NMHS-Himalayan Institutional Project Grant

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

NMHS Reference No.:	GBPNI/NMHS-2017/SG-01/

Date of Submission:	0	9	1	2	2	0	2	2
	d	**D**	**m**	**m**	**y**	**y**	**y**	**Y**

PROJECT TITLE (IN CAPITAL)

INNOVATIVE AND SUSTAINABLE DECISION SUPPORT SYSTEM FOR DRINKING WATER SECURITY IN INDIAN HIMALAYAN REGION OF SIKKIM AND WEST BENGAL

Project Duration: *from* (**23.02.2018**) *to* (**30.11.2021**).

***Submitted to*:**
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NMHS-Final Technical Report (FTR)

Demand-Driven Action Research Project

DSL: Date of Sanction Letter

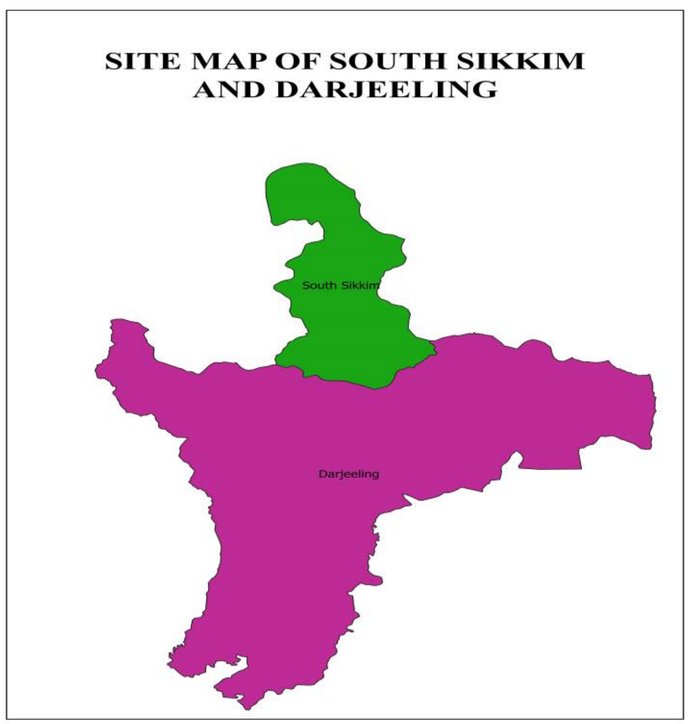
2	3	0	2	**2**	**0**	**1**	**8**
d	d	m	m	y	y	y	y

DPC: Date of Project Completion

3	0	1	2	**2**	**0**	**2**	**1**
d	d	m	m	y	y	y	y

Part A: Project Summary Report

1. Project Description

i.	Project Reference No.	GBPNI/NMHS-2017/SG-01/
ii.	Type of Project	Small Grant
iii.	Project Title	Innovative and sustainable decision support system for drinking water security in Indian Himalayan Region of Sikkim and West Bengal
iv.	State under which Project is Sanctioned	**Sikkim and West Bengal**
v.	Project Sites (IHR States covered) (Maps to be attached)	

vi.	Scale of Project Operation	Local		Regional		Pan-Himalayan	
vii.	Total Budget/ Outlay of the Project	Rs. 49,30,200/-					
viii.	Lead Agency	National Institute of Technology Sikkim					
	Principal Investigator (PI)	Dr. Md. Nurujjaman					
	Co-Principal Investigator (Co-PI)	Dr. Barun Kumar Thakur Dr. Kanish Debnath Dr. Debi Prasad Bal					
ix.	Project Implementing Partners	National Institute of Technology Sikkim Flame University Birla Global University RV University					
	Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail	Dr. Md. Nurujjaman Assistant Professor, NIT Sikkim Email- jaman_nonlinear@yahoo.co.in, md.nurujjaman@nitsikkim.ac.in Ph No-9734252861/7479013207					

2. Project Outcomes

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

Drinking water security is an essential requirement for populations living in the towns and cities of the Indian Himalayan Region. Increasing population pressures at higher altitudes have led to a decline of both the quality and quantity of water. Therefore, to assess pathways to improve the drinking water availability in the region, this project was run with the following objectives –

1. To assess quality and quantity of water resources in the districts of South Sikkim and Darjeeling,
2. To establish drinking water security through a participatory approach,
3. To estimate the cost of drinking water in the region,
4. To build a Decision Support System to support water demand,
5. To devise a long-term Policy Framework integrating all the stakeholders.

To meet the objectives, we performed the following activities –

1. Visiting water sources observed from baseline and also by asking locals and mapping of the latitude, longitude, and elevation of the source
2. Observation of the surrounding areas and land usage and spring usage
3. Measurement of the flow rate of springs (if possible)
4. Collection of water sample – either directly from springs or spring pools or household taps
5. Field tests of the water sample using field test kits. The parameters checked were pH, total hardness, alkalinity, iron, fluoride, chloride, nitrate and turbidity.
6. If the field test cannot be conducted, then the temperature is recorded and the water is collected in glass containers, labelled them, and brought to the laboratory.
7. We also asked local residents about each source and tried to estimate the number of households that are dependent on the water source.
8. We also ran household surveys using a questionnaire
9. We estimated the price elasticity of drinking water in Darjeeling and the Water Quality Index of water sources in Sikkim.
10. We plotted the observation in GIS maps.

We found the water quality in most areas to be good and fit for drinking. However, there is an imminent shortage of water in a few of the rain-shadow areas and during the lean season in most areas. We recommend the active role of local governments and stakeholders in actively using Integrated Water Resource Management practices to ensure sustainable upkeep of the resources. For the long term policy-making we suggest following the SMART practices that are –

1. Save and rejuvenate spring sources,
2. Monitor water quality in sources,
3. Awareness about drinking water quality,
4. Reduce Water Wastage, and
5. Treat Wastewater effectively.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (in bullets points)
1	To assess quality and quantity of water resources in the districts of South Sikkim and Darjeeling	(a) We have assessed the quality of water from spring sources in South Sikkim. (b) We also measured the flow rate of spring water wherever it was possible to observe and collect water from the source. (c) The quality of water from springs in Darjeeling was assessed, and the flow rates of some springs, wherever possible, were recorded.
2	To establish drinking water security through a participatory approach	(a) In addition to recording data from spring sources, we also measured water quality from households in South Sikkim and Darjeeling. We have collected more the 250-household data by conducting a survey. (b) We conducted wo workshop cum awareness programmes through which we explained the rationale of our project objectives and also informed about the perils of poor quality water and harmful effects of different impurities like nitrates, e-coli, arsenic, iron, etc.
3	To estimate the cost of drinking water in the region	(a) To estimate the cost of drinking water in the region, we use the midpoint method to compute the price and income elasticity of water demand. This work was published with the title – "Estimation of price and income elasticity of water: a case study of Darjeeling town, West Bengal, India" in an issue of the journal – Current Science in the year 2021. (b) We also evaluated the Water Quality Index (WQI) for the South Sikkim district to gain an estimate the cost of drinking water in the region. Based on WQI values, surface waterfalls under the projected area of South Sikkim district into two categories: excellent water and good water (ranging from 0 to 50). However, water scarcity continues to remain a major challenge.
4	To build a Decision Support System to support water demand	(a) In order the build a decision support system that can aid local governance of drinking water, we look at the field survey details of 150 households randomly selected from five major areas of the district of South Sikkim - Ravangla, Melli, Temi, Jorethang, and Namchi. We have plotted our findings on GIS maps. (b) Another objective was to build a dynamic system that updates the data from the baseline and shows the same on GIS maps. We were unable to complete that due to lack of time and resources caused by Covid-19

