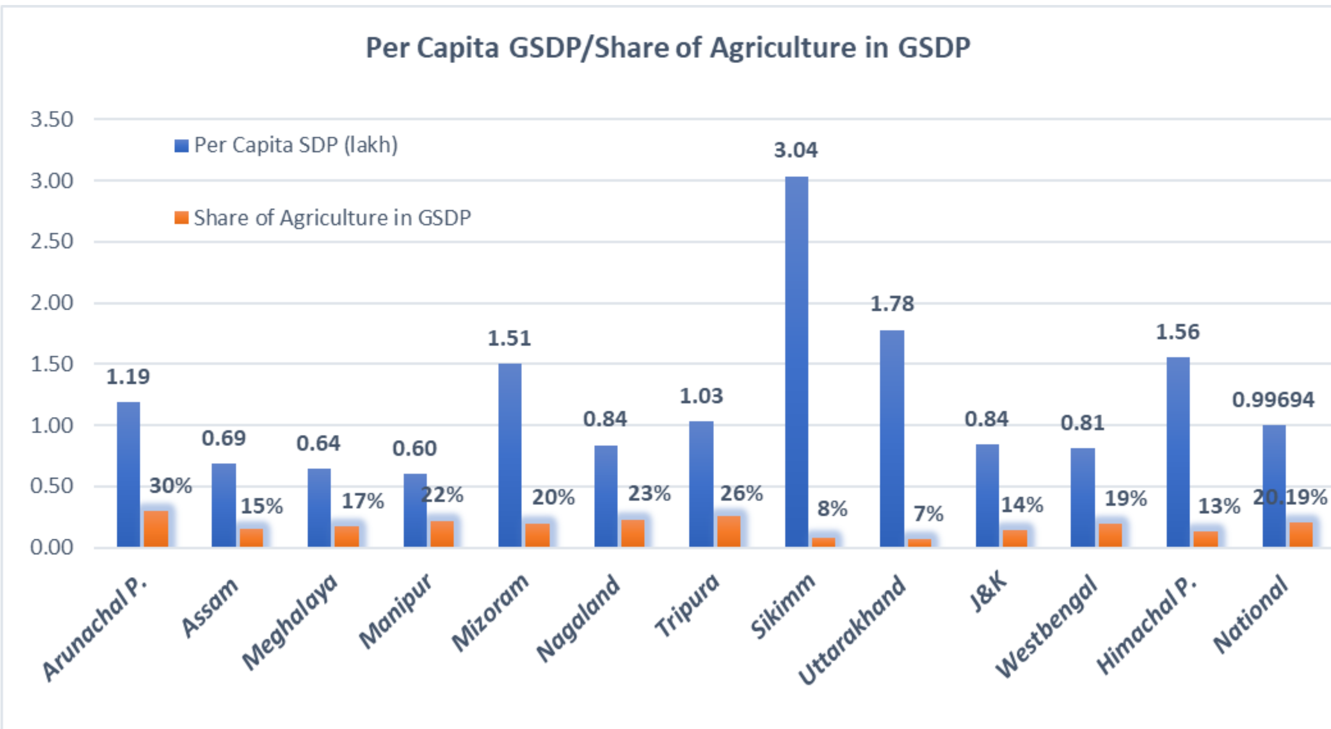
Agriculture and Economy

Agricultural growth is one of the most potent strategies for combating extreme poverty, boosting shared prosperity, and feeding a projected 9.7 billion people by 2050 (World Bank, 2021). In fact, it is more successful (two to four times) than other sectors in improving the earnings of the poorest people (World Bank 2021). Agriculture contributed for 4% of global gross domestic product (GDP) in 2018 (a typical year before the pandemic), and it accounted for more than 25% in certain developing nations, indicating its critical significance in emerging countries' economic development. Agriculture has been the only bright spot in India, despite the Covid 19-imposed economic crisis (leading in a negative growth rate of -7.2 percent for 2020-21). Aside from growing at a pace of +3.4 percent, agriculture's contribution to GDP has surpassed 20% (20.19 percent) for the first time in 17 years (Economic Survey, 2021). In 2003-04, the agricultural sector contributed 20% to GDP for the first time. The following graph shows the share of agriculture in Gross State Domestic Product in the Indian Himalayan region.

As shown in the bar chart on next page, agriculture contributes more to GSDP in states like Arunachal Pradesh, Manipur, Mizoram, Nagaland, and Tripura than the national average, indicating their reliance on this sector. In addition, when looking at GSDP figures, most states' GSDP per capita is lower than the national average. Because they are the states with the largest agricultural potential, policy measures to improve their agricultural sectors are required to strengthen their economies.

Besides being a significant contributor to GSDP of Indian Himalayan region states/UTs, this sector provides employment to more than 50% of the region's population (although there is some variation among states but a minimum of 50% population is engaged in each state/UT). However, in terms of agricultural productivity, irrigation coverage (in Mizoram, only 5.33 percent of total land is classified as agricultural land, and only 14 percent of it is irrigated, whereas in Uttarakhand, 90 percent of agriculture land is non-irrigated), application of fertilisers and pesticides, organised marketing facilities, crop insurance, construction of godowns and warehouses, and processing of various agricultural products, this region falls short of the rest of India.

More importantly, over the past few decades food production has become harder for communities in the Himalayan region due to significant climatic changes including higher temperatures, lower rainfall and more extreme and unpredictable weather. A recent report titled 'Smallholder Farming Systems in the Indian Himalayas' shows that farmers in the eastern and central Himalayas have experienced increasingly erratic rainfall, drought and floods, higher temperatures, and a rise in crop pests and diseases, leading to lower yields (Mukherjee et al., 2018). In view of the importance of this sector for Himalayan region both production and post production reforms are needed to combat climatic and other challenges faced by the people directly or indirectly related to this sector. Most importantly measures to increase the land under irrigation, easy access to improved hybrid seeds, farmers training programmes, adequate storage and remunerative markets for farmers should be focused upon.

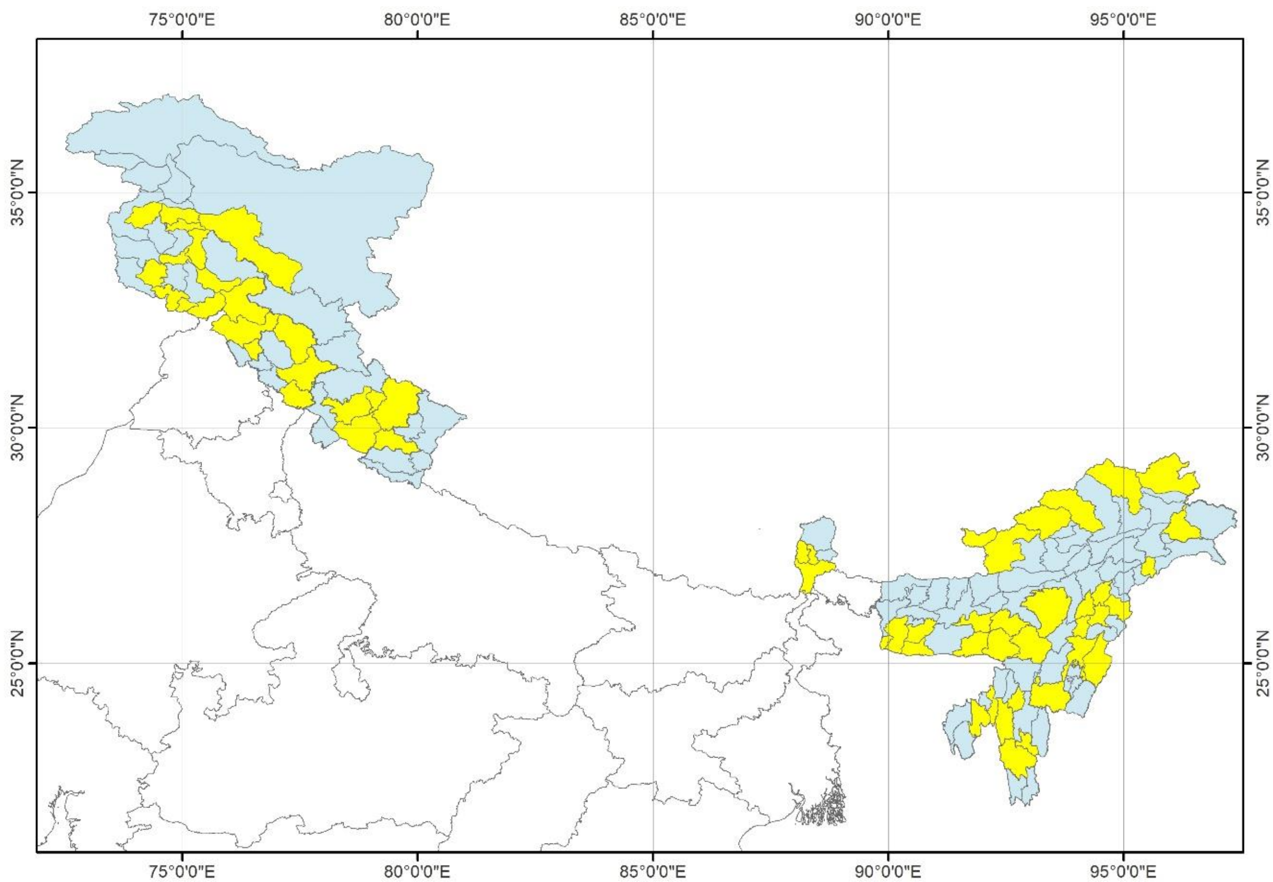


(Figure: Share of agriculture in GSDP with reference to per capita GSDP in Himalayan state of India)

* Rainfall data: https://giovanni.gsfc.nasa.gov/giovanni/
All population figures: Census of India, 2011

Objectives and Methods

1. Quantification of the water-scarcity in the climatically sensitive and socio economically vulnerable mountain region of Himalaya.
2. Identification of causes and consequences of water scarcity with reference to the status of natural water resources.
3. Documentation of the traditional practices of sanitation, conservation and management of water resources.
4. To suggest the method(s) of conservation and recharge of the natural water sources.



(Figure: Surveyed district of Indian Himalayan Region-in yellow colour)

Methods

The following methodologies were opted to achieve the set objectives:

A. *Social survey*

A random social survey was carried in the IHR through personal interview based on a designed questionnaire to -

- Calculate water deficit in water consumption for household.
- Understand the role of different factors (Physical/Social issues/conflicts etc.,) as constraints of water security.
- Assess the indigenous practices, past and present Government initiatives and policies of water.
- Assess of impact of water scarcity on socio-economy of mountain villages.

B. *Field visits and documentation of traditional water harvesting techniques and to assess their scope in handling the water scarcity.*

C. *GIS and remote sensing to understand the topographic constraints and spatial distribution of rainfall across Himalaya and generation of thematic maps.*

Sampling Procedure

According to the 2011 census, there are 152 districts in the 12 Himalayan states, with 100 of them being hill districts. The research was conducted in the Indian Himalayan region's 53 districts (almost half of the mountainous districts), which included 124 developmental blocks and 1123 villages. With a few exceptions, the villages were chosen based on their closeness to the block headquarter: two villages closest to the block headquarter, three villages 5 to 10 kilometres distant from the block headquarter, and four villages more than 10 kilometres away from the block headquarter. In each community, about 10-20 households were surveyed. A total of 18060 households in the region were surveyed for the study.

Secondary data:

The data on topography, rainfall, population, forest cover, water harvesting structures and connections (Govt. initiatives) were taken from the secondary sources (e.g., Block/Tehsil head offices and state government websites).

Basic Water Requirement for domestic use: 55 lpcpd

- Drinking-3 lpcpd
- Cooking-5 lpcpd
- Bathing-15 lpcpd
- Washing utensils and house-10 lpcpd
- Ablution/toilets-10 lpcpd
- Washing of clothes & other uses-12 lpcpd

Assessment of Water scarcity (in terms of deficit):

Initially, the idea of a "basic water requirement for human activities" (BWR) was proposed by Gleick, (1996). He proposed a minimum annual per capita need of 20 m^3 for living a healthy life, which comes to around 55 litres per capita per day. Further, BWR of 55 lpcpd is adopted in many Govt. of India water supply schemes (*Jal Jeevan Mission; National Rural Drinking Water Programme* etc.), which includes (in lpcpd): drinking-3, cooking-5, bathing-15, washing utensils and house-10, ablution/toilets-10, washing of clothes and other uses-12. Further, the *Jal Jiwan Mission* has directed the use of 55 lpcpd as the benchmark use for living a normal lifestyle. In this assessment, we have also adopted 55 lpcpd as the benchmark to calculate the water deficit. Use of water less than this amount is considered a "water deficit.":

$$Water\ deficit = 55 - average\ consuption\ (lpcpd)$$

(Photo: Household survey in Kargil, J & K)

Table: Survey (2021) information

S.N.	State/U. T/ Region	District	Block	villages	Households	Surveyed by
1	Jammu	6	18	180	2700	**CJU**
2	Kashmir	5	10	100	1500	CUK
3	Himachal Pradesh	6	12	120	1200	CUHP
4	Uttarakhand	5	20	177	3540	HNBGU
5	Sikkim	2	3	27	405	SU
6	Darjeeling (W.B)	1	3	27	405	SU
7	Assam	2	4	36	540	AUS
8	Arunanchal Pradesh	8	16	144	2160	RGU
9	Nagaland	5	10	90	1350	NU
10	Meghalaya	4	7	63	1260	NEHU
11	Manipur	3	9	39	600	MU
12	Tripura	2	4	40	800	TU
13	Mizoram	4	8	80	1600	MU
	Total	**53**	**124**	**1123**	**18060**	

CUJ-Central University of Jammu; CUK-Central University of Kashmir; CUHP-Central University of Himachal Pradesh, Dharmshala; HNBGU-Hemwati Nandan Bahuguna Garhwal University; SU- Sikkim University; AUS-Assam University Silchar; RGUAP-Rajiv Gandhi University Arunachal Pradesh; NU-Nagaland University: NEHU-North-Eastern Hill University, Meghalaya: MU-Manipur University; TU- Tripura University: MU-Mizoram University:

Water scarcity in Indian Himalayan Region

According to an estimate more than 60% population of IHR depends on natural springs for domestic and agricultural needs (Niti Ayog, 2018). In Himalaya the mean annual water yield from springs is estimated between 720 Litre/day and 56000 litre/day (Rai et al., 1998). These springs are the result of the downward flow of water from the unconfined aquifers formed by joints and fractures mainly (CGWB, 2014). Over the last few decades, a degradation in the groundwater resources of Himalaya has been reported (Panwar, 2020 and references therein), which resulted a decline in the discharges and drying of springs in many parts of Himalaya at an alarming rate (Negi and Joshi 2002; Valdiya and Bartarya, 1991; Tiwari and Joshi, 2012; Agarwal et al., 2012, Niti Ayog, 2018). The drying of springs has caused a severe threat to the availability of the drinking and domestic water throughout the Himalaya.