5	To devise a long-term Policy Framework integrating all the stakeholders	To devise a long-term Policy Framework integrating all the stakeholders, we engaged into Stakeholder meeting, Expert discussions and planning for future demand of drinking water. Taking above things into account we arrive a policy suggestion that should aim at SMART. a) Save and rejuvenate spring sources, b) Monitor water quality in sources, c) Awareness about drinking water quality, d) Reduce Water Wastage, and e) Treat Wastewater effectively.

2.3. Outputs in terms of Quantifiable Deliverables*

S. No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, & Reason thereof:
1	Decision Support System (DSS) within a GIS Platform;	No. of New Database/ Datasets generated on the water quality and quantity (Nos.);	Datasets created and updated on baseline	
2	Policy framework on water supply management;	Regular updates on region-specific best practices/ DSS developed (No.);	GIS maps created	Due to Covid-19 pandemic
3	Panchayats/local bodies (around 700 households) will be benefited;	No. of Stakeholders benefitted (No. of Rural Youth, No. of Women, No. of Households, and Total No. of Beneficiaries);	Approx. 500 households in Ravangla and Darjeeling benefitted	Due to Covid-19 pandemic
4	Water Quality Database of supply drinking water of 700 households;	Policy framework/ drafts (No.) for assisting the regional decision-making in the identified area and dynamics, i.e. Water Supply Management;	250 households reached	Due to Covid-19 pandemic
5	At the end of project, at least 2 research papers, 01 book, 01 action plan on water security and DSS will be made.	Other Publications and knowledge products (Nos.).	3 research papers and 2 field reports published.	

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

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

S. No.	Particulars	Number/ Brief Details	Remarks/ Attachment
1.	New Methodology developed	Section 3.1 [Part-B]	
2.	New Models/ Process/ Strategy developed	Section 3.1.1-3.1.6 [PART-B]	
3.	New Species identified	NA	
4.	New Database established	2	Submitted to NMHS
5.	New Patent, if any	NIL	
	I. Filed (Indian/ International)		
	II. Granted (Indian/ International)		
	III. Technology Transfer (if any)		
6.	Others (if any)	NA	

3. Technological Intervention

S. No.	Type of Intervention	Brief Narration on the interventions	Unit Details (No. of villagers benefited / Area Developed)
1.	Development and deployment of indigenous technology	NA	
2.	Diffusion of High-end Technology in the region	NA	
3.	Induction of New Technology in the region	NA	
4.	Publication of Technological / Process Manuals	3	
	Others (if any)	NA	

4. New Data Generated over the Baseline Data

S. No.	New Data Details	Status of Existing Baseline	Additionality and Utilisation New data
1	**2 set**	**Submitted to NMHS**	**NA**

5. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S. No.	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	**ST**	**Woman**	**Total**
1.	Workshops	2	To make aware of water quality and scarcity	NA	NA	NA	98
2.	On Field Trainings	NA					NA
3.	Skill Development	4	Field investigation				4

4.	Academic Supports	NA					
	Others (if any)						

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

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held	Beneficiaries
1.	Sustainable Development Goal (SDG)	Study and water quality and demand	3	Scientific community and general people of Sikkim
2.	Climate Change/INDC targets	NA		
3.	International Commitments	NA		
4.	Bilateral engagements	NA		
5.	National Policies	NA		
6.	Others collaborations	NA		

7. Project Stakeholders/ Beneficiaries and Impacts

S. No.	Stakeholders	Support Activities	Impacts
1.	Gram Panchayats	5	Study will benefit the common people
2.	Govt Departments (Agriculture/ Forest)	NMHS and Sikkim Govt.	
3.	Villagers	Awareness workshop conducted	
4.	SC Community	NA	
5.	ST Community	NA	
6.	Women Group	NA	
	Others (if any)	NA	

8. Financial Summary (Cumulative)

S. No.	Financial Position/Budget Head	Funds Received	Expenditure/ Utilized	% of Total cost
I.	Salaries/Manpower cost	488400	942249	192%
II.	Travel	430000	231216	53%
III.	Expendables &Consumables	60000	79189	99%
IV.	Contingencies	40000	45441	112%
V.	Activities & Other Project cost	500000	800282	160%
VI.	Institutional Charges	0	0	0
VII.	Equipments	480000	167906	35%
	Total	20,48,400	22,66,283	110%
	Interest earned	106582		
	Grand Total	21, 54, 982		

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

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

S. No.	Name of Equipments	Cost (INR)	Utilisation of the Equipment after project
1.	Laptop	84800/-	Department of Physics
2.	Printer	23445/-	Department of Physics

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

10. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States Covered	*2*	*Sikkim and West Bengal*
2.	Project Site/ Field Stations Developed	*NA*	
3.	New Methods/ Modeling Developed	New Methodology developed	Section 3.1 [Part-B]
4.	No. of Trainings arranged	*2*	
5.	No of beneficiaries attended trainings	*98*	
6.	Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA):	*JRF-1, and RA-1*	
7.	SC stakeholders benefited	*NA*	
8.	ST stakeholders benefited	*NA*	
9.	Women Empowered	*NA*	
10.	No of Workshops Arranged along with level of participation	*2*	
11.	On field Demonstration Models initiated	*NA*	
12.	Livelihood Options promoted	*NA*	
13.	Technical/ Training Manuals prepared	*NA*	
14.	Processing Units established	*.NA*	
15.	No of Species Collected	*NA*	
16.	New Species identified	*NA*	
17.	New Database generated (Types):	*2*	*Submitted to NMHS*
	Others (if any)		

11. Knowledge Products and Publications:

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal Research Articles/ Special Issue:	2	1	2.1	Attached
2.	Book Chapter(s)/ Books:	NIL			
3.	Technical Reports	NIL			
4.	Training Manual (Skill Development/ Capacity Building)	NIL			
5.	Papers presented in Conferences/Seminars	NIL			
6.	Policy Drafts/Papers	NIL			
7.	Others:				

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

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

Particulars	Recommendations
Utility of the Project Findings	Water quality data of household of 96 and spring of 346, and water demand survey of 189 household will be useful for quality and quantity assessment of water. Number of 5 panchayat are benifited from the study.
Replicability of Project	Same study can be carried out in West, North, and East Sikkim and Kalimpong Region of West Bengal
Exit Strategy	Exit strategy is presented in Sec-7 [Part B]

Jaman 09/12/2022

(PROJECT PROPONENT/ COORDINATOR)

(Signed and Stamped)

Assistant Professor
Department of Physics
National Institute of Technology Sikkim

9/12/2022

(DEAN R&C OF THE INSTITUTION)

(Signed and Stamped)

Dean
(Research and Consultancy)
National Institute of Technology Sikkim

Place: NIT Sikkim, Ravangla
Date: 09/12/2022

PART B: PROJECT DETAILED REPORT

Innovative and Sustainable Decision Support System for Drinking Water Security in the Indian Himalayan Region of Sikkim and West Bengal

NMHS project reference number: GBPNI/NMHS-2017/SG-01/

Project duration: 01 March 2018 to 30 November 2021

Report Prepared by:

Dr. Md Nurujjaman (PI)

Dr. Barun Kumar Thakur (Co-PI)

Dr. Kanish Debnath (Co-PI)

Dr. Debi Prasad Bal (Co-PI)

Mr. Bikram Paul (Project Scientist)

Name and Address of Project Implementing Institutes:

1. National Institute of Technology Sikkim, Ravangla, India- 7373139,
2. FLAME University Pune, India- 412115,
3. RV University, Bengaluru, India- 560059,
4. Birla Global University, Bhubaneswar, Odisha, India-751003.

1. Name and Contact of Project principal Investigator [From 26.12.2019--30.11.2021]:

Dr. Md. Nurujjaman

Contact No: 9734252861/ 7479013207 (mob); jaman_nonlinear@yahoo.co.in

2. Name and Contact of Project principal Investigator [From 01.03.2018--26.12.2019]:

Dr. Debi Prasad Bal

Contact No: 6295688679 (mob); debiprasad.bal@gmail.com

1 EXECUTIVE SUMMARY

The Executive Summary of the project should not be more than 3–5 pages, covering all essential features in precise and concise manner as stated in Part A (Project Summary Report) and Part B (Comprehensive Report).

Drinking water security is an essential requirement for populations living in the towns and cities of the Indian Himalayan Region. Increasing population pressures at higher altitudes have led to a decline of both the quality and quantity of water. Therefore, to assess pathways to improve the drinking water availability in the region, this project was run with the following objectives –

1. To assess quality and quantity of water resources in the districts of South Sikkim and Darjeeling;
2. To establish drinking water security through a participatory approach;
3. To estimate the cost of drinking water in the region;
4. To build a Decision Support System to support water demand;
5. To devise a long-term Policy Framework integrating all the stakeholders.

For this purpose, the study areas chosen were the districts of Darjeeling (West Bengal) and South Sikkim (Sikkim). The sites visited in South Sikkim were the habitations in Ravangla, Melli, Temi, Jorethang, and Namchi, and the sites visited in Darjeeling were the habitations in Darjeeling City, Sukhiya, Bijanbari block and Kurseong. To assess quality and quantity of water resources in the districts of South Sikkim and Darjeeling, we actively enquired about springs and wells from locals. We then reached and mapped the source of most springs and wells. We also went to some random households in each area and collected water samples from each place. At each site, the following activities were carried out –

1. Mapping of the latitude, longitude, and elevation of the source
2. Observation of the surrounding areas and land usage and also spring usage
3. Measurement of the flow rate of springs (if possible)
4. Collection of water sample – either directly from springs or spring pools or household taps
5. Field tests of the water sample using field test kits. The parameters checked were pH, total hardness, alkalinity, iron, fluoride, chloride, nitrate and turbidity.
6. If the field test cannot be conducted, then the temperature is recorded and the water is collected in glass containers, labelled them, and brought to the laboratory.
7. We also asked local residents about each source and tried to estimate the number of households that are dependent on the water source.

Overall, our team could test water samples from 160 sources in South Sikkim and 72 sources in

Darjeeling leading to a database of 232 sources. At the time, we tested the water quality of 96 households (38 in Darjeeling and 58 in South Sikkim). Tests on water flow rate could not be performed everywhere. In most places, there were multiple outlets (or jhoras) and in some places the water came from the underground into a well. Overall, water flow rate was measured at 114 sources (29 in Darjeeling, 85 in Sikkim).

To establish drinking water security through a participatory approach, we engaged with local residents, village level and block level policymakers, state level representatives, other stakeholders, and experts. We had expert lectures and awareness drives. Two stakeholder meetings were conducted to discuss about the problems the residents face with regards to drinking water in the region. The ensuing discussions enabled us to refine and improve our household survey questionnaire. The survey was completed by 189 households in South Sikkim and an earlier version of the survey was completed by 100 households in Darjeeling. The survey questions were used to estimate the costs of drinking water in the regions and also find the factors that impact the demand for drinking water the most in these places.

To estimate the cost of drinking water in the region, we use the midpoint method to compute the price and income elasticity of water demand. Elasticity has been calculated using the formula –

$$\left|\varepsilon_p\right| = \frac{(Q_2 - Q_1)/(Q_2 - Q_1)/2}{(P_2 - P_1)/(P_2 + P_1)/2}$$

Where, Q2 is the quantity demand in the second period, Q1 is the first-period quantity demand, P2 is the price of the second period, and P1 is the first-period price. We use a Panel Regression Model is used to check the robustness of the results. This work was published with the title – "Estimation of price and income elasticity of water: a case study of Darjeeling town, West Bengal, India" in an issue of the journal – Current Science in the year 2021. We divided the households into groups of 25 each according to the mode of consumption of water, such as domestic pipeline, commercial pipeline, domestic water tanker and commercial water tanker. This study concludes that the price for domestic pipeline connection, commercial pipeline, domestic water tanker and commercial water tanker is elastic by using the midpoint formulae of elasticity. More specifically, the consumption of water from commercial tankers and households that have commercial pipeline connection have relatively high elasticity as compared to households depending on domestic pipeline connection and domestic water tanker. Further, the result shows that the income elasticity of water demand is relatively high. Mainly, the income elasticity is less in households under domestic pipeline and domestic water tanker compared to those under commercial pipeline and commercial water tanker. The overall implication of the study is that rising water per litre price has compelled the residents to compromise on the quality of drinking water in the Darjeeling region.