The springs are important source of renewable fresh water in the Himalaya. As per an estimate of UNDP 90% of the fresh-water needs in Uttarakhand is fulfilled from about 260,000 natural springs (Sharma, 2018). The limited data from the state show a multi fold increase in water scarcity in last few decades (SAPCC Uttarakhand, 2018). The severity of emerging water crisis can be estimated from an example of Uttarakhand, where only 19% villages were facing water crisis in 1981 which increased to 80% by 1986. Another report pointed out that out of 360 springs of Almora district only 60 could sustain in last 150 years (Niti Ayog, 2018). Himachal Pradesh, which share the similar topographic and climatic setting is also facing decline in water resources. In general, the springs and ponds of the state dry out during pre-monsoon summer season and flow in the streams reduce down during the winter months. According to a study, nearly 70% of the water resources of the state are not recharging properly and going to dry in near future (Directory of water resources of HP,). This results in water scarcity of a few months in some regions and a year-round problem in others. The surface water resources of Kashmir Valley are unparallel in the Himalayas. But nearly similar situation is being experienced in Jammu and Kashmir region, where a rural population (of about 91 lakh) is under a deficit of about 55 MGD (Tribune, 2019). Here, the increasing stress on existing water resources with increasing population is very clear and the impact on agriculture production is also a matter of concern in this region. The springs are drying at much higher rates in the bordering district Poonch and Rajouri. And, the severe scarcity of portable water in Ramban, Doda and Kishtwar areas has also been highlighted.

Compared to the NW Himalaya, the NE Himalayan region receives more rainfall, despites report of declining discharge and drying of springs and water scarcity are also very common from this area. Arunachal Pradesh, which host thousands of springs, lakes, glaciers and many rivers has a considerable (2.56 BCM) amount of replenishable groundwater resources. However, the state of groundwater development is negligible (0.04%) due to significant runoff (TERI School of Advanced Studies, 2018). Although, this varies from place to place, but deficiency in ground water recharge and excess runoff is the root-cause of water scarcity in Himalaya. In Tripura many springs have been dried up and many have become seasonal—consequently, many people lack quality water for drinking. Due to the high dependency on springs the state faces an acute water problem during winter and dry season.

Assam has plenty of water resources in terms of surface water with limited ground water resources—mainly wells. The Karbi Anglong district has ring-wells in almost every household with depth ranging from 60 to 110 m. But there are reports of drying of these wells. The low lying/plain area have sufficient water supply but the quality of water is not good due to the excess amount of iron, fluoride, calcium, magnesium and carbonate etc. In the high altitudes areas, due to lacks of natural resources, the people purchase water supplied from Jatinga River—on rates that keep increasing with elevations that varies between Rs. 600 and Rs. 1000 per 1000 litres. The water is usually supplied twice or thrice a week through the government scheme, but it turns insufficient to meet the domestic needs.

In Nagaland state, the water scarcity is observed throughout the state. In Wokha district, water availability from natural resources is limited to only up to 6 months—causing major reason for water scarcity. The water-shortage with monsoon rain variability in Manipur has been highlighted several times and now the problem seems to be aggravated due to the decreasing discharge and impounding of river for hydropower. In addition, there are reports of increasing water crisis with the changing land-use and drying of springs. Mizoram receives plenty of rainwater during the ISM but faces scarcity during the winter dry season. The state Meghalaya, which literally means the 'abode of cloud', also faces severe water scarcity in upland areas during the lean season—and people spend a good amount of money for drinking water. In the state many perennial sources have become seasonal. In Sikkim people have also reported water scarcity due to natural disaster (2011, earthquake) (Tiwari, 2012). And people are shifting towards tourism industry from their tradition farming. Similar situations are also found in Darjeeling where people are shifting towards labour work. Further, the socio-political situations of Darjeeling have also led to the depletion of resources.

Over the last few decades, the practices of water supply have undergone a huge shift from the traditional resources to tapped water. In rural areas the tapped water is also supplied from the springs but it could not become the reliable and constant means of receiving water due to poor supply infrastructure, planning and drying of springs. Recent studies also indicate a fast urbanisation in many parts of Himalaya, and increase in demand of water, which can aggravate the problem.

The water scarcity for the daily needs of people is definitely a matter of concern and therefore more visible. However, the impact of water scarcity on ecosystem, agriculture and other business is also important for the long-term socio-economic development. The agriculture and ecosystem are more sensitive towards climate change therefore, they are experiencing a very high degradation compared to the impact on human-being—

because of adaptability. Though these data provide a clear indication of increasing water crisis in Himalaya, they fail to provide a quantified scarcity and associated causes—that are necessary for decision making.

The estimate of water consumption, based on the social survey shows that the people in Himalaya are forced to minimize the water consumption/use due the acute shortage of water. On an average people are consuming 37 lpcpd with a deficit of 18 lpcpd for domestic use. Many of the reasons are not directly related to physical scarcity of water, but they are also compounded by the socio-economic factors.

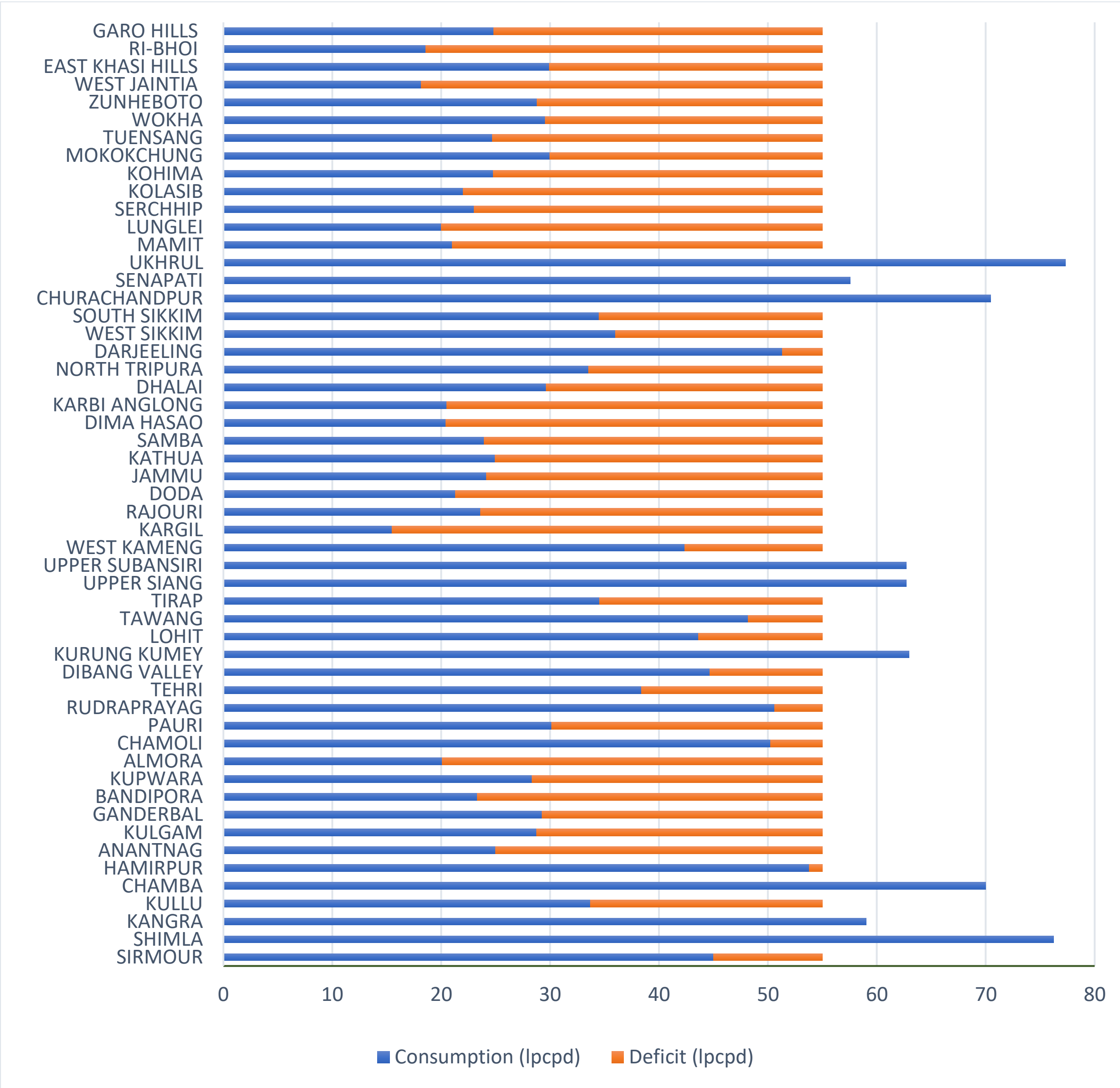


Figure: Average water consumption (litre per capita per person) and deficit in surveyed districts of Himalaya. Source: Field survey, 2021)

(Water scarcity in Himalayan Region; Photos: HNBGU (top) and MU (bottom)

Causes of water Scarcity

"There is a water crisis today. But the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people—and the environment—suffer badly"

-World Water Vision, 2000

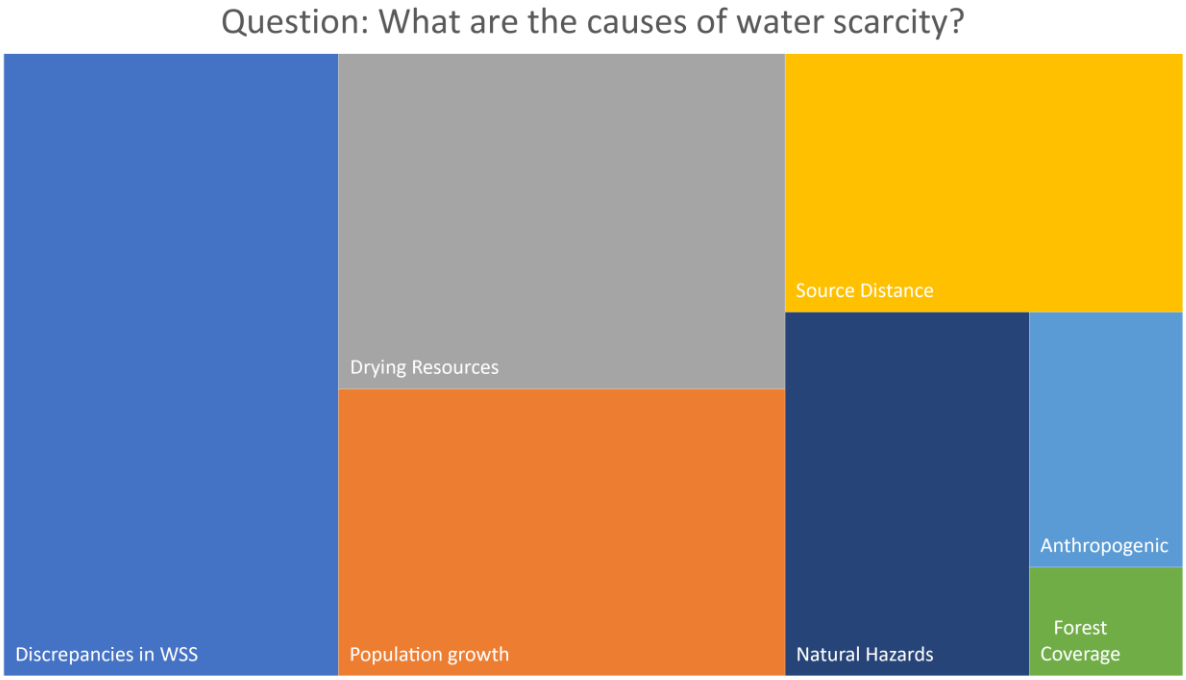


Figure: Results of survey-2021 question on causes of water scarcity (WSS: water supply system).

Population growth, lifestyle change, and climate change have been identified as the key factors contributing to water scarcity globally (CWC, 2003; Gleick, 1987; Messerli et al., 2004; Immerzeel et al., 2010; Tambe et al., 2012). And, population growth has a direct relationship with water scarcity in water scarce regions. In the last century, the population of the world has tripled and the water requirement has increased six times (Cosgrove and Rijsberman, 2000).

Compared to this, the impact of climate change is not that straight forward—and requires a long-term analysis of geo-hydrology with changing climatic factors. During the last half century, the temperature in Hindukush-Himalayan Region has increased by 1.3°C—the snowfall has decreased and glaciers are receding (Sabin et al., 2020). The long-term ISM rainfall of Himalaya shows a significantly decreasing trend (Palazzi, 2013). The rainfall variability is also associated with the topography and geographical locations—adding more complexity. These factors are the primary causes of water scarcity at regional scale. However, this is the fact that a significant proportion of rainwater drain out unutilized.

Since the Himalayan rivers are the source of fresh water for millions of people in the Himalaya and the north-Indian plain, the water scarcity in the Himalaya seems to be unbelievable. But, in view of the present scenario, water scarcity has a broader meaning than just the physical quantity of water. The factors such as scant infrastructure development, inequitable distribution of resources and inaccessibility to water poses difficulties in getting enough water for agriculture or domestic purposes have been identified as the indicators of 'economic water scarcity' (IWMI, 2007; The CEO Water Mandate, 2014). Therefore, the lay-person seems to be more concern for the immediate and more visible causes—the local cause of water scarcity. The tapped water supply has been projected as the big solution of water crisis in rural India and a considerable investment has been made to provide the household connections during the last decades under various schemes such as NRDWP. However, these schemes could not achieve the objectives because of the discrepancies in their planning and execution (CAG Report, 2018).

At local level there are a number of factors responsible for water scarcity like collapsed infrastructure and distribution systems, contamination, conflicts, poor management of water resources and anthropogenic factors.

Algal bloom in water tank

Uncovered and littered water storage

Dried water tank

Abandoned water tank

(Some examples of conditions of water tanks in Arunachal Pradesh; Photo: RGU)

Discrepancies in water supply System

Throughout the last few decades, the primary goal of water supply schemes has been to reach an increasing number of households while ignoring the ground realities and carrying capacities of the water source. These infrastructures are susceptible to minor tampering or disturbance caused by natural activity, humans, or animals. Because of the poor planning and limited capacity of the resources, they are underutilised in some places and incomplete and abandoned in others. In many cases, such as Dima Hasao, Assam, people were observed buying and repairing pipelines with their own money and efforts in the absence of timely solutions. In most places, the infrastructure is very basic and gravity-based, but during the dry seasons, water must be pumped up from the streams. All of these discrepancies in the supply scheme are evident everywhere.

(Brocken pipeline in Meghalaya; Photo: NEHU)

Anthropogenic activities

Anthropogenic activities such as deforestation, forest fires, and developmental activities have been reported to reduce water discharge. Obstacles in water supply or damage to natural resources have been reported from all over the Himalaya due to high-way construction. Hydropower projects have also been blamed for water scarcity in some media reports. There have been instances in Mizoram where road and highway building have destroyed supply pipelines. In many regions, there are reports of encroachment on water supplies at the local level.

Traditional water resources such as wells and springs have some geohydrological components that are very delicate and, if tampered, the sources can dry. The legacy of this traditional wisdom could not be continued due to the increasing water demand and the shift towards tapped water. At many locations where these sources were renovated through modern engineering material/cements, the discharge was reduced or the sources have dried up. Pollution is another increasing anthropogenic cause of water scarcity.

(Brocken pipelines due to developmental work in Uttarakhand; Photo: HNBGU)

Distance to water source

It has been highlighted that there is an abundance of fresh water in the Himalayas. The proximity of water resources has been an essential factor in traditional inhabitation.

However, with time, these sources have dried up or the demand has increased manifold—forcing people to walk miles for water. We observed that in mountain areas where people have to fetch water from natural sources, the average consumption is limited by their capacity to fetch water. The water fetching capacity is determined by the family constitution (such as number of family members, genders, age and health), distance from water sources, burden of other domestic and agricultural work, and the family's economic status. Families living closer to water resources or having more members can fetch more water. However, families with elderly people and small children restrict their usage accordingly.

The distance to the source also varies with the changing seasons and is maximised during the lean season. In several districts, such as Rajauri and Kargil in J&K and Tawang in Arunachal Pradesh, these distances stretch up to 3 km in the lean season.

(Girl fetching water from distance source in Meghalaya; Photo: NEHU)

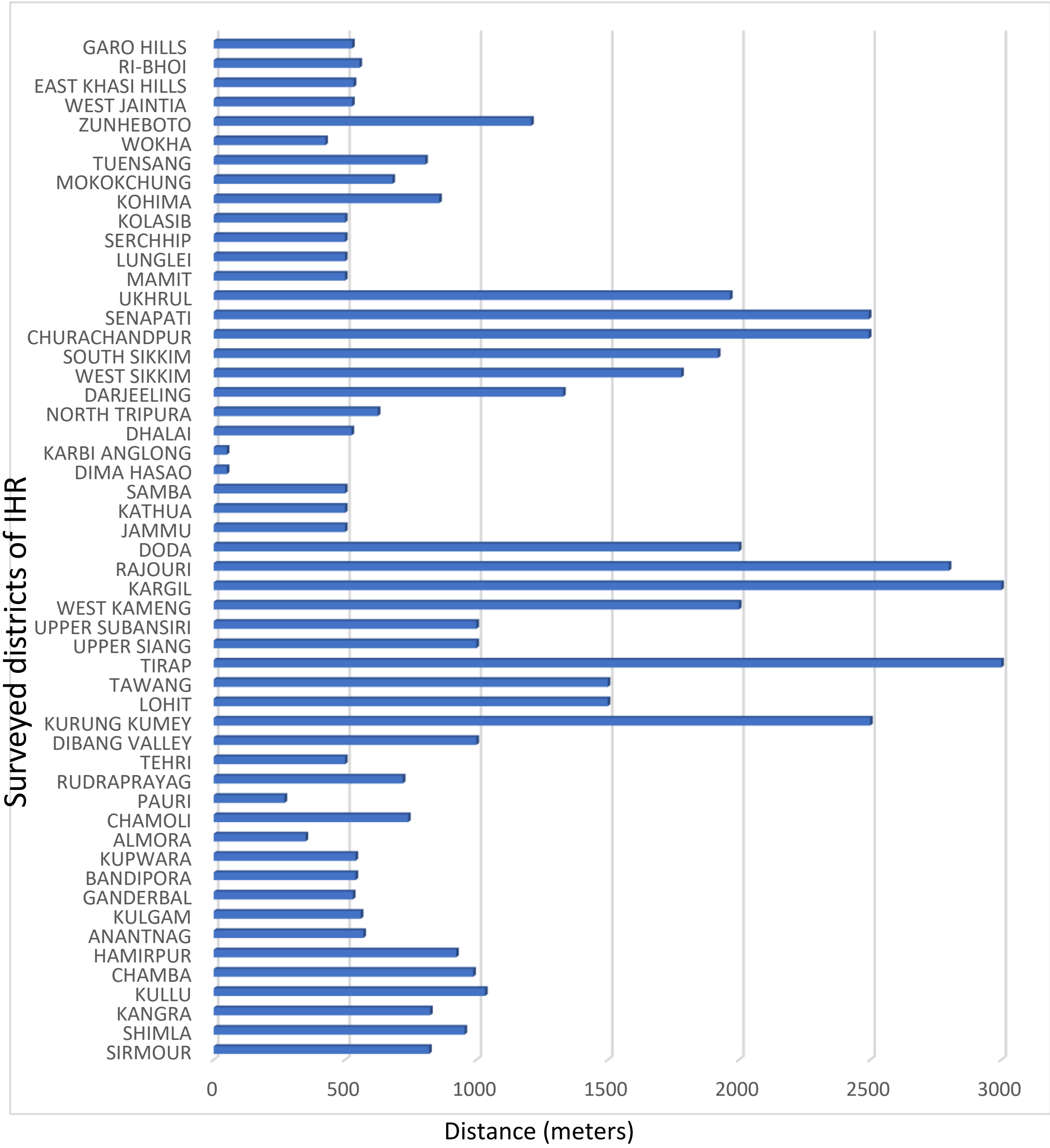
Natural Hazards

In some cases, natural hazards and developmental activities have also interrupted the supply of traditional water resources. The 2011 earthquake in Sikkim and associated slope failure significantly damaged the pipelines in the area and interrupted the drinking water supply (Tiwari, 2012), which is also confirmed by this survey. Frequent damage to water infrastructure due to flashfloods/floods has been reported in Uttarakhand and Arunachal Pradesh. During the flood, reports of clogging of the water lines and treatment units are very common (TOI, 2019). However, the damage to the smaller schemes supplying water to remote areas is mostly under-reported.

(Damaged pipeline due to landslide in Uttarakhand; Photo: HNBGU)

Forest type and land-use

People also believe that certain tree species, such as oak, are more efficient in facilitating water percolation and recharging the aquifer compared to others, such as pine. (Singh and Pande, 1989), which seems plausible because the composition of the superficial material also determines the rate of percolation and recharge (Illien et al., 2021). In some villages in Mizoram, people complained about teak plantation for absorbing huge amount of underground water. Though this is a broader view among people, in a few areas, the tree species of the forest are not in accordance with this observation. Therefore, the relationship needs to be worked out through more empirical studies. Meanwhile, the deforestation and overexploitation of forest resources in some parts of the Himalaya might have aggravated the problem. For example, 32% of the surveyed villages in Mizoram reported a decline in forest cover around their villages and catchments. In the past, the hilly region had a cooperative/volunteer water governance system, but it is no longer in operation, and people now rely on government aid for these tasks.



(Average distance (in meters) of water resources from houses in surveyed districts of IHR; Survey-2021)

Some observations on the impact of deforestation on water quality and quantity

Rainwater and other surface water percolate through the soil overburden and fill the rock fractures that form the aquifers in mountain regions. Thus, the composition of the soil overburden significantly influences the rate of percolation and, finally, the discharge of the springs (Illion et al., 2021 and references therein). The dense forest cover also facilitates the percolation, and therefore, forest depletion can be directly linked with the decline of spring discharge. People have reported the impact of changing forest types on spring's health. It was observed that the natural springs located in the forest of oak and other broader leaves trees are still sustaining. However, a quantitative account of such a study is lacking from Himalaya. Nevertheless, reducing water recharge because of deforestation is an important issue in the Indian Himalayan Region, and it varies from NW to NE.

In the NE Himalaya (Assam, Arunachal Pradesh, Nagaland, Manipur and Mizoram), deforestation is also blamed for declining water availability. The catchment areas of many rivers are undergoing deforestation due to jhum cultivation, landslides and reckless destruction of forests. Due to large-scale deforestation, mining, and jhum, including commercial cash crop cultivation, the small rivulets and springs are gradually drying up (Down to Earth, September 9, 2021). For instance, in Arunachal Pradesh, unregulated logging and mining activities have degraded the water quality for many years and led to the drying up of small streams near Rangrinkan village in Changlang district (The Arunachal Times, November 22, 2021). The field survey data also revealed that deforestation is one of the reasons for the drying up of natural water resources in the above states.

The Ministry of Environment, Forest and Climate Change revealed that Nagaland lost 235 sq km of forest cover in two years, as per the India State of Forest Report (ISFR) 2021. Manipur is observed with 27.30% of the total geographical area under land degradation for the period of 2020-21, out of which the forest/vegetation degradation is approximately 26.82% (Desertification and Land Degradation Atlas of India). It has further impacted the water recharge and aggravated the water scarcity during the lean season, where about 54 % of the villages depend upon spring water resources. Another north-eastern state, Mizoram, is experiencing the highest deforestation among the Indian Himalayan states (India State Forest Report 2017). The state's forest cover has decreased by 531 sq km from 2015 to 2017 mainly due to the shrinkage of the moderately dense forest. The Darjeeling region of West Bengal has recorded heavy deforestation and excessive cultivation, and soil erosion has increased considerably in recent times. Land use patterns and changing characteristics over the last 150 years highlight that the forest cover is under threat due to the rapid increase in cultivated land (except tea gardens), settlement expansion, and road construction.

However, in Sikkim, the forest cover has increased by approximately 4% over the last 20 years. The rural water sources have rejuvenated, wildlife populations have gone up, forest gaps have been filled, and soil erosion has been checked to a larger extent. Water bodies have increased by 2 km^2 due to the protection of forests with strict enforcement of relevant forest laws and rules in the State. Forest felling and grazing are banned in the state of Sikkim. Sikkim has, however, witnessed increased forest fire incidences over the years. Reportedly, the fire incidents have damaged a total area of 5,047.16 ha of land.

Uttarakhand, Ladakh, Himachal Pradesh, Sikkim, and Arunachal Pradesh are the states where the glaciers are the major source of freshwater besides the natural springs, but climate change and subsequent resource depletion and deterioration have impacted the water quantity.

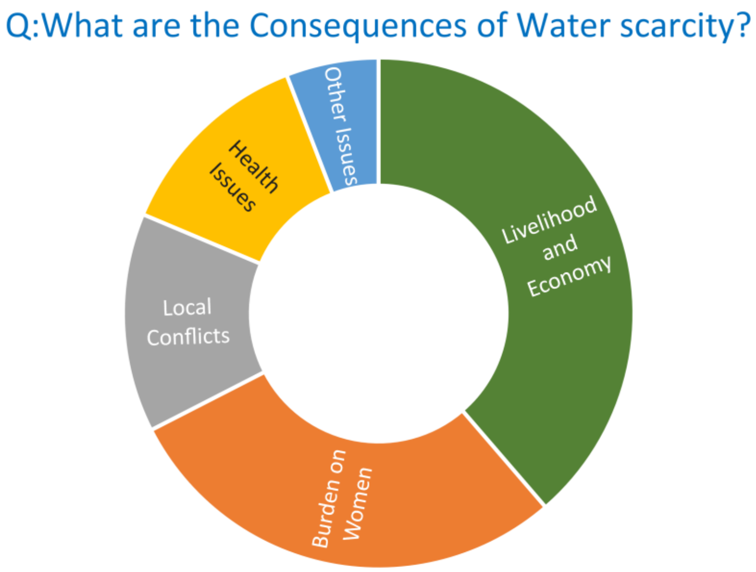
Though forest felling has been banned entirely in the Uttarakhand Himalaya after the 1970 Chipko movement, in recent times, thousands of trees were cut down to widen the roads under the Chardham Project and the Railway Project of Uttarakhand. The direct relation between deforestation and the depletion of natural springs is not easy to establish, but there have been cases where these activities have substantially reduced the discharge. In addition to this, frequent forest fires have been a major challenge that has had a severe impact on biodiversity, but it is impacting the natural resources by pumping black carbon into the atmosphere that has been found to facilitate glacial melting and cloud nucleation. These phenomena may increase the number of flash floods and water supply disruptions.

Due to forest fires, hundreds of hectares of the forest are damaged every year. Besides, there is an unaccounted loss of other green covers, mainly shrubs and small plants. Forest fires significantly affect soil productivity, changing the forest structure and causing soil erosion. All these impacts reduce the percolation and ground recharge.

(Forest fires and biodiversity loss in Uttarakhand. photo courtesy: Dr. Hemant Dhyani)

The survey responses in this study suggest that the 'mismanagement of water resources' is the most prominent cause of water scarcity. Because tapped water has been identified and highlighted as the immediate solution, the issues related to water supply systems are more evident. This raises a serious question about the schemes of tapped water supply to each household, such as *har ghar jal* in the mountain region, without carefully assessing the water potential and cost of the infrastructure. (Photo: HNBGU)

Consequences of water scarcity



Four major consequences of water scarcity are identified (based on responders' views): Impact on livelihood and economy; burden on women and children; increase in local conflicts and health related issues.

Impact on livelihood and Economy

The rural population of Himalayan region identified water scarcity as a slow but prominent threat to their livelihood. In particular, the problem seems to impact the livelihood and economy of the people who are fully or partially dependent on agriculture and animal husbandry. Some studies have also highlighted the fact that if water scarcity increases (or demand of water), the people will gradually depart from agriculture (and allied activities) due to lack of water for irrigation and livestock. Though, agriculture contributes only a small portion of the state GDP in hilly states (Economic Survey-Uttarakhand, 2021), but this form essential means to run the economy of hilly region in the absence of alternatives. For example, in Sikkim, people are shifting towards labor work from agriculture—and this situation prevails throughout Himalaya. In addition, the direct/indirect income from agriculture is more important for the low-income population to sustain.

Burden on Women and Children

The people believe that declining water resources/increasing demand is putting pressure on water resources and forcing people to track a considerable distance as well as spend more time in this work. This will cause hindrance in the other daily chores. A study claims that about 72% women and 14% children fetch water from the source (Sharma, 2018) in Uttarakhand state.

(Women fetching water in Arunachal Pradesh; Photo: RGU)

The burden is more on women because most of them have to walk at least 0.5 km, which increases up 4 km in some cases for water. Whereas, waiting hours for waters in queue is also common in these situations. This has direct impact on health and education of women and children. As per our survey the distance of water resources from houses (mainly for springs) varies between 50m and 4.5 km (average 1km) in Himalayan region. In some cases, people have to carry water on mules and trucks from 8-10 km.

Local Conflicts

Often the supply of water from a source of one village to another village becomes the matter of conflict due to the traditional ownership on resources. So far, the water resources have been unofficially owned by the villages and communities. The positive side of this system was that it also motivates people for maintenance and hygiene of the resources. The nationalization of the water resources has changed the system and people are unwillingly sharing their traditional water source with other communities. Whenever the scarcity will increase this unwillingness may transform into the conflicts. The conflicts also exist between different classes of the societies, where the higher classes have better hold on resources such as wells and springs—and the lower classes are prohibited to take water from these sources (e.g., Uttarakhand). These conflicts become more visible during the seasons when the discharge in most of these sources decline significantly. During the water delivery and distribution via trucks and tanks in the event of a shortage, many discrepancies and conflicts emerge. Surprisingly such conflicts are also reported from high rainfall states such as Meghalaya, Sikkim and Mizoram during the lean season. In the absence of a systematic and sufficient supply, at places such conflict also increases among villagers during the peak irrigation season (e.g., Himachal Pradesh).