We also evaluated the Water Quality Index (WQI) for the South Sikkim district to gain an estimate the cost of drinking water in the region. Due to the rapid development of the tourism industry in the region, water scarcity has become one of the significant issues in some parts of the South Sikkim district. The lack of sufficient spring water to meet their drinking water needs has forced the local people to depend on alternate sources such as surface or rainwater. The main aim of the current research is to determine the acceptability of drinking water sources using the Water Quality Index (WQI) values. The Bureau of Indian Standard (BIS 2012) was used to evaluate the WQI and evaluate the quality of water for the water sources. Physicochemical parameters such as potential of hydrogen (pH), hardness, alkalinity, iron (Fe), fluoride (F^-), chloride (Cl^-), nitrate (NO_3^-), and turbidity were analysed using standard devices and found that water is safe for drinking purpose. The presence of all these parameters did not affect the water quality as all are below the permissible limit. The water delivered after conventional treatment to individual households by local administration is free from contaminants and suitable for drinking. In other places the local residents obtain water through their own arrangements. Based on WQI values, surface waterfalls under the projected area of South Sikkim district into two categories: excellent water and good water (ranging from 0 to 50). However, water scarcity continues to remain a major challenge.

In order the build a decision support system that can aid local governance of drinking water, we look at the field survey details of 150 households randomly selected from five major areas of the district of South Sikkim - Ravangla, Melli, Temi, Jorethang, and Namchi. A DSS can be viewed as “an integrated, interactive computer system, consisting of analytical tools and information management capabilities, designed to aid decision makers in solving relatively large, unstructured problems” (Watkins and McKinney 1995). Many decision support systems have been developed to face the problems of water-resource management. The need for a DSS is clearly emergent as a result of the increasing complexity of the decision situations caused by the numerous conflicting, often spatially related objectives, and the dissimilarity of stakeholders involved (Mysiak et al., 2005). Indian mountainous regions are generally facing severe water related problems mostly because the authorities are not planning and executing the things properly though rainfall is moderate to severe in most of the Himalayan part of India. Another causes for scarcity of water is due to the increasing population and economic growth, urbanisation and changing climatic patterns (Haque et al., 2014). Our study show that the GIS-referenced models can be used as a tool to take a constructive decision on the consumption of drinking water. It also suggests that a preliminary survey followed by a detailed survey is required to collect the important data on which drinking water consumption are dependent, are extremely effective for the preparation of a DSS. Finally, a statistical analysis is done to find out the water demand index, which will be an extremely efficient parameter to get an idea about the water demand of in Ravangla, South Sikkim. Though this problem has existed for years, a proper solution has not been worked out. We plan to bring in a modern approach to the persisting management problem of water. We are envisaging a decision support system for the water resources rejuvenation and management by harnessing the knowledge of local stakeholders and end-users.

To devise a long-term Policy Framework integrating all the stakeholders, we engaged into Stakeholder meeting, Expert discussions and planning for future demand of drinking water. Taking above things into account we arrive a policy suggestion that should aim at SMART – an acronym that is formed of the actions briefly detailed below.

Save and rejuvenate spring sources:

Saving and rejuvenating spring sources is important for a number of reasons. First and foremost, springs are a critical source of fresh water for many communities, providing drinking water for people and irrigation for crops. Rejuvenating springs can help ensure that these water sources remain healthy and productive, providing a sustainable source of water for generations to come.

In addition to their practical value, springs also have significant ecological importance. Many species of plants and animals rely on springs for their survival, and the health of spring ecosystems can serve as an indicator of the overall health of a region's environment. Protecting and restoring spring sources can help support the biodiversity of an area and protect the natural habitats of a wide range of species.

Finally, rejuvenating spring sources can also have cultural and historical value. Springs often have deep cultural and spiritual significance for the communities that rely on them, and protecting these sources can help preserve the traditions and heritage of these communities. In addition, many springs have a long history, and protecting these sources can help preserve a vital piece of our natural and cultural heritage. Integrated Water Resource Management (IWRM) means that basin management will engage individuals who have an interest in or who will be impacted by decisions about water resources and that information will be freely distributed. Finding effective solutions depends on having access to information. The IWRM approach is challenging to implement in situations when there is a lack of accountability or transparency, when individuals who are affected are left out, or when corruption is rampant. Therefore, there has to be a plan of action to rejuvenate the spring sources that are dead or dormant.

Monitor water quality in sources:

Government representatives, lawmakers, representatives from non-governmental organisations, and laypeople who meet to discuss issues related to water management make up a basin council, which may be formal or informal. Typically, councils are formed to provide government with advice. A council lacks regulatory authority in contrast to a commission, another group of specialists. Basin associations or councils (also known as syndicates) may coexist with the formal administration and serve to represent various user groups, nongovernmental organisations (NGOs), or local community organisations. These organisations or councils can play a number of different roles, including advising, educating, and inspiring ownership of basin natural resource management, as well as fostering information interchange. They may also serve as watchdogs. Sometimes they are designed to address a particular issue or for a specific basin. Rejuvenating the spring sources is not only enough but they must be regularly monitored for their health and a spring or river basin monitoring council is the way forward.

Awareness about drinking water quality:

Public education and awareness programmes for basins are used to keep residents and employees informed about basin issues and basin management. The target audiences are numerous and diverse, and they include residents of the basin, businesses operating both inside and beyond the basin, include water utilities, industries, tourist destinations, fisherman, and farmers. These programmes assist basin management by conveying concise communications regarding problems, solutions, and advancements. There has to be programs for school and college students that instil a basic responsibility towards managing the quality and quantity of springsheds in South Sikkim and Darjeeling. Awareness of the problems caused by different impurities in the water like nitrates and microorganisms like E.Coli are important to maintaining family health and workforce.

Reduce Water Wastage:

During our study we found that there is a lot of unnecessary water wastage from households like washing of cars, vehicles, and courtyards with hose-pipes, flood irrigation in agriculture in some areas, and water wastage through hotels and restaurants. Awareness of the glaring issue of the quick depletion of the water sources due to the drying up of springsheds, lower glacier melt, and rising temperatures due to climate change are needed to be ingrained into the habits and behaviours of every households and hotels in the mountain state. Reducing water wastage is an imperative for arresting climate change.

Treat Wastewater effectively:

Effective treatment of wastewater is important for several reasons. First and foremost, untreated wastewater can pose a significant health risk to people and animals. It can contain harmful pathogens and chemicals, which can contaminate drinking water sources and cause a range of diseases. By treating wastewater, we can remove these contaminants and make the water safe for human and animal consumption.