(Children fetching water in Meghalaya; Photo:NEHU)

Health Issues

In the Himalayas, the water from natural springs is usually considered adequate for drinking. However, the water quality has been declining along with the quantity of water in the region. People have mixed experiences with the quality (good to bad) of tapped water. Recent studies have reported several harmful chemicals and biological contaminants in the spring water of the Himalayas (Kothari et al., 2021). In particular, the presence of total coliform (TC) and faecal coliform (FC) in the spring water of the Himalayas is a matter of concern (Tyagi et al., 2015).

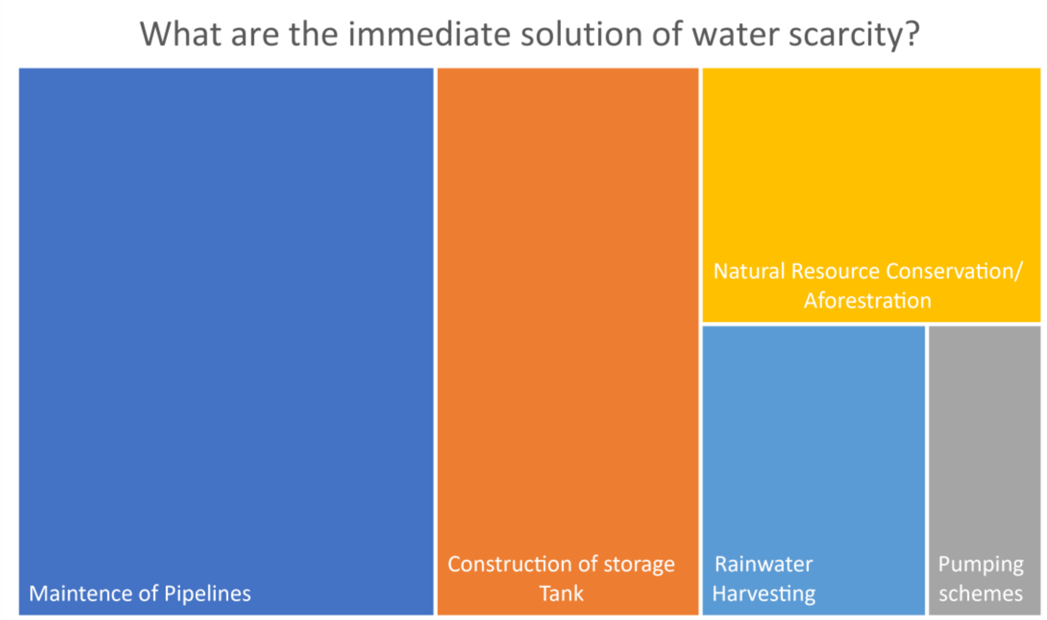
People have also noticed the impact of water scarcity on their health because water scarcity has a direct impact on sanitation practises. Lack of hygiene practises is the major cause of the gastro-intestinal problem (Prűss et al., 2002). Water-related diseases like diarrhea, hepatitis, roundworm, hookworm infection, trachoma, guinea worm, schistosomiasis, leishmaniasis, lymphatic filariasis, cholera, and malaria have been reported from every corner of the Himalaya. Biological contamination is increasing in natural resources due to human activities. Though, the concentration of chemicals is still within the acceptable limit in most places, it is also a matter of concern in some regions. It is noticed that people of Karbi Anglong district of Assam, suffers either from dental or skeletal fluorosis type of diseases due to the high concentration of fluoride in the water.

Water scarcity will cause more expenditure on fetching water in terms of money and time, which may have secondary consequences such as migration and health issues. Water scarcity has lready been attributed to the outmigration in the Pauri district of Uttarakhand state (Singh, 2016). However, some cases of migration due to water scarcity have recently been reported from Ladakh. A water crisis due to migration is also perceptible where rapid (semi)-urbanization is taking place (e.g., Imphal valley).

(Children fetching water in Uttarakhand; Photo: HNBGU).

(People storing rainwater for domestic use; Photo: HNBGU)

Solutions of water scarcity



Given that the layperson is considerably more familiar with the local environment and concerns, we solicited recommendations from locals for a practical solution to water scarcity. They offered a few options, which we have classified into the five categories depicted in the preceding presentation—which demonstrates the critical necessity for effective water infrastructure. These answers are straightforward and self-evident—and are not detailed individually.

People have reported the poor water infrastructure in every part of IHR. The schemes could not become viable alternatives to the traditional resources. But they are still the big hope for people. For instance, the pipelines have been laid down under different water schemes but people are still waiting for water (e.g., in Meghalaya). Therefore, the construction of water tanks of the required capacity, the digging of wells, the installation of hand-pump, the proper fitting of pipes, and the cleaning of tanks are the primary solutions for the layperson. They also suggested an investment in a scheme for pumping water from the rivers. Public opinion differs considerably from the views of experts, because they are more concerned with the immediate solution. People usually don't think about the long-term effects of climate change, population growth, and changes in lifestyles, which are important to experts when they come up with solutions. However, their responses also reflected a sustainable approach, such as tree planting, water harvesting, and the construction of conservation structures.

Most of the studies related to climate change and groundwater indicate a drastic decline in the number of Himalayan springs and discharge, which seems inevitable (The Hindu, December 7, 2015). Clustering of villages into semi-urban localities is also a growing trend in response to changing lifestyles and socio-economic conditions

(Satterthwaite, 2010). Such trends are everywhere in the Himalayas (e.g., Uttarakhand, Imphal valley of Manipur, etc.). This trend, on the one hand, will increase the demand for water, but at the same time, it will provide an opportunity for easy decision-making for a substantial solution.

A layperson believes that the water supply system needs to be more efficient to deal with water shortages.

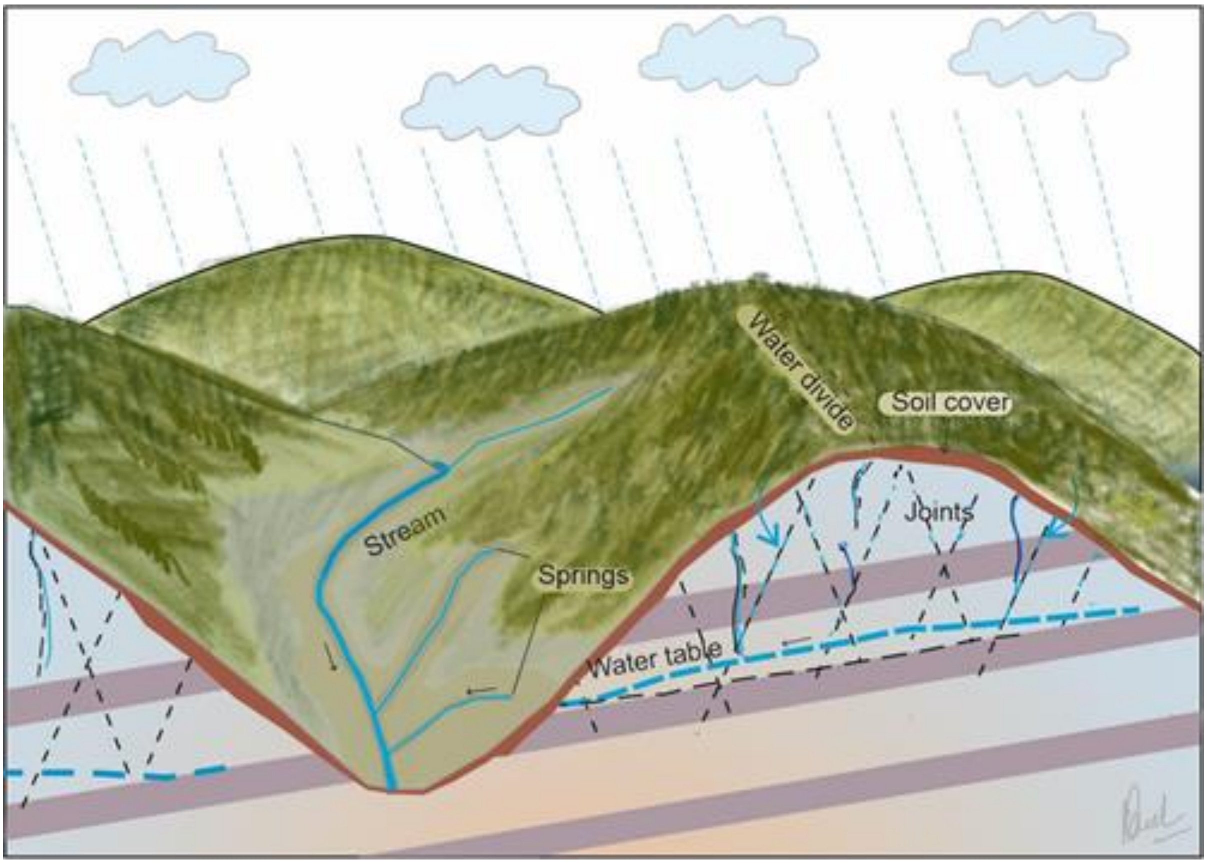
Rainfall is the primary source of water in the Himalaya, which is limited to a few months, and a major portion of this water is also wasted through surface runoff. A small fraction of rainfall can fulfil a substantial proportion of human needs. For instance, only 3% of the annual rainfall of Uttarakhand state is sufficient to fulfil all domestic, industrial, and agricultural needs of the state (Water policy of Uttarakhand, 2019). The conservation and harvesting of this water has to be promoted through adequate storage and recharge methods. The construction of recharge pits and ponds has to be monitored through a participatory approach under the supervision of a specialised agency/organization. And, the success rate and response of these structures need to be documented for improving the site-selection and construction methods.

The geological setup of Himalay is very complex, which also causes an obstacle in the adaptation of simple recharge techniques. Therefore, many of the geohydrological solutions for spring recharge have been site-specific. Research on the recharge mechanism of the mountain aquifer and aquifer mapping also needs to be encouraged to create the resources for action-oriented research. In the Eastern Himalaya, some non-government organisations have initiated such experiments, which are providing good results.

If we see the total demand as per the benchmark criteria (55 lpcpd), we have to make a big investment in developing an efficient infrastructure for sustained water supply. For this purpose, the water supply components have to be an integral part of the mega-scheme on rivers. At the same time, initiatives need to be taken to demand regulations. Without making sure that enough water is collected and that there is enough infrastructure for maintenance, the idea of water reaching to every home seems impossible and unsustainable.

As water scarcity is directly associated with health issues (Prüss et al., 2012) and stored and tapped water have more chances of contamination, sufficient efforts have to be made to maintain the purity of water. In some studies, the amount of faecal contamination has been highlighted as an increasing threat to Himalayan water resources (Seth et al., 2016). Therefore, the construction of toilets has to be done in the proper way.

The majority of the population of the Himalayan region is associated with agriculture and allied activities. In the event of increasing water scarcity due to erratic rain or other climate change induced factors, agriculture will be severely impacted. People raised their concern about it during this survey. The decline in agriculture output may have secondary consequences, such as poverty and migration. In order to support minor irrigation, the techniques of irrigation have to be modified, such as the replacement of flood irrigation with sprinkle irrigation, etc. It is felt that the traditional wisdom of water harvesting and conservation has been lost to a great extent. People have to be provided with adequate knowledge through participatory approaches, training, and workshops. The concept of citizen science needs to be used to develop a task force of para-geohydrologists.

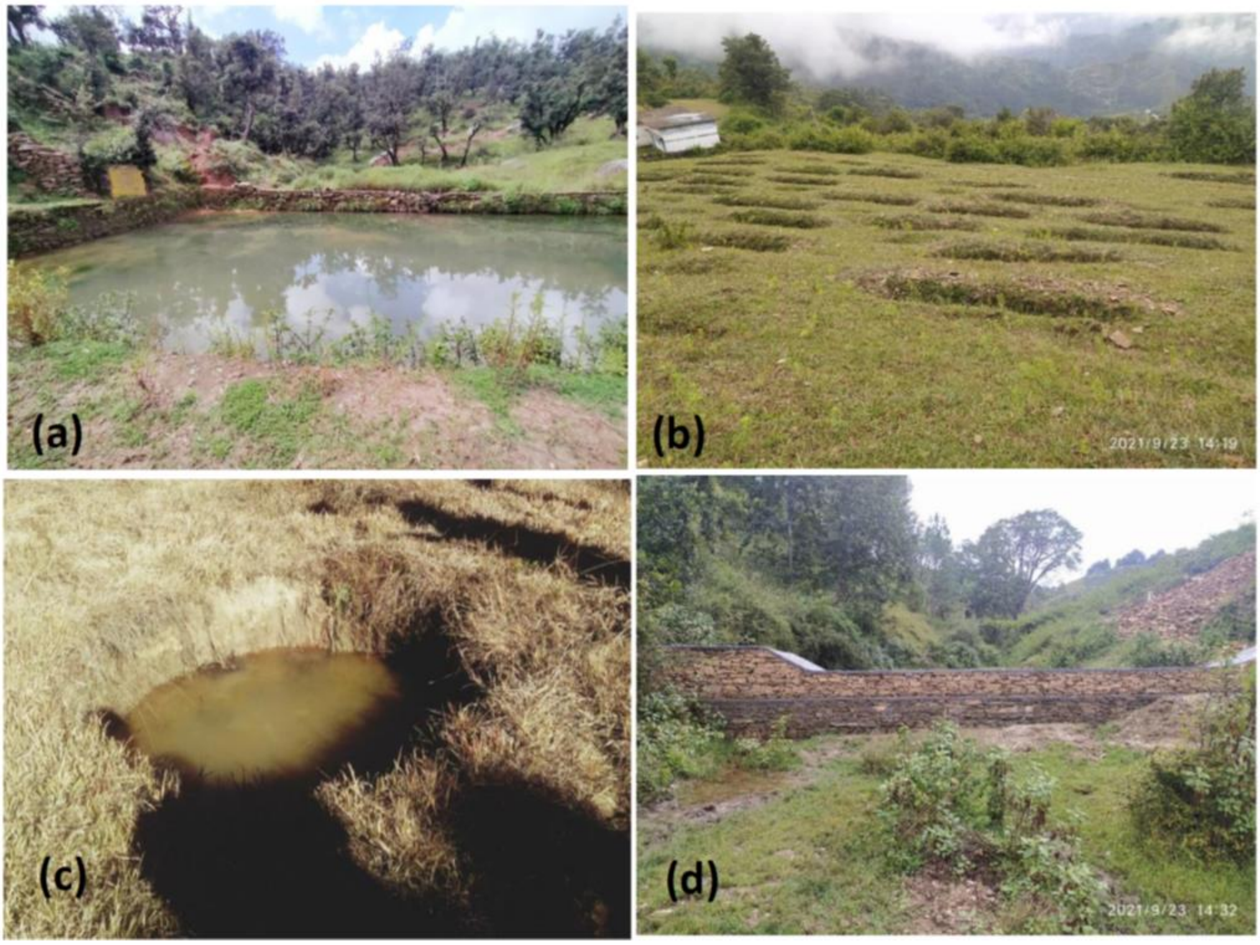


(Figure: A conceptual model of Groundwater recharge mechanism in mountains)

Springshed Management: A long-term solution

The availability and accessibility of groundwater are determined by a variety of hydrological, climatic, topographic, and geological factors. The majority of Himalayan rocks are metasedimentary, metamorphic, or igneous, with little primary porosity, insufficient to generate an aquifer. In mountain terrain, groundwater is stored in secondary porosity generated by fractured and jointed rock mass. Due to gravitational force (or seepage), this water flows towards lower levels—generally downslope—and forms springs where it comes into contact with the surface (CGWB, 2014). However, when the water table rises owing to constant recharge, it occasionally comes into contact with the surface and forms a spring. Groundwater transit is determined by the characteristics of the rock mass and other geological factors (Agarwal et al., 2012). Precipitation and surface water flow through a superficial 'vadose zone' during percolation before filling the deep storage (saturated zone). Thus, in addition to the amount of precipitation, the composition of this 'vadose zone' influences the rate at which these aquifers store water (Illion et al., 2021 and references therein). In the monsoon-dominated Himalaya, the water budget is largely determined by rainfall, snow-glacier melt, and a small amount by evapotranspiration (Andermann et al., 2012); hence, these factors also influence the distribution of groundwater and yield in the Himalaya. Due to the fact that water percolation is impacted by the complex arrangement of recharge zone characteristics, a spring's perennial ecological flows may be altered to lower base flows or seasonal flows in the event of a disruption in this environment. As a result, springshed management entails restoring natural conditions and constructing structures that aid in percolation into the ground.

The topography of the Himalayan Mountain range comprises a complex geology characterised by a range of structural and lithological variability. These topographic and structural complexities lead to the extension of the recharge area (or aquifer) of a spring beyond the catchment boundary. So, the augmentation efforts need to be expanded beyond the catchment after the delineation of the recharge zone by a thorough geological investigation of the rocks and topography of the area. The springshed management activities are usually focused on mitigation of the impact of climate change and land-use change on the recharge area. And the actions are usually implemented through a participatory approach merged with ongoing developmental initiatives. The following are some engineering techniques used to develop a springshed:



(Common groundwater recharge techniques: a-Pond; b-Trenches; c-Percolation pit; d- Check dam; Photos: HNBGU)

Pond: Ponds (often called "chaal-khal") are the traditional and most prevalent structure used for collecting surface runoff and increasing water percolation to recharge the aquifers. Ponds are often built on terrain with a slope of less than 5 percent and also serves for irrigation, domestic and livestock needs.

Trenches: In hilly or mountainous environments, trenches are a common treatment method for increasing groundwater and controlling erosion. It reduces surface runoff during rainstorms and allows for significant water infiltration. Trenches can often be built up to a 50% slope of land, and the dimensions are typically 2 m long, 0.45m wide, and 0.45m deep, which may vary according to slope. For effective results, the trenches are constructed in a few patterns depending on the slope and soil type. Trenches are divided into three categories. 1. staggered contour trenches, 2. continuous trenches, 3. trenches along the retaining wall.

Percolation Pits: In the Himalayan regions where the slope is between 40% and 60%, percolation pits are formed as recharge structures. Generally, these pits are approximately 1 x 1 x 1 ft.

Check dams: Check dams are used in drainage lines to control stream velocity and soil erosion. This type of structure is built across the channel or drainage bed. Check dams are used to prevent gully or drainage erosion, as well as to increase siltation for plants upstream of the channel. Check dams are constructed from a variety of materials. Rocks, gravel, logs, hay bales, and sandbags are frequently used as temporary construction materials since they are inexpensive and readily available.

Vegetative measures: Vegetative measures include the planting of grass saplings and seeding operations in the recharge region of the source to improve moisture retention and erosion control in a specific area. The roots of plants or trees generate infiltration galleries, which are critical for water infiltration and also serve to hold the soil cover in the recharge region.

(Educating and involving people is key to successful springshed management. *Photo courtesy: Vargish, PSI*)

Scope of cost-effective irrigation techniques

Most of the Himalayan agriculture depends on rainfall, which is heavily influenced by the fluctuation of precipitation due to climate change. Poor groundwater potential and complicated topographical conditions further increase the difficulty of the mountain irrigation system. Considering the crop pattern, socio-economic conditions and physical constraints, the erratic rainfall substantially impacts the production of traditional crops. Though increasing the efficiency of water use may be the most critical priority in water-scarce places (Chawdhary et al., 2016), such as IHR, technological intervention can regulate demand for the production of valuable crops and vegetables.

Many physical and social aspects, such as the nature and locations of water supplies, rainfall conditions, crop patterns, people's economic conditions, and affordability, influence the selection of an adequate (water-saving) technique for irrigation. The availability of water resources and their locations are essential in the selection of the technology. At the same time, the availability of funds for investment can be a deciding factor. In IHR, a few sustainable irrigation systems have been in practice, which need to be revived with the help of technology and policy intervention. For example, the bamboo drip irrigation system of Meghalaya, the Zabo system of Nagaland and the Apatani system of Arunachal Pradesh, Dongs of Assam are among the best examples (see pg. no. 42-44) of sustainable water management. The sprinkle or drip irrigation system has been identified as one of the efficient irrigation techniques in irregular and high slopes with high infiltration rates or water scarcity. However, the appraisal of the crop's optimal return will greatly influence how and what technology can be used. Therefore, the local conditions' advantages and disadvantages must be considered when choosing an irrigation method. Some of the water-saving techniques are discussed here under:

Sprinkle and drip irrigation: This method is designed to reduce water wastage by supplying water directly to plants. This method effectively reduces soil erosion and water loss due to surface run-off and evaporation. In general, gravity pressure maintains water supply and sprinkling, and several advanced emitters have been designed to decrease water loss and maintain equal pressure down the hills. Such technology might cut water usage by up to 80% while maintaining optimal moisture levels in the root zone for maximum yield (Kumar et al., 2020b).

(Use of sprinkle in place of flood irrigation to save water; *Photo courtesy: Dr. B.P. Bhatt*)

Poly tanks*:* One of the most viable solutions for improving irrigation in the Himalaya is rainwater harvesting (Kuniyal, 2003). The main difficulty in rain-fed agriculture is storing rainwater and making it accessible to crops. Poly tank is one of the least expensive ways to keep and use rainwater (Kumar et al., 2020b). The construction of these structures requires very little time, money, and skill.

These tanks can be built temporarily and for a long time by placing a poly sheet within a pit or trench of various sizes. These tanks can be used to provide water to valuable crops through the gravity-based supply system.

Crop-diversification: Crop diversification refers to the adoption of a broader range of crops to improve the production of more profitable crops over conventionally cultivated crops. This notion is also helpful for adapting to climate change and mitigating risk. It has been argued that crop diversification can aid in combating water shortage by introducing more resistant (drought tolerant), valuable crops that provide the best return on investment for technological interventions. The implementation of crop diversification in Himalaya, which poses challenges (Pratap, 2011), must be adopted cautiously by analyzing market requirements and long-term effects.

Mulching: Mulching is the method of covering the soil with organic or inorganic material in order to reduce water loss through evaporation and increase soil fertility. Wintertime germination of seeds in mountain ecosystems where agriculture relies mainly on precipitation is hampered by the loss of residual moisture. Under these conditions, mulching can significantly enhance water productivity (Ngangom et al., 2020).

(Poly tank are the low-cost and easy to construct water harvesting structures-. *Photo courtesy: Dr. B.P Bhatt*)

Success stories of water conservation and harvesting practices in IHR

i. Successful Rainwater Harvesting Projects of Arunachal Pradesh

Rainfall in Arunachal Pradesh varies greatly in both time and space. In such a situation, water storage becomes critical to combat scarcity. As a solution, the state government has begun rooftop rainwater collection and artificial groundwater recharge projects under the 'Groundwater management and regulation' plan, which encompasses 235 projects across 11 districts. The programmes intend to make rainwater harvesting mandatory for all buildings in the state using their resources (TOI, 2012). These projects were completed successfully and handed over to the user agencies for operation, maintenance, and water use for various purposes. Ruskin was the first successful project (East Siang district).

ii. Resolving Shimla water crisis in Himachal Pradesh: a lesson for water management

The 2018 Shimla water crisis was a wake-up call for the Indian Himalayan Region, as residents were without fresh water for nearly a week. However, it became a success story and a model worth replicating in other regions. Water availability in the hill town was increased from 38 million litres per day (MLD) to 49-51 MLD thanks to the efforts of the local and state governments volunteers and stakeholders. Several measures were adopted throughout this work to boost water availability from the sources and to correct the existing water supply system. People were also trained on how to handle water more efficiently due to this campaign. Following the success of this campaign, the authorities intend to repeat the approaches in other tourist-friendly towns throughout the state. This narrative suggests that better water resource management can significantly alleviate the situation.

(Rainwater harvesting, Mizoram; Photo: MU)

iii. Strengthening the legacy of Rain water harvesting in Mizoram

Mizoram has a long tradition of collecting rainwater for domestic consumption, and most homes have sloping roofs with corrugated sheets to aid in rainwater collection. Due to inadequate storage, however, this water does not last until the lean season. The Jal Jeevan Mission made an effort to build water harvesting reservoirs and catchment roofs in the village of Vachengte. This project has aided in meeting the community's water needs throughout the dry season and providing free water to all families. Another example of water governance through community activities is Leng village's water conservation practices. For water conservation initiatives, Leng village has been awarded the "Best village in North East India" by the Ministry of Jal Shakti. Moreover, the spring shed management concept is also being implemented in some villages of the state.

(Spring revival activities in Nagaland. *Photo: Vargish, PSI*)

iv. Spring revival to sustainable water supply in villages of Nagaland

Despite enough monsoon rains, Nagaland's peasants endure a severe water shortage every year during the lean season. Senior executives from Department of Land Resources (DoLR) under Pradhan Mantri Krishi Sinchayee Yojana-Watershed Development Component (PMKSY-WDC) cooperated with the People's Science Institute (PSI) in 2015 to start spring-shed management in the state. First, they chose 11 springs in 11 districts around the state and carried out a variety of engineering, environmental, and social measures to improve aquifer recharge. Thanks to the DoLR’s keen attention, the programme was effective, and a large rise in spring discharge was seen. This accomplishment prompted the agencies to develop a state wide plan for safeguarding the rural drinking water supply. As a result, in 2018, a coalition of partners led by RD&DoLR, PSI, ACWADAM and the North East Initiative Development Agency (NEIDA) took on the challenge of securing potable water in 100 villages across the state—and significantly improved the discharge of 105 springs in 95 villages. The fund for these spring-shed management efforts was converged from the Rural Development-MNREGA budget.

The DoLR and PSI have also gone through comprehensive exercises as part of the NMHS programme to assess the water demand and supply gap and select communities for spring shed management efforts. For example, Khrimtomi, a village of around 120 families, recognized a great demand and supply mismatch. The Kuhuboqazu spring in Khrimtomi village was chosen for rejuvenation because of its proximity to the community, the people's reliance on it, and its feasibility. The village has 120 families, with 80 of them utterly reliant on Kuhuboqazu spring for their drinking and domestic needs. Digging 300 trenches with recharge ponds, planting 8000 coffee saplings as a vegetative measure, and constructing a collection chamber and pipeline link up to the community were all part of the intervention. As a result, the people have had access to water all the year, even throughout the dry season. This is the narrative of many more villages in Nagaland that have been turned into sufficient water thanks to the DoLR's continual and meticulous attention.

v. Dhara-Vikash program of Sikkim: A milestone of watershed management

Sikkim faces water scarcity during the dry winter season. In 2010. A Spring shed Development program called 'Dhara Vikas' was initiated by Rural Management & Development Department, Government of Sikkim partnered with DST, WWF-India and People's Science Institute, Dehradun and many others to overcome this problem. The program was initially based on a series of participatory activities to reduce the surface runoff of rainwater to enhance the ground recharge and then with many conservation practices and training for developing para-hydrologists.

The key aspects of the Dhara Vikas Programme are: ensuring rural water security; resource mapping through the creation of Village Spring Atlases; Spring-shed Development Works; MG-NREGA-funded programme; capacity building in collaboration with WWF-India and People's Science Institute etc.

This unique program of community efforts, guided by technical experts and scientists, funded by public resources was a successful endeavour that revived many springs, recharged lakes and reforested many hilltops in Sikkim. In the long run, the program positively impacted livelihood and economic practices due to improved irrigation. This has motivated farmers to cultivate new crops, but a significant increase in the yield of the irrigated crop was also recorded in the project area. In addition to the direct benefit to the people, this program has also helped in environment conservation.

vi. From the restoration of the Garh-Ganga to the provision of sustainable water in Uttarakhand's Chured Dhar: a few ideas worth replicating in IHR.

Mr. Sachidanand Bharti, a school teacher in Uttarakhand's Pauri Garhwal area, spearheaded one of the most successful initiatives, the 'Paani Raakho Andolan.' This was a campaign to raise awareness about the importance of water conservation. Thousands of water pits (Chal-khal) were built during this effort in a water-scarce area of Pauri Garhwal, transforming the arid terrain of a Gadh-Kharak village into a water-rich area. The success of this initiative inspired people to implement a spring shed project to address the state's water scarcity.

Before a few years, residents of Chured Dhar village in Uttarakhand's Tehri district had no choice but to descend 1km down the hill to obtain water for their domestic needs. Since 2002, an NGO named Himmothan has been striving to alleviate the situation by supplying villages with a rooftop water gathering system. For the lean season, however, the situation remained unresolved. And to help relieve the issue, the NGO created a solar system to pump water to the village. A number of engineering structures were created in the catchment region to improve the discharge of the source, including Gully plugs, Recharge ponds, Contour trenches, Brushwood check dams, Crate wire Check dams, and RR Dry check dams—and a considerable increase was seen. The villagers manage this system, which runs for 2-3 hours every day and stores water in a 6000-litre tank. This village of 38 families now has year-round access to safe drinking water.

(Community managed water supply in Chured Dhar, Uttarakhand; *Photo: HNBGU*)

There are many more achievements of Himmothan, such as the initiative concentrated on spring-shed management in 312 communities in the Pithoragarh district. This is an example of a more scientific project in which hydrogeological knowledge and participatory approaches were used to determine the causes of drying springs. Then the recharge structures were built in stages. The cooperation of scientific institutes and local people was key to this endeavour. According to the Tata Trust, many streams have significantly been revitalized (for example, 6 LPM to 30 LPM) in the project area. The trust has also concentrated on educating people and developing opportunities to maintain a consistent supply and actively solve their problems.