In addition to protecting public health, effective wastewater treatment is also important for the environment. Untreated wastewater can pollute rivers, lakes, and other bodies of water, harming aquatic life and reducing the water quality. By treating wastewater before it is released into the environment, we can prevent this pollution and help protect the health of our water sources.

Finally, effective wastewater treatment can also have economic benefits. In many areas, wastewater treatment is a critical part of the infrastructure, and investing in effective treatment systems can help support local economies and provide jobs. In addition, by preventing pollution and protecting water sources, effective wastewater treatment can also support industries that rely on clean water, such as agriculture and tourism.

2 INTRODUCTION

2.1. Background of the Project:

Drinking water is a commodity that is required by all, but only few are aware and have access to water that is safe for drinking. Further, water sources have reduced while population has risen, leading to water scarcity in many regions in India. The problem is acute in the Indian Himalayan Region. In many parts, water availability due to shrinking of glaciers, decreased temporal spread of rainfall due to climate change, multiple uses of water (e.g. car washing, agriculture), lack of storing capacity of rain water and the improper and inefficient recycling of waste-water has created a huge crisis in the supply and management of drinking water sources. Though this problem has existed for years, a proper solution has not been worked out.

Water is now a scarce resource both in terms of quality but also quantity. Water is not only essential to human well-being but it serve a variety of purpose such as demand for domestic water supply, irrigation for crops, recreation values, and livestock etc. (CIMSHE 2005). It can be used as both use and non-use value. Due to increasing population pressure, rise in irrigation, drinking water, and industries the demand utilization in the State of Sikkim will be doubled by 2050 (CIMSHE 2005). According to an estimation by irrigation department, Government of Sikkim the projections of water utilization demand in the rural areas will increase more than two-fold from 17.2 in 2010 to 37.53 in 2050. On the other hand, water problem in Darjeeling is more severe than Sikkim as the population in Darjeeling has increased 12 times from the population in 1915, but the water supply has not improved accordingly. In the context of these scenario the conservation of water in general and drinking water in particular is need of the time for sustainable development to not only inter generation but also for intra generation.

The present proposal also highlights the vision of National Rural Drinking Water Program (NRPPD) and Rural Management and Development Department (RMDD) to provide clean, safe and adequate drinking water to all the inhabitants in general and in particular the rural habitation to ensure water security. The management of water supply using a Decision Support System (DSS) on a Geographic Information System platform is therefore envisaged here. The DSS will be strengthened through knowledge community participation and involvement of local stakeholders will be useful to spread awareness among the people and to help them to sustain their present and future water scarcity with judicious and careful use of water resources.

2.2. Overview of the major issues to be addressed

Drinking water scarcity in the Himalayan region is increasing progressively especially during the spring and winter seasons. South district of Sikkim and Darjeeling district of West Bengal have been included in our project, where the main problems are related to the increasing water demand with respect to the current capacity. Simultaneously, there are lack of awareness and knowledge on the quality of water, which are prone to water scarcity. Hence the following issues have taken for the study in the project:

- **Increased water stress and demand in the south district of Sikkim and Darjeeling district of west Bengal:**

  It has been observed that the effect of water scarcity in India is depend on the geographical diversity and management of water resources. Due to the increase in population, unplanned development and topographical barriers, the water crisis is increasing day by day in the Indian Himalayan Region (IHR). Similarly, Sikkim and Darjeeling are also facing same problem. Though the water demand in the region of Sikkim and Darjeeling has increased exponentially with the increasing population and urbanization, improvement is not done in the water infrastructures and supply for a long period (Mondal, T.K. and Roychowdhury, P., 2019 and Tiwari, A., 2012). Hence, in order to quantify the present status of water uses are very much required to get the water demand.

- **Lack of information on areas facing scarcity and hence supply not meeting demand:**

  The water scarcity is more prominent in the south and west district of Sikkim due to the less rainfall in this part of Sikkim (Sharma, S., Kumar, K. and Singh, K.K., 2013). Though some dry areas surrounding Namchi, south sikkim has been identified, there is a need to carry out survey surrounding the Ravangla. Moreover, there are some other area near Ravangla, South Sikkim, where the water scarcity is present.

- **Low awareness of the water quality of natural springs and reservoirs:**

  In spite of substantial water resources in the study region, the lack of knowledge on water security and harvesting Sikkim, especially south Sikkim suffers from water shortages and crisis (Tiwari, A., 2012). Further, in some region of south Sikkim water samples contains contamination such as high basicity. In order to educate the general people about such problem, awareness programme is necessary.

2.3. Baseline data and project scope:

2.3.1. Study Area

Due to increased water stress in the Indian Himalayan region, South district of Sikkim and Darjeeling district of West Bengal are selected for the study. The South Sikkim is one of the major commercial and tourist centres of Sikkim. The district is covered by terraces of agricultural grounds and stepped slopes, intercepted by spring- patched forests, waterfalls, and majestic mountains. It is bounded by the latitude 27°14′20″ N and longitude 88°18′15″ E with an area of about 750 km^2. As per the 2011 census report, the total population of the South Sikkim district is 1,46,742 and lies at an altitude between 400 metres and 2000 metres (CGWB 2019). There are various climatic conditions in this region, and the average annual precipitation is recorded at 162.5 cm. Mainly three seasons are observed, i.e., summer season (April to June), rainy season (July to September), and winter season (October to March). The average maximum temperature observed 17-27 °C and a minimum of 02-21 °C (District profile, South Sikkim). Five major areas (Ravangla, Melli, Temi, Jorethang, and Namchi) under the South Sikkim district have been identified to collect and analyse water samples. The location of the study area on perennial and seasonal springs are presented in Figure 2.1.