Water conservation and harvesting practices

Water resources in IHR

India contributes about 4% to global water resources. The country receives about 117 cm (4000 km3) annual precipitation with a considerable variation in space and time. Out of this total yearly precipitation, only 1869 km3 flows in the rivers as an annual average potential flow and only 1123 km3 of this can be utilized (Mir, et al., 2021). The IHR is endowed with plenty of natural water resources in the form of glaciers, perennial rivers/ streams, lakes, springs, and groundwater. There are three principal river systems, namely the Sind (Indus), Ganges and Brahmaputra, with numerous tributaries that form the backbone of the region's economy. In terms of utilizable flow, the Ganges, with 421 BCM of water, is the richest basin (INAE, 2012). Apart from the major river systems, other freshwater resources such as lakes, springs, and glaciers also yield about 500 cm3 water/year (Sati, 2015). Out of these resources, the springs form the primary source of freshwater for the Himalayan region. And, out of the total five million springs of India, about three million are located in the IHR (NITI Aayog, 2017). Springs are the expression of groundwater in the mountain region, and groundwater is the most widely exploited water source for fulfilling India's domestic and irrigation demands (CGWB, 2006). It contributes nearly 62% in irrigation, 85% to the domestic water supply and 50% to the urban water supply of India.

In this study, we found rivers/ streams, springs, wells, and ponds as the major natural water sources used by the local people to meet their domestic and livestock water requirements. The mountain communities had efficiently managed the mountain springs for sustainable water utilization like Dhara in Uttarakhand, Baudi/ Nawn in Himachal Pradesh, Nag in Jammu and Kashmir, etc. Springs are also believed to be sacred sources of water and worshipped by people of many regions, such as the ethnic people of Arunachal Pradesh. The utilization of groundwater resources through shallow wells (Naula), dug wells, ring wells, tube wells, etc., were observed in various states of the IHR. Besides, the use of ponds to meet daily water requirements in Assam (Dongs) and Arunachal Pradesh have also been found.

Traditional wisdom on water harvesting and conservation

India has a long and outstanding tradition of systematic exploration and development of water resources. Many villages in the remote hilly regions still use the old water harvesting system (Rautela, 1999). Rainwater harvesting has been practised in

India for many centuries, and the traditional harvesting system proved to be more successful for domestic needs (Borthakur, 2008). The IHR is inhabited by diverse ethnic groups enriched with traditional water conservation and harvesting practices. The Uttarakhand and Himachal states of the NW Himalayan region, have a glorious profusion of water harvesting structures. The decoration and architecture of these structures point towards the people's deep attachment with their water resources. These structures are living examples of sustainable technologies as the local people continue to use them even after hundreds of years of construction. There has been a tradition of building small ponds called Chal-Khal to store the rainwater in many parts of Himalaya, primarily for livestock and secondarily for recharge purposes. Usually, these ponds have a dimension of 10 to 15 meters with a depth of 1-2 meters. These ponds were located in places where the topography allows maximum water collection. With time, due to the deposition of clay at the bottom, these pits retain water for a considerable period with controlled percolation (Rautela, 2015). This also caters for the need for livestock. These percolation pits used to be built and maintained by mountain communities.

Some of the best examples of traditional rainwater harvesting practices of the region include Zing-Tanks for collecting water from ice in Ladakh; Kuhls, Naulas, Baoris, Nauns, Dharas, Panihars, Chharedus, Chal-Khal, Khatris, etc. in Jammu & Kashmir, Himachal Pradesh and Uttarakhand; Apatani system of terraced plots, bamboo pipelines and concept of sacred water sources in Arunachal Pradesh; Zabo arrangement for collectin runoff in Nagaland; Bamboo drip irrigation in Meghalaya; Dongs (ponds) in Assam, etc. Further, the villagers of Manipur and Mizoram are often involved in social forestry to conserve spring sources in the hills. At the same time, recharge pits are reportedly being identified and protected by the people in Tripura. Besides, the region's indigenous communities are also known for sustainable utilization of water resources through traditional water flour mills (Gharat in Himachal Pradesh & Uttarakhand and Chuskor in Arunachal Pradesh). However, the conventional wisdom of water resource management strategies is losing ground nowadays. Therefore, there is an urgent need of combining traditional sound practices with modern scientific knowledge for reasonable and sustainable utilization of the available water resources.

(Tradition water storage in Tripura; Photo: TU)

The Apatani System–Arunachal Pradesh

It is a traditional arrangement of paddy cum fish farming developed by the Apatani Tribes of Ziro in the Lower Subansiri district of Arunachal Pradesh in elevated regions (about 1600m) and gently sloping lowlands. This system collects both rainwater and surface water, which is used for irrigation and pisciculture at the same time. Water is tapped from small streams and springs by erecting temporary mud walls that act as barriers, diverting water flow to terraced and valley fields. The water is transported from one terrace to another using bamboo or wooden pipes placed 15–25 cm above the bed to ensure the right water level. Bio-fencing is placed across the main canals to prevent soil erosion. To ensure proper water supply and distribution, a group of farmers led by Bogo Ahtoh manages the irrigation systems (Dolo, 2009). To keep the water level stable, dykes or bunds are built in the fields, supported by bamboos and wooden clips. The dykes' widths range from 0.6 to 1.4 m, and their heights range from 0.2 to 0.6 m. The wastewater from households discharged into irrigation canals is a useful source of manure in the field. Agricultural wastes, paddy straw, rice husk, ash, and weeds, among other things, are recycled to preserve soil nutrients. After the harvest, green manure can be added by allowing free cattle grazing.

Furthermore, degraded leaf litter draining from the forest land is collected in distinct pipes connected to the central canal before being distributed to the plots. As a result, the local drainage network is combined with the irrigation facility, enhancing the nutrient of the water needed for rice growth. It is one of the most sustainable strategies for showcasing waste management, water management, and agricultural best practices (NITI Aayog, 2017).

(Apatani sytem, Arunachal Pradesh; Photo: RGU)

(Bamboo drip irrigation, Meghalaya; Photo: NEHU)

Zabo – arrangement for collecting runoff in Nagaland

The Zabo (meaning 'impounding runoff') or Ruza system is a traditional and sustainable method of supporting long term soil and water management by integrating water conservation with forestry, agriculture, and animal husbandry. This system is practised in high altitude villages of Nagaland, such as Kikruma, which faces water scarcity despite heavy monsoon rainfall. Zabo is made up of many components: the forest land that functions as a catchment area, water collection systems such as ponds, cow barns, and agricultural areas in the downslope region. Rain falls on the catchment's protected forest region, and the water runs down the slope through many terraces and gathers in ponds on the intermediary levels. The channels also traverse past cattle yards, collecting animal excrement before eventually winding their way down to the paddy fields. The paddy field ponds are then utilized to raise fish and cultivate medicinal herbs. Every year, usually during the pre-monsoon season, the entire system and the catchment region are maintained by the villagers (Agarwal and Narain, 1997).

Bamboo drip irrigation - Meghalaya

The bamboo drip irrigation system is an amazing water conservation technology that has been used in northeast India for over two centuries. The region's tribal farmers have devised an irrigation system in which springs water is directed to fields via bamboo pipes of various sizes and forms. From the site of water diversion to the application location, there are around four to five steps of distribution (Dhiman and Gupta, 2011). The method guarantees that tiny drips of water are sent straight to the roots of the plants, making it ideal for crops that require less water. Farmers in the Khasi and Jaintia hills utilise this traditional technology to drip-irrigate their black pepper crops. Many other villages in Meghalaya's Ri Bhoi district catch flowing stream water for residential usage using bamboo pads. The flowing stream water in the Jowai district is held in a tiny cement plastered pond by bamboo, which is enjoyed by the entire community, and the overflowing water is used for agricultural in the catchment regions (Borthakur, 2008). Bamboo drip irrigation prevents leaks, boosts crop productivity while using less water, and is one of the most environmentally friendly distribution methods. Iron pipes and channel irrigation are increasingly being utilised to irrigate fields, according to the Center for Science and the Environment.

Dongs (ponds) – Assam

In Assam, the Bodo tribe used a decade-old traditional technique to route river water into communities (Priyanka Waghmare, 2021). On the Pagladiya river, which flows along Assam's border with Bhutan, such structures are well-known. The river water is redirected through mud canals to the communities. The diverted water is held in ponds known as Pukhuri throughout the area. Water is often taken straight from the mud channels for irrigation. The people have also relied on indigenous engineering skills to keep the canals flowing. The highland streams are diverted in these canals as they descend to the plains, and the flow is controlled by the dams made up of tree branches, stones, and rocks. The major canal is divided by several sub-canals known as shakhas and prakhashas. The resulting network ensures that water reaches every nook of the community. Water is released into these sub-canals from the main canal at regular intervals, generally twice a day. This water distribution system is managed by Dong-bandh committees, which have existed in the region since the early 1900s. The funds required for the operation and upkeep of dongs are met through money paid by local communities at the rate of Rs. 10 per year each 'bigha' of agricultural land.

(Naula, Rudraprayag-Uttarakhand; Photo: HNBGU)

Naula (shallow well)

People in NW Himalaya developed a stone-lined shallow well called Naula in local dialects to exploit groundwater (usual seepage from springs) for domestic purposes (primarily drinking) (Rautela, 2015). The structure and design of Naulas reflect ancient hydrogeological and architectural knowledge. Ancient mountain people used to locate these wells based on their understanding of the soil and topography. They used to test the amount of water for a year and then build the stone structure to sustain it. The 'Naula' usually has steps built to narrow and deepen the Naula to reduce evaporative water loss. People believe that trees indicate the availability of water, which aided in selecting Naula's locations. Except for a small entrance to the Naula, which would prevent animals from entering, these constructions are mostly hidden from all angles.

Some of the oldest functioning Naula in Uttarakhand is 1,000 years old in Suryakot (Almora), 700 years old in Haat (Kalika temple Naula) in Gangolihat (Pithoragarh), and 7 BCE in Badrinathji-Ka-Naula in Chamoli district. People stopped building after the last Naula was built around 75 years ago due to a lack of technique and a sense of ownership. Most villages now use a distributed water system, with Naula serving only as a summer stop for cool drinking water.

Dhara (Spout Spring)

Dhara (spout springs) is the primary natural freshwater source in Uttarakhand. It also forms a significant water source for irrigation in many parts of the state's mountain regions—Dharas form where sloping ground surface and groundwater table intersect. In most cases, the water sources of such springs are unconfined aquifers formed by the fractured rock mass. The total yield and gravity control the flow of water. Planting trees near the Dhara has been a practice for symbolizing the sanctity and conservation of water. The water from a spring or a subterranean source is generally channelled through artificially carved outlets, often in the shape of animals like tigers and cow's heads.

(Dhara in Uttarakhand; Photo: HNBGU)

(Women working under MG-NREGA for Chal-Khal construction, Uttarakhand; Photo: HNBGU)

Current status of water harvesting and conservation in IHR

Water harvesting includes the methods and techniques developed by people to collect and store the flowing water such as rainwater, snow, surface runoff, lakes & ponds, and groundwater such as springs and wells (Samra, et al., 2002). The methods can be broadly divided into three categories (i) surface water collection, (iii) groundwater collection and (iii) enhancement of groundwater recharge. India's National Water Mission (NWM) has also recommended rainwater harvesting and artificial recharge to groundwater for water conservation, preservation, and augmentation. Rainwater being the primary source of water, can be collected through cost-effective, sustainable and adaptable techniques, improving water efficiency and agricultural productivity by various means (Reiz et al., 1988; Li et al., 2000). The general structures recommended for artificial recharge and rainwater harvesting includes pits, trench, simple well/injection well, shaft, ponds/reservoirs, farm ponds, surface storage, recharge through dug and defunct bore wells etc. (National water mission, 2022).

The current water harvesting structures in IHR consists of rooftop rainwater harvesting, check dam, reservoirs, recharge pits, gully plucking, embankments, contour canals/ bunds, storage tanks, reverse osmosis plant, water ATMs, Chal-Khal, Khantiya, etc.

The common water fetching practices are buckets of different sizes, vessels (Gagar and Bantha in Uttarakhand), silver pots, containers, gallons, urns, Matka, etc. With time, some new and innovative practices/ approaches of water harvesting have been implemented in the region through various central and state government schemes like storage tanks, pipeline, hand pump, gravity, motor, solar pump, pipelines, dug wells, bore wells, rooftop rainwater harvesting, recharge pits, etc. Among the states of IHR, the highest percentage of households with tap water supply is Himachal Pradesh with 91.82%, followed by Sikkim (78.79%), Manipur (61.29%), Jammu & Kashmir (56.70%), Arunachal Pradesh (51.72%), Uttarakhand (50.44%), Mizoram (46.46%), Tripura (39.85%), Nagaland (38.03%), Meghalaya (33.47%), Assam (29%), and the lowest in Darjeeling (West Bengal) with 15.10% (Jal Jeevan Mission, 2022). Similarly, in this study also, the highest percentage of tapped water coverage was found in Himachal Pradesh with 86.50%, followed by Jammu & Kashmir (60.90%), Arunachal Pradesh (59.12%), Tripura (58%), Mizoram (57.90%), Uttarakhand (36%), Assam (25%), Manipur (20%) and only a few villages in Nagaland.

This survey observed that the rural areas of the Indian Himalayan Region are not receiving enough water to meet their minimum basic requirement of 55 lpcd. The concept of reuse is very common in rural cultures. The same water is often used at multiple stages, from human needs to animal, domestic, and agricultural needs. However, the region has not introduced proper water recycling after treatment. Given the availability (supply) and water demand, the concept of recycling cannot be practical in this state. However, it can be helpful in a small town where the minimum basic requirements are met, and the demand is growing manifold.

The agriculture of the Indian Himalayan region is mainly rain-fed, and therefore, the changes in the rainfall pattern due to climate change are the primary factors for reduction in production. However, the water-saving irrigation methods and diversification of crops need to be demonstrated for valuable crops, vegetables and medicinal plants. It must be remembered that the irrigation method and technology have limits in mountainous terrain.

Some examples of water harvesting in IHR: Uttarakhand (top; Photo: HNBGU) Mizoram (middle; Photo: MU) and Meghalaya (bottom; Photo: NEHU)

(Slogan for awareness, Tehri-Uttarakhand; Photo: HNBGU)

Awareness of people and participation in harvesting and conservation programs

Awareness of the rural people and their participation in water harvesting and conservation programmes is an essential strategy to overcome water scarcity and sustainable utilization of the available resources. The study reveals poor awareness, lack of participation and meagre efforts for rainwater harvesting in most of the states of IHR like Arunachal Pradesh, Assam, Himachal Pradesh, and Tripura. In Jammu and Kashmir, the villagers are aware of water harvesting and conservation techniques (42.07% have knowledge of groundwater recharge) but the participation in such programmes is less (18%). The villagers of Manipur, Mizoram, Nagaland and Uttarakhand were aware of harvesting and conservation techniques but lacked resources and skills. The National Water Mission (NWM) has launched a campaign in February 2020 with the tagline 'Catch the rain, where it falls, when it falls' to promote the construction of check dams, water harvesting pits, rooftop rainwater harvesting, etc. through the active participation of people.