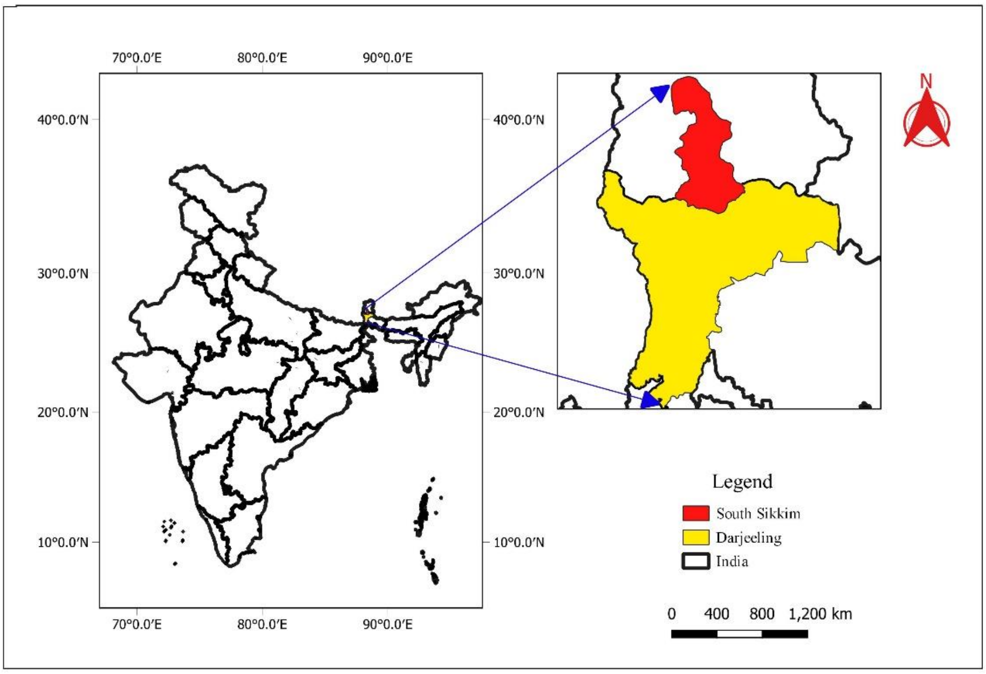


Fig. 2.1. Location of map of the study area of the project

Darjeeling is a famous district of West Bengal. It is known for its tea industry, various tourist attractions for its natural beauty. It is also a UNESCO World Heritage Site. As per the government site of West Bengal, Darjeeling district covers an area of 3,149 km^2 with a population of 18,46,823. It is situated with latitude 27° 2' 9.6252" N and longitude 88° 15' 45.6192" E. According to India Meteorological Department, annual mean maximum temperature of Darjeeling district or city is 17.2 °C, the mean minimum temperature is 8.5 °C and average annual precipitation is 2,380 mm.

Proposed solution:

Addressing the major issues related to the water stress in the region of south Sikkim and Darjeeling, a proper water management scheme should be developed so that a government could take the necessary action to manage and supply the water as per requirement from the local areas. It has been seen from the previous studies that a decision support system will serve the purpose of water management related issues (Mysiak et al, 2002). However, assurance cannot be given in terms of river water quality and quality of spring water. In that case, a field survey has been conducted to collect the spring water and finally testing has been carryout to ascertain about the water quality. Not only the quality of water is important but also, we should have some knowledge about the security of water resources. Water security could be achieved by gathering proper knowledge like storing the drinking as well as regular purpose use, recycling of water, rain water harvesting etc.

2.3.2. Direct Beneficiary and Indirect Beneficiary

As we have conducted field survey and gathered real data from the field, the project gives benefit to all gram panchayat and local bodies, which are associated with the survey. Due to the clear idea getting from the field will help the government or local authority to act against the water quality related problem or water scarcity. A workshop and an awareness programmed were organized with help of the local authority so that the people can gather some knowledge about the quality drinking water, security of water. Indirectly, all population of Ravangla and its surroundings has been benefitted from the project by government scheme.

2.3.3. Water Price and Income Elasticity of water:

The exponential rise in the price of water per litre in Darjeeling town, West Bengal, India has compelled the residents to compromise on both the quality and quantity of drinking water. However, south Sikkim has faced water related problem due to less rainfall in the rangit valley region and the increasing tourist during the tourism seasons in Namchi, Ravangla, Jorethang and many other regions (Sharma, S., Kumar, K. and Singh, K.K., 2013). The price of water keeps increasing at regular intervals owing to the monopoly market, where there is no prescribed benchmark to fix the price of drinking water. The daily water requirement of the town is about 1,860,0000 gallons, but the municipality supplies only about 527,5000 gallons of water, thereby inducing a water deficit of about 1,332,5000 gallons per day (Department of Information Technology, Annual Report. Government of Sikkim, 2012). Statistics shows that an increasing population has resulted in a reduction in per capita consumption of water every year in India (Shashikumar 2005). The contribution of this study is as follows. So, it is extremely important to gather knowledge and study to examine the price and income elasticity of drinking water in the case of the Indian Himalayas in general and Darjeeling in particular.

2.3.4 Water Demand

The Darjeeling city in the state of west Bengal and south Sikkim of the state Sikkim always have water stress in dry seasons despite of high rainfall during the rainy season overall. Now, the demand of water is more prominent in this area, especially due to the issues like global warming, unsteady ecological balance etc. A water deficit of about 1,332,5000 gallons per day has been confirmed by govt. of Sikkim in their annual report (Department of Information Technology, Annual Report. Government of Sikkim, 2012). Looking at the demand related problem in almost all the IHR region, we need to study the water demand in these regions.

2.4. Project Objectives and Target Deliverables:

2.4.1. The aims and objectives of the project are: -

1. To assess quality and quantity of water resources in the districts of South Sikkim and Darjeeling
2. To establish drinking water security through a participatory approach
3. To estimate the social and economic cost of drinking water in the regions
4. To build a Decision Support System to support water demand
5. To devise a long-term Policy Framework integrating all the stakeholders.

2.4.2 Target Deliverables: –

1. Decision support system to augment the current water security situation within a Geographic Information System (GIS) platform;
2. Generation of a database of water quality of households drinking water sources of around 200 households from 5 GPs;
3. Establishing the cost to improve the standards of drinking water quality as per Bureau of Indian Standards (BIS) specifications;
4. A policy framework integrating all the stakeholders for water security;
5. Estimating the social and economic costs of access to safe drinking water; and enhanced engagement and learning for local communities.

3. Methodologies, strategy and approach

3.1. Methodologies used for the study

We have chosen to use the survey methods for collecting data from the households regarding water usage and quality of water at their house.

3.1.1. Survey Method

Survey research is a common method of collecting data from a target population. It involves administering a questionnaire or a set of standardized questions to a sample of individuals, with the goal of gathering information about their attitudes, beliefs, behaviours, and other characteristics.

Surveys are widely used in the social and behavioural sciences, as well as in market research and other fields. They can be administered in a variety of ways, including in person, over the phone, by mail, or online.

One of the key advantages of survey research is that it allows researchers to collect data from many individuals quickly and inexpensively. This makes it possible to study a wide range of topics and to gather data from a representative sample of the population, which can provide insights that are generalizable to the larger population.

Another advantage of survey research is that it allows researchers to ask questions that are standardized and consistent across all respondents. This makes it possible to compare the answers of different individuals and to analyse the data in a systematic way.

However, survey research also has some limitations. One of the key challenges is ensuring that the sample of individuals who participate in the survey is representative of the target population. If the sample is not representative, the results of the survey may not be accurate or generalizable.

Another limitation of survey research is that it relies on self-reported data, which can be subject to bias. For example, individuals may not always remember or report their attitudes, beliefs, and behaviours accurately. They may also be influenced by social desirability bias, where they answer questions in a way that they believe is socially acceptable, rather than being truthful.

Overall, survey research is a valuable method for collecting data from many individuals quickly and inexpensively. While it has some limitations, it can provide valuable insights into the attitudes, beliefs, and behaviours of a target population when used properly.

Surveys can be useful for gathering information about water usage in a variety of ways. Some examples of the benefits of using surveys to gather data on water usage include:

1. Identifying trends in water usage: Surveys can help researchers and policymakers understand how water usage patterns have changed over time. This information can be used to identify trends and to develop strategies for conserving water and reducing waste.
2. Evaluating the effectiveness of water conservation programs: Surveys can be used to assess the effectiveness of water conservation programs by comparing the water usage habits of individuals who have participated in the program with those who have not. This information can help to identify the most effective strategies for reducing water usage.
3. Assessing the impact of drought and other environmental conditions on water usage: Surveys can be used to evaluate the impact of drought and other environmental conditions on water usage. This information can be used to develop strategies for dealing with water shortages and to plan for future droughts.
4. Identifying areas for improvement in water management: Surveys can be used to gather information about individuals' water usage habits and attitudes towards water conservation. This information can be used to identify areas where water management could be improved, such as by providing education or incentives to encourage water conservation.
5. Gathering data for water resource planning: Surveys can provide valuable data for water resource planning by helping researchers and policymakers understand how much water is being used and where it is being used. This information can be used to develop strategies for managing water resources more effectively.

3.1.2. Estimation of Water Quality Index

In the present work, eight significant parameters were selected to analyse quality of Water. Water quality index (WQI) is estimated to quantify the quality. The WQI has been calculated using the standards of drinking water quality suggested by the Bureau of Indian Standard (BIS). The values of weighted arithmetic index method, shown in table- 3.1, have been taken to evaluate the WQI of the water.

The Proportionality constant (K) value is calculated using the following equations (Chandra et al., 2017)

$$K= [1/(\sum_{i=1}^{n} 1/ Si)] \qquad (i)$$

where S_i is standard permissible for nth parameter.

Calculate unit weight for the nth parameters:

$$Wn= K/S_n. \qquad (ii)$$

W_n = unit weight for the nth parameter. S_n = standard value for nth parameters.

The quality rating (q_n) for nth parameter is calculated using the formula:

$$q_n=100 \{(V_n-V_{io})/(S_n-V_{io})\} \qquad (iii)$$

Whereas V_n = Estimated value of the nth parameter of the given sampling station. V_{io}= Ideal value of nth parameter in pure water. And S_n=Standard permissible value of the nth parameter.

Finally, the Water Quality Index (WQI) is evaluated by using the following formula,

$$WQI = ((\Sigma W_n * q_n)/\Sigma W_n) \qquad (iv)$$

Table 3.1.: Water Quality Rating as per Weight Arithmetic Water Quality Index Method (Tyagi et al., 2013)

Water Quality Index Level	**Classification**
0 -25	Excellent Water Quality
26-50	Good Water Quality
51-75	Poor Water Quality
76-100	Very Poor Water Quality
>100	Unsuitable for Drinking

3.1.3. Water testing methods: Chemical test

We have taken household as well as water source samples to analyse the quality of water. Both perennial and seasonal source have been taken for this study. pH, hardness, alkalinity, Iron, fluoride, chloride, nitrate and turbidity tests have been carried out to test the quality of the water. pH measures the acidity or basicity of a water sample. Presence of solids in water increase turbidity of a water sample. The other parameters like hardness, alkalinity, chloride, nitrate, iron, fluoride also affect the quality of water and presence of more than desirable concentration can cause of harmful diseases such as keratosis, melanosis, fluorosis, methemoglobinemia (blue baby disease). The pH & TDS value is measured using a portable pH & TDS meter.

3.1.4. Water demand elasticity

Elasticity in general is a measure of how sensitive the quantity demanded to its price. In order to calculate the price and income elasticity of water demand, midpoint method is used. The price elasticity of demand computes the percentage change of quantity demand with respect to the percentage change of its price. More specifically, it measures how much the quantity demand responds to a change in price. The demand is considered to be elastic when the quantity demand responds more to a small change in its price. On the other hand, the demand is considered to be inelastic when the quantity demand responds less to a small change in its price. So, the general formula to measure the elasticity of demand can be written as

$$|\varepsilon_p| = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q}$$

where ε_p is the price elasticity of demand, ΔQ the change of quantity demand for water, ΔP the change in water price, P represents the original water price, and Q is the original quantity demand for water. The absolute value of the elasticity of demand varies between 0 (perfect inelas- tic demand) and infinity (perfect elastic demand). If the calculated value is zero, then the demand for the goods and services is perfectly inelastic. The perfectly inelastic demand indicates that no substitute goods or services are available. Similarly, if the measured value is infinite, then it is a perfectly elastic demand indicating that a large number of substitute goods and services are available to the consumers. If we use the above formula to measure the elasticity from one point to another point and reverse, we may get two results. The reason is that the calculation is done with a different base. So, to avoid such problems, we use the midpoint method to measure the elasticity as follows

$$|\varepsilon_p| = \frac{(Q_2 - Q_1)\,/(Q_2 - Q_1)\,/\,2}{(P_2 - P_1)\,/(P_2 + P_1)\,/\,2},$$

where, ε_p shows price elasticity demand, Q_2 the quantity demand in the second period, Q_1 the quantity demand first period, P_2 the price of the second period, and P_1 is the price of the first period.

3.1.5. Panel regression model

We used two-period panel regression models in our analysis; that is, the year 2019 and 2020. It allows us to analyze the dynamic change of price and income on its quantity demand from 2019 to 2020. In the beginning step, we considered the regression model as follows

$$QD_{i2019} = \beta_0 + \beta_1 DPPW_{i2019} + \beta_2 DPY_{i2019} + \mu_{it}$$
$$QD_{i2020} = \beta_3 + \beta_4 DPPW_{i2020} + \beta_5 DPY_{i2020} + \mu_{it}$$

In the next step, we have taken the difference of the period 2019 and 2020 and the regression model as follows

$$QD_{i2019} - QD_{i2020} = \alpha + \beta_1 DPPW_{it} + \beta_2 DPY_{it} + \vartheta_{it}$$

Here $DPPW_{it}$ indicate domestic pipeline water tanker price for water, DPY_{it} show the income of households that consume from domestic pipeline.

QD is the quantity demand for water and is defined as $QD_t = \beta_0 + \beta_1 p_t + \beta_2 m_t + \mu_t$. Here β_1 is the intercept term and is the slope coefficient of price and β_2 is the slope coefficient of income and μ_t is the error term.