Further, the mission recommends working closely with local governance institutions for successful implementation of mass water replenishment and a conservation project that includes restoration of ponds, construction of check dams, bore wells, door to door connection, and installation of water ATM, etc. However, most of the states in IHR appear to be lagging far behind in implementing and achieving the mission's objectives. Therefore, more significant efforts to create awareness and encourage the rural people for larger participation in harvesting and conservation activities are need of the hour to ensure water security in IHR.

Table: Water Scarcity (WS) related data of Indian Himalayan Region

State/Region	Water Consumption (lpcpd)			Distance to water source (m)	Total Springs*	Access to toilets (%)	Water borne diseases reported*	Major causes of WS	Expected consequences of WS	Suggested solution of WS
	Max	Min	Average							
Arunachal	63	42	**50**	1600	2086	100	Diarrhoea, Typhoid, Viral Hepatitis; Cholera.	Mismanagement/Damage of Pipeline; Increasing Population; Source Dried/Seasonal; Source Distance; Natural Hazards.	Impact on economy of Farmers/ Animal Husbandry workers; Health Issues; Problem for women in daily Chores; Local Conflicts.	Maintenance of Pipeline and properly connection; Preserve Natural Resources; plantation of Oak tree in catchment area; Water Storage tank Construction; Rainwater Harvesting for irrigation purpose; Water from River could be used for irrigation.
Assam	21	18	**20**	1200	--	97	Diseases like skeletal fluorosis.	Less rainfall; Pipeline damages; Distance of source; PHE not fully developed; Drying up of wells.	Impact on livelihood of people dependent on agriculture and animal husbandry; Education and health issues of women	Proper maintenance of pipeline; Digging of wells between few households; By providing water through PHE; Installation of water reservoir; Installation of water treatment plant.
Darjeeling	50	24	**51**	2000	--	100	Gastroenteritis, cholera, typhoid, giardiasis, hepatitis, diarrhoea.	Natural hazards like earthquake, landslide; Heavy rainfall or drought; climate warming; deforestation; Population growth; Weak water management.	Serious water crisis; Water conflicts among the villagers	Afforestation of the catchment area with relevant species, water conservation programs, public awareness and training, and water harvesting and storage measures. Traditional Water Harvesting in Sikkim-Darjeeling Himalaya.
Himachal	173	17	**56**	924	--	95		Mismanagement/Damage of Pipeline; Increasing Population; Anthropogenic activities.	Affect Economic Status of Farmers/ Animal Husbandry workers; Problem for women in daily Chores; Local Conflicts.	Maintenance of Pipeline and properly connection; Water Storage tank Construction Required; Water from River could be used for irrigation; Rainwater Harvesting Planning for irrigation purpose.
Jammu	23	13	**22**	--	--	100	Acute Diarrheal Disease, Bacillary dysentery, Viral hepatitis, Enteric fever, Cholera and Fever.	Source distance; Source Dried/turned Seasonal; Increasing Population; Anthropogenic activities; Mismanagement/ Damaged pipeline.	Impact on livelihood of people associated with agriculture and animal husbandry; Burden on women; More expenditure in terms of money and time in fetching water; Increase in local conflicts; Health issues.	Investment in water infrastructure such as construction of tanks of required capacity; Conservation and harvesting of rainwater; Plantation of oak trees in the catchment.
Kashmir	40	16	**28**	500	3300	93	As above	Increasing Population; Freezing of pipelines during winter; Non availability of Piped water supply; Decrease in water outflow from natural resources or source dried up; Topography of village.	Decrease in agriculture output; Health Issues; Higher domestic chores for women; Local conflicts.	Increased number of water supply connections to village households; Facilitating Use of Ground Water by Providing Increased Number of Tube wells; Channelling Water from Spring/Canal of Neighbouring Village; Poly-tanks for Rain Water Harvesting; Promoting rain harvesting from roofs by providing subsidized water storage tanks to households.

Manipur	84	48	**63**	200	26390	95	Diarrhoea; Typhoid; Worm infestation; Jaundice.	Lack of govt initiatives of water supply; Decline in yield of springs; Distance of source; Population growth; Anthropogenic activities for livelihood	Impact on livelihood of people dependent on sustenance of livestock. More stress on women; More expenditure in terms of money and time in fetching water; Health issues	Construction of storage tanks, diversion channels and check dams; Water Conservation and harvesting of rainwater; More resources on social forestry.
Meghalaya	87	10	**32**	500	382	75	--	Mismanagement/Damage of pipeline; Increasing Population; Source Dried/Seasonal; Source Distance; Anthropogenic activity Forest Type; Natural Hazards	Affect Economic Status of Farmers/ Animal Husbandry workers; Problem for women in daily Chores; Local Conflicts; Health Issues; Impact of quality and quantity of water; Wetland destruction.	Maintenance of Pipeline and properly connection; Water Storage tank Construction Required; Water from River could be used for irrigation; To Preserve Natural Resources plantation of Oak tree; Rainwater Harvesting structures.
Mizoram	29	14	**21**	1500	373	100	Diarrhoea, cholera and jaundice.	Seasonal sources and dry up during dry months; Distance of source; Declining rainfall pattern and Forest area; non-availability water infrastructure; developmental activities; Population growth.	Intra-village conflicts; Financial strain during dry seasons; Consumption of unhealthy water; Difficulty in management of forest fires.	Formulating an effective spring shed management system; Permanent Farming and constant check on deforestation; Water pumps and Reservoirs; detailed study of geo-hydrological aspects needed in Mizoram.
Nagaland	48	17	**27**	800	--	100	Dental Fluorosis; Skeletal Fluorosis.	Seasonal drying natural resources; absence of water harvesting structures	Fetch water from distance	Afforestation; Installation of more pipelines; construction of water storage structures; Construction of water harvesting structures; Pumping facility
Sikkim	49	26	**36**	2000	--	100	Gastrointestina l diseases like diarrhoea, dysentery, cholera, and typhoid.	Population Growth and deforestation; Mismanagement in water supply; major part district lies shadow of south in rain- the Darjeeling Himalaya; Source dried or seasonal.	Intra-village conflicts; Threat to rainfed farming practice; Impact on livelihood of people dependent on agriculture and animal husbandry.	Afforestation of the catchment area with relevant species, water conservation programs, public awareness and training, and water harvesting and storage measures; Traditional Water Harvesting in Sikkim-Darjeeling Himalaya
Tripura	46	20	**32**	500	--	86	Diarrhoea; viral fever; Typhoid.	No pipeline connections; No electricity; Maintenance issues.	Iron water; no drinking water; no proper irrigation water	Regular supply of drinking water; quality of water should be improved; Supply point and water tank should be built; More pipeline connections
Uttarakhand	65	20	**35**	500	26000	97	Dysentery, Diarrhoea, Typhoid, Dental Fluorosis	Mismanagement in water supply; Source dried or turned seasonal; Distance of source; Population growth; Deforestation and developmental (Anthropogenic) activities; Natural hazards.	Impact on livelihood of people associated with agriculture and animal husbandry; Burden on women; More expenditure in terms of money and time in fetching water; Increase in local conflicts; Health issues.	Investment in water infrastructure such as construction of tanks of required capacity; Conservation and harvesting of rainwater; Plantation of oak trees in the catchment.

*Secondary data resources; WS= Water Scarcity

State specific Recommendations

Jammu

Rainwater Harvesting Planning (with focus on Check Dam, Chal, and Khal) should be implemented for irrigation purposes while maintenance of water pipelines to avoid leakage and loss of water should be focused upon for better domestic water supply.

In the Kandi Belt (Shivalik foothill region of the Himalayas), the artificial pond structure known locally as ‘Chapris" needs to be reactivated with the community-based approach of the local people.

A moratorium on any kind of construction activity or deforestation (for about 30 years) should be implemented, and awareness campaigns should be undertaken to educate people about efficient water management practices.

Water audits need to be conducted at frequent intervals for the estimation of water budgets in Jammu Province.

Star Ratings of the Villages need to be done on efficient practises adopted for water conservation and harvesting strategies to boost the community level participation for the success of the policies/schemes of the government. Besides, water-efficient landscaping in collaboration with the Social Forestry Department of UT of J & K can supplement efforts for water conservation and harvesting.

Kashmir

As the Kashmir valley is presenting a case of scarcity amidst plenty, there is a need to create a digital inventory of all the water bodies (especially springs which are most reliable source during harsh winter days, as reported by respondents during survey). This digital inventory, besides proving the information about the location, should also provide information about the potential outflow, quality of water, wastage because of perennial runoff, areas/households that it can provide water to and maintenance status (if needed) of the water resource. The database should be rich enough to identify the list of water bodies/ resources that need to be renovated/ rejuvenated, or from which encroachments need to be removed.

Poor quality of water (mostly visible in terms of clay and slit particles associated with water) has led to the abandonment of wells in many villages. Village people, to meet water requirements, attempt to exploit the ground water (by digging wells) without using scientific methods, resulting in a loss of money and labour. As people know little (or have no knowledge) about the diversified geological formations, lithological variations, tectonic complexity, and geomorphological dissimilarities that give rise to a variety of ground water situations, the government should take the lead in this regard by at least providing necessary information about the availability or non-availability of ground water (and its quality) in different areas. Such water facilities may be provided through the public-private (PP) model.

Various government schemes, like MGNREGA, should prioritise the construction of village irrigation water tanks so that runoff generated from rain may be channelized into them by the formation of ridges and gullies on land surfaces.

The government should take appropriate and timely steps to enlighten people through workshops, training programs, and other contacts with extension agencies in order to bring about behaviour changes and promote water conservation and judicious use among people. As found during the survey, women shoulder the responsibilities of fetching water (with slight help from male folk during winter days) for household uses and also for the provisions for drinking water for cattle. Their participation in such programmes/workshops should be prioritized.

Water harvesting practises should be encouraged in areas where people do not have a sufficient/perennial source of water. Collecting rainwater from the roofs of buildings in residential areas using "parnala" (a thin iron sheet bent in the shape of the English alphabets "U" and "V") should be promoted. Permission for the construction of different buildings should be subject to the use of parnala in roof design in urban areas, and in the case of rural areas, local Panchayats should be authorised to ensure such designs within their localities. Use of filters for the same should be incentivized by subsidising the equipment required for it.

Himachal Pradesh

It has come-out from the households' survey, people in Himachal Pradesh experience water scarcity for a few months. However, there are some areas where people reported a year-round water shortage.

In different districts of Himachal Pradesh, the water supply through pipelines is adequate and good in quality. However, insufficient supply has been reported in some areas. The government of Himachal Pradesh has been successfully implementing the Jal Jeevan Mission of the government of India. Currently, Himachal Pradesh ranks 8th in the country in providing tap water connection to rural households and is striving hard to ensure tap water connection in 100% of rural households under the Har Ghar Nal Ka Jal scheme by 2024.

The inhabitants of Himachal Pradesh, in general, are concerned about water conservation and natural water sources. However, in several districts of Himachal Pradesh, there is a sizable population that is careless with natural water supplies. In some parts of Himachal Pradesh, construction work and encroachment on drains and ponds are said to be the main causes of flooding and natural resource depletion. During the irrigation season, fights for water distribution have been observed often in villages across Himachal Pradesh's districts.

People in several districts of Himachal Pradesh think that by restoring streams, springs, and ponds, flooding in their villages may be controlled and water scarcity issues can be resolved. They also believed that government programmes have helped to tackle water issues to some extent.

It has been observed that most of the people in the villages are not aware of water conservation and harvesting programs being run by government and non-governmental organizations.

As a conclusion, it is suggested that additional efforts be made in Himachal Pradesh to map and restore natural water resources such as streams, springs, and ponds. Furthermore, increased water conservation and water harvesting using traditional methods (adapted to the locality) should be promoted through public awareness campaigns.

UTTARAKHAND

Human waste must be properly disposed of to reduce anthropogenic water contamination. It is necessary to implement toilet construction guidelines.

To comprehensively investigate the causative elements underlying water scarcity, a dense network for acquiring hydrogeological data is required. The concept of citizen science can be used for this purpose.

The discharge of springs can be enhanced by rainwater recharge only. Invest in action-oriented research on spring revival and training human resource for the construction of water harvesting/conservation structures.

Considering the limited number and low carrying capacity of water resources for long-term supply and to minimise the wastage of water, the community stand post should be preferred over tapped water for each house (*har ghar Jal*).

A suitable convergence of the MGNREGA fund is required for the construction of an effective water recharge structure.

Secondary measures, such as crop diversification, can aid in farmer economic recovery.

Plantation of trees such as oak need to be promoted in place of pines for reducing soil erosion and promoting groundwater recharge.

A significant investment must be made on a small solar-powered water pumping scheme in many areas where the gravity-based schemes are not feasible.

It has to be insured that the developmental projects such as road construction and dams do not disrupt the natural springs.

SIKKIM AND DARJEELING (WEST BENGAL)

Pipeline damage is the major issue faced by the villagers. Water pipelines are too old and rusty, they should be renovated to prevent leakages and augment efficiency. P.H.E water should be equally distributed to every houses. Moreover, water tanks are not properly constructed. More tanks should be built and old one should also be repaired.

Public awareness should be continuously improved to ensure the conservation and augmentation of primary natural resources such as water. Government officials and panchayats must take the initiative in water conservation.

Government scheme should be equally divided among all so that it reaches every household of the village.

There are fewer water sources in the villages, which are insufficient for all of the houses. People must learn to practise water harvesting in order to benefit in the long run.

The increasing population has caused water scarcity as well as deforestation. Programme for promoting afforestation need to be seriously implemented.

The water supply in Darjeeling (Gorkhaland Territorial Administration region) is directed by social structures (caste/tribe line), which appears to be creating a new ground for water conflict in the area. The government should try to ensure that water is provided to all households, regardless of their social class or race.

Agriculture should be given more preference as it is the primary source of income and livelihood.

Many villagers are shifting from agriculture to tourism business because of water problem. In many clusters, water problem/crisis have reduced after people started moving towards tourism business from agriculture.

Sustainable and inclusive water governance should be prioritised. In Darjeeling district, more coordination is needed between Gorkhaland Territorial Administration (GTA). There is a need for mapping of all the streams/jhoras and springs in the Darjeeling district (hilly portion) and undertaking spring-shed development programs in line with Sikkim. All the villages need to prepare their own Village Water Resource Atlas (WRA) with the help of participatory resource appraisal method (PRA). Sikkim should handhold Darjeeling for the efficient management of its fast-depleting water resource.

We need to have a Village Water Security Plan (VWSP) in every village, drafted carefully with the participation of villagers. The plan should be periodically revised and updated. The concept of VWSP is already there in Sikkim, it needs to be replicated to Darjeeling and other Himalayan States.

Every village should constitute a 'Water Security Committee' (WSC)/ Jal Sanrakshan Samiti consisting of senior members of the village with no less than 50% of women participation; it should also have a panchayat/block representative. In addition, every community should have well-trained 'Young Water Ambassadors' (YWA) / Jal Doots who will work closely with the WSCs to promote water conservation and sustainable water use. In collaboration with the PHE department, the Block Development Office, and other line departments, these two important microbodies should organise training and capacity building programmes in their respective villages on a regular basis. WSC and YWA should also monitor and assess all water development projects and report on the project's quality and progress to the relevant administration and funding agency.

ASSAM

Due to the presence of a limited number of wells in most of the villages of Dima Hasao, it becomes difficult for the people to meet their daily water needs. To overcome this problem, we recommend the digging or installation of more wells or reservoirs.

The water harvesting systems in rural areas of Dima Hasao and Karbi Anglong districts are almost non-existent. Therefore, the installation of such systems by creating small embankments of natural rain-fed water bodies and rain-water harvesting is very crucial to overcome the water scarcity problem in the rural areas of both the districts to a certain extent.

The PHED water supply system is yet to be developed in the rural areas to ensure sufficient water supply. The people of the villages, where the PHED connections are available, are still facing an inadequate and untimely supply of water. Therefore, proper connection of PHED with periodic water supply and regular maintenance of pre-existing connections in rural areas are recommended.

Water quality is a key concern, particularly in Karbi Anglong, where groundwater is contaminated with iron, fluoride, calcium, magnesium, carbonate, and other contaminants. Skeletal fluorosis, back discomfort, joint pain, and kidney failure have all increased as a result of these pollutants. As a result, it is recommended that a water treatment facility be built at a strategic location so that contaminated water could be filtered before being supplied/used.

The majority of individuals in both districts are unaware of water harvesting and conservation practises, according to a household survey. This is a big concern, and public awareness campaigns in this area should be done on a regular basis and with a high priority.

Arunachal Pradesh

Many people in the rural areas are unaware about water availability, consumption, conservation and rainwater harvesting techniques. Therefore, multilingual awareness campaign on regular basis could be helpful in educating the local stakeholders for ensuring water security.

The rate of deforestation and land degradation are on rising trend in different parts of the state due to increasing population, agricultural practices, illegal timber operations, construction of roads, dams and other developmental activities. Hence, suitable efforts to check deforestation particularly in the catchment areas of water sources and encouraging afforestation of degraded areas could prove fruitful in maintaining the water availability.

So far, the state has meagerly utilized the absolute surface water availability and only 0.23 percent of groundwater availability owing to various constraints such as low fund availability, lack of manpower and geographical constraints in many districts. So, enhancing the utilization of available water resources needs to be prioritized.

Suitable mechanisms for better water distribution system through regular maintenance of pipelines, water treatment and establishment of other infrastructural requirements to ensure equitable distribution of water and check the wastages of water resources.

Currently, water conservation and rainwater harvesting strategies in the state appears to be meager except few governmental efforts and the prevalent traditional practices. Therefore, greater emphasis should be paid on popularization of water conservation and rainwater harvesting strategies by involving all the stakeholders.

There is a need of amalgamation of various government schemes like PMKSY, Jal Jeevan Mission (JJM), and MGNREGA, etc. with the traditional water conservation and harvesting practices for sustainable utilization of water resources in the state.

Development of fish ponds in plain areas, catch pits and furrow farming in hilly areas, and declaration of catchment areas as protection zones and replication of success stories of other areas must be prioritized to improve water conservation and harvesting in the state.

Nagaland

There is a need to construct water harvesting structures such as community ponds or reservoirs to store rainwater in different parts of the state.

Proper management of spring water and exploration of groundwater wherever it is possible is necessary to meet the increasing demands. In addition, the installation of a water pipeline (tap water) has to be effectively implemented.

Afforestation needs to be promoted for a long-term solution to water scarcity.

Water scarcity can also be overcome through the intervention of line departments and some of the government schemes like Jal Shakti Mission in order to meet the water requirements of each individual, including livestock, as a good number of live stocks are reared by the villagers.

Integrated watershed development programmes should be implemented in different parts of the state.

Watershed development practices, planning and management of water resources need to be enhanced through training, conferences, and workshops.

Meghalaya

Construction of water harvesting and storage by constructing community reservoirs in the spring shed wherein even the rainwater can be harvested. At times, it is noticed that with the heavy rains, landsliding blocking the channel creates further hardships for the people.

Groundwater recharging and utilisation should be encouraged at certain places to ensure water availability, particularly during the dry season.

Proper management of spring sheds and watersheds is of importance with the installation of water pipelines for the communities at least. As it is noticed that pipelines are laid down and left abandoned in forest and at times only a part of the village get benefit from supplies through pipelines, which brings in conflict among the communities.

An integrated watershed development programme, especially under the JJM/MGNERGA, should be implemented after a proper survey to fulfil the requirements of the people.

Check dams, stone bunds, watersheds, ponds, tanks, percolation ponds, and poly-tanks, among other water conservation structures, are needed in hillside settlements for potable water and agriculture.

The state should conduct training, conferences, workshops, and public awareness programmes on integrated watershed development, planning, utilisation, and management of water resources.

Farmers should be encouraged to use appropriate crops and modern technology for farming with soil and water analyses, and traditional methods of water distribution and conservation should be explored and promoted with the incorporation of modern tools and harvesting techniques.

Community involvement to conserve the water resources and their management is of prime importance and they should be consulted to construct and maintain various schemes.

MANIPUR

The Manipur government has promised the potable water for all its people by 2022. Manipur has around 4.51 lakh rural households, out of which tap water supply is available to 1.67 lakh (37%) households in 1991 and the state aimed to provide 2 lakh Functional Household Tap Connections in 2020-21. The State has planned for 100 per cent tap water connections coverage by 2024 under Jal Jeevan Mission (JJM).

The adoption of rainwater harvesting technologies increases agricultural production, improves the farmers' standard of living and reduces environmental degradation. Rainwater harvesting is ideal for farmers in areas where irrigation is difficult. Historically, the culture of artificial ponds/Pukhri as well as natural wetlands is adopted in the state. However, the technologies need to be properly tailored to the socio-economic and physical conditions of the locality where they are being promoted. There is a need to create the awareness among the villagers to adopt the technology along with financial assistance.

The agricultural area available with farmers in the hill districts for cultivation is limited and their homes are situated within the cultivated field. Therefore, to store water in a Jalkund for longer periods during off-season, roof water collection may be linked up wherever possible. During winter months when there is no rainfall, water conserved in polylined ponds (Jalkund) act as a lifeline for the seasonal crops. The MNREGA can also be provided for improving these Jalkunds for an incentive to the villagers.

There is a need to sustain the catchment or spring sheds for sustenance of springs water. The afforestation drive by the Forest Department is highly recommended. Usually, villagers participate in the social forestry programmes in the state. Considering the present forest degradation scenarios in watersheds, it is highly recommended to conserve them for future.

The rooftop water harvesting is also recommended for domestic uses in the villages especially located in valley area. The government may also encourage with financial assistance in water harvesting technologies.

TRIPURA

Springs are the most reliable source in all the seasons. Thus, exciting springs, percolation tanks, ponds, and streams need to be rejuvenated to conserve water and recharge the groundwater. The government should encourage the local public to get involved in the above-mentioned structures through proper schemes.

Villages need to construct check dams, stone bunds, watersheds, ponds, tanks, percolation ponds, etc., in suitable places for water conservation for irrigation and the development of agricultural activities.

Water quality is poor (mixing with mud and even bad small spring water) during the winter and non-rainy seasons. In Tripura, iron (Fe) is common in groundwater in all districts since the influence of lithology and minerals, but arsenic (As) is also found in a few districts. Therefore, concerned villages need water treatment plants on an urgent basis.

Since people rely on obtaining water from outlying springs and streams, the government should promote better water distribution systems by maintaining pipelines, water treatment plants, and timely repairs to prevent water waste.

Multilingual workshops/seminars should be conducted in communities to raise awareness about the importance of water bodies and their use, water security, and conservation, as well as to support traditional and modern rainwater harvesting practises. Farmers should also be encouraged to use appropriate crops and water saving irrigation technology.

The current scenario necessitates the collecting of digital data from rural settlements on all extant water bodies. This can be accomplished through crowdsourcing techniques such as the free smartphone apps Crowd Water and Stream Tracker, which were created to collect data, ideas, and services from a broad number of local individuals.

MIZORAM

In Mizoram, traditional water collection and use technologies have been used for many generations. Because the Mizos built their settlements on top of hills and ridges, water provision has always been a challenge.

Aside from appropriate rainfall, the region is blessed with numerous rivers, streams, and their tributaries, indicating the abundance of water resources. Regardless of adequate water supplies, numerous rural communities confront a constant and acute water shortage. Men and women would line for many hours to gather a few buckets of water, especially during the summer months when the water sources became dry.

The majority of springs in communities are seasonal, diminishing during the post-monsoon season and drying up during the dry (lean) months of March to May, causing shortages since residents are reliant on PHED supply with little to no rain water available for harvest. Study showed that springs are drying at fast rate due to multiple reasons. It is recommended to launch an extensive programme on the restoration of Springs and VSS in entire state of Mizoram.

Because tuikhur is the main supply of water for more than half of the population, it barely meets their daily demands, posing a major challenge for the people. Village leaders, such as the Village Council in particular, and government officials in general, must devote their whole focus to improving this situation.

The government of Mizoram has developed a number of water initiatives, including the Accelerated Rural Water Programme (ARWP), Swajaldhara, National Rural Water Monitoring and Surveillance, and the Rajiv Gandhi National Drinking Water Mission (RGNDWM), although these have not been adequately implemented. To solve the problem of water scarcity in the state, it is highly recommended to closely monitor the on-going initiatives of State and Central Government.

Despite the installation of water pipelines, the most villages in the state have yet to receive water. This is the primary cause of the village's water shortage. This issue must be brought to the attention of the State Government's involved department and resolved as soon as feasible.

Natural springs (Tuikhur) and streams have been observed to be contaminated with suspended particles in all of the villages examined, especially during monsoon seasons, rendering the water unsafe for direct use. It is recommended to initiate programme for removing of silt from most of the springs and regularly monitor the fitness of water of drinking purpose.

Majority of villagers claimed that their villages lacked sufficient water pumps to gather water from sources to meet the village's demands during lean periods. It is recommended to launch some schemes to distribute larger tanks (either PVC or steel) to rural poor families.

Given the importance of the forest in its role as a natural sponge and storage for water, the decline in forest area is concerning and might possibly be the cause of the state's water deficit.

Rain is the ultimate source of water in Himalaya-catch it!
(Photo: HNBGU)

Conclusions and way forward

All states of the Indian Himalayan Region are facing water scarcity at a different level and for a different time-span, controlled mainly by rainfall. The survey shows people in IHR are using only about 37 lpcpd (a deficit of 18 lpcpd) for domestic use and do not have access to sufficient water (55 lpcpd). In some districts, water consumption is limited to 18 lpcpd only. People have to walk 1 km on average to fetch water for their domestic needs, which may increase to 4.5 km during the lean season. This deficit in water use has been linked to physical scarcity of water as well as socioeconomic and sociopolitical factors. The socio-economic status of the people/community and their representation (socio-political) have been deciding factors in their access to water. Although a systematic assessment of the role of socio-economic factors has not been part of this study, these factors seem to determine the traditional wisdom of water conservation practices, ownership (unofficial) of resources, investment in water infrastructure, and physical capacity of fetching water.

In addition to assessing water scarcity, the survey also provides information on people's perceptions of various aspects of this problem. People are more concerned about the mismanagement of the water supply (infrastructure) and the drying of the natural springs, whereas source distance, growing population, anthropogenic activities, and natural disasters were also identified as the causes of water scarcity. The locals believe that the water scarcity will increase the workload—mostly on women. The mountain people also have concerns about the shortage of water for crop cultivation because it will severely impact their livelihood and the most economically weak sections of society may face the worst impact. The survey also indicates that the scarcity will lead to outmigration in some regions in the long term, and several conflicts among different classes, groups, and inhabitants may arise. According to the larger population, the immediate solution to this problem is to improve the water supply infrastructure with better tank capacities, more pumping schemes, and regular maintenance of the supply system. A need for developing water conservation and harvesting strategies was also highlighted. The traditional wisdom of water conservation and harvesting practises is vanishing, and there are only a few successful examples of the water conservation and harvesting programmes that are being conducted by experts (NGOs and research organizations). The forest type also controls the groundwater recharge, but we couldn’t establish its relation with water scarcity due to the unavailability of tree species maps with the Forest Survey of India. More recently, some studies have highlighted the deterioration of the water quality of natural resources in IHR, primarily due to biological pollutants, which is a growing threat.

Considering the problem of water scarcity and its future projection, many water supply and sanitation schemes have been introduced throughout the IHR. However, the widespread public dissatisfaction towards the status of the water supply scheme indicates a gap between the theoretical considerations and ground implementations/deliberations. For example, the assessment of water availability before planning the scheme has not been fully exercised in most cases. The quality of infrastructure for sustained water supply is not as per requirement. There has been very little investment in the maintenance and human resources required to maintain the regular supply. The quality standard for water supply structures has to be improved in mountain areas considering the terrain instability, mountain hazards, and disturbances due to developmental activities and animals.

With the help of public participation, some NGOs have successfully demonstrated the hydro-geological techniques for spring rejuvenation in a few areas. These examples indicate the potential of participatory approaches for spring recharge. Presently, there is a slight emphasis on research on various aspects of water resources/aquifers to generate the primary data required for developing a successful plan.

Though the increase in water scarcity is inevitable, the problem can be reduced by appropriate measures. Here we have identified some strategies:

- Educate and involve people to collect water-related data (e.g., discharge, rainfall, quality, etc.) using the concept of citizen science and construct water conservation and harvesting structures under the guidance of experienced people (para-hydrologists).
- Water conservation and harvesting techniques may be included in the school curriculum to educate and raise awareness.
- Invest in action-oriented research to assess the ability of natural water resources to recharge and understand their recharge mechanisms at the spring shed level.
- Immediate relief can be provided through substantial investment in viable supply infrastructures, emphasising maintenance and requiring human resources.
- Assess the carrying capacity of resources and terrain conditions before designing the water infrastructure (scheme).
- Encourage water-saving technology for irrigation and diversification of crops towards valuable (e.g., medicinal and aromatic plants) and indigenous crops.
- Encourage plantation of tree species such as oak that facilitate groundwater recharge in addition to providing fodder to the villagers.
- Save water resources from anthropogenic disturbances and pollution. Provide guidelines for the construction of toilets to avoid contamination.

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