3.1.6. Cost benefit analysis:

The cost-benefit analysis is a method for valuation of ecosystem services. This can be measured either in market based or non-market-based approach. The non-market-based approaches are such as revealed preference, cost based stated preference and benefit transfer approach. There are two types of method to which we can able to measure the non-marked valuation of ecosystem services, i.e., indirect and direct method. Under direct method we can use Hedonic price method, travel cost method, replacement method and contingent valuation method. The travel cost method is generally useful in the case of measuring the recreational activities such as waterfall, natural spring, national park etc. The replacement method can avoid the damages and improve the water quality by measuring the cost of controlling efficient emission. Further, the Hedonic pricing method can give the clue for the available resources through which we can able to analysis their cost and benefit of ecosystem services. Finally, the contingent valuation approach can able to measure the willingness to pay for availing the ecosystem services and by considering the stakeholders' viewpoints we can able to analysis the cost and benefit of the ecosystem services. In our study we will use the method of Hedonic or replacement and contingent valuation method to analysis the cost and benefit of water demand.

3.1.7. Methodology Including Literature Review:

A decision support system (DSS) can be viewed as "an integrated, interactive computer system, consisting of analytical tools and information management capabilities, designed to aid decision makers in solving relatively large, unstructured problems" (Watkins and McKinney, 1995). Many decision support systems have been developed to face the problems of water-resource management. The need for a decision support system (DSS) is clearly emergent as a result of the increasing complexity of the decision situations caused by the numerous conflicting, often spatially related objectives, and the dissimilarity of stakeholders involved (Mysiak et al, 2002). Indian mountainous regions are generally facing severe water related problems mostly because the authorities are not planning and executing the things properly though rainfall is moderate to severe in most of the Himalayan part of India. Another causes for scarcity of water is due to the increasing population and economic growth, urbanisation and changing climatic patterns (Haque, Rahman, Hagare, & Kibria, 2014).

It has been observed from the previously published literature that decision support system has been developed on a GIS platform to highlight the area, whether the area has any water problem or not and based on the DSS any authority or Govt can take decision for the further improvement. A sustainable water supply management system should be developed based on the water consumption data of house hold and factors influencing the water consumption, which will further help in forecasting the future water demand for that area (Hussien et al., 2016). They also analysed household characteristics, behaviour and intensity of water users and indoor and outdoor water users by carrying out survey. 763 households were interviewed to collect data of the domestic household water consumption, and they found 117.0 litre as the daily average water consumption with a standard deviation 35.8 in rural India (Singh et al, 2012). Increasing demand in domestic water consumption indicates the need to forecast the domestic water demand using a static microsimulation technique, which will be a starting from the regulatory point of view and minimizing the environmental impacts like water abstraction, water quality and the water cost (P. Williamson et al., 2002). It was reported that Kandi region in Jammu, a Northern Himalayan Region, always faced a water related problem, especially for drinking water scarcity and also suggested a probable solution adopting rain water harvesting technique. Water balance study had been done by estimation water balance assessment with the help of remote sensing and GIS (Jasrotia et al., 2009)**.**

A Geographical Information System (GIS) technique was adopted for a watershed development program to identify the different sites for water conservation, where different types of structure can be constructed. Integrated analysis of all the maps and their respective weightage in GIS platform was evolved a map showing potential zones for water conservation structures and their appropriate measures (Varade et al., 2017). A survey was conducted to collect the data for estimating domestic water use and adopting a water conservation measures in Turkey and finally, it was checked by conducting an experiment (Yurdusev et al., 2007).

The above studies show that the remote sensing and GIS can be used as a tool to take a constructive decision on the consumption of drinking water in Sikkim and Darjeeling. It also suggests that a preliminary survey followed by a detailed survey is required to collect the important data on which drinking water consumption are dependent, are extremely effective for the preparation of a decision support system. Finally, a statistical analysis is done to find out the water demand index, which will be an extremely efficient parameter to get an idea about the water demand of State Sikkim and Darjeeling, a district of West Bengal.

3.2. Preparatory actions and agencies involved

The entire field work was initiated and completed by the project team and there were no other agencies involved.

3.3. Details of Scientific data collected and Equipment's Used

Garmin-GPS instrument was used to collect the geographical information (latitude, longitude, elevation) about the source as well as the households (see picture below).

Fig. 3.1. Instrument used to collect the geographical information.

Flow rate of the source was measured using marked buckets of different sizes and stop watch (see picture below). The flow rate was measured multiple times at different positions of the source and an average flow rate was calculated. The flow rate is defined as:

$$Flow\ rate = \frac{Volume\ occupied}{Time\ taken}$$

Fig. 3.2. Instrument used to measure flow rate of the water sources.

Borosil glass bottles were used to collect the water samples (see picture below). In order to avoid any contamination these bottles were thoroughly cleaned and dried after every survey in the laboratory of Chemistry department NIT Sikkim. A thermometer was used to measure the temperature of the sample immediately after the collection.

Fig. 3.3. Borosil glass bottles kept for sterilization before collecting water samples.

Water testing master kit: Prerana laboratories master kit was used for water testing (see pictures below). The testing kit was taken at source as well as household survey. The kit consists of the manual and all the necessary chemicals and tubes for the tests. The test of pH, iron, nitrate, and fluoride is carried out by colour comparator method. The colour comparator consists of two parts: 1. Colour chart and 2. Comparator unit. There are four different colour charts for above four parameters with their corresponding values. After the chemical test is performed as per the manual, we compare the colour of the sample with the chart comparator. The matching colour value is the value of the test. For hardness, alkalinity and chloride test colour change method is used. In case of hardness test, drop-wise reagent D-25 is added until the colour changes from pink to blue. Each drop of reagent D-25 = 10ppm.

Fig. 3.4. Prerana field test kit for testing water samples.

Fig. 3.5. Water quality tests being performed.

3.4 **Primary Data Collected**

Water samples were collected from the water source and households from different parts of South Sikkim and Darjeeling district to test the water quality. Field survey was conducted by a local field-investigator, project employee and a hired local person of the area. The help of the local person was required to identify and reach the water source as most of the source was situated at difficult areas. Their presence also made the source survey very comfortable.

Water quality tests were conducted on the site itself. Different water quality parameters like pH, hardness, alkalinity, chloride, fluoride, iron, nitrate, turbidity was tested using multi-parameter water testing kit.

Geographical information like latitude, longitude, elevation of the source was collected. This information will be required to identify and map the exact location of the source. Water flow rate and the nature of source were also collected to understand the water availability for the people dependent on the source. Temperature of the sample was taken directly after the collection (see picture below).

Fig. 3.6. Collection and field testing of water samples.

Household surveys were also conducted to collect the information about their family, water consumption, health problems faced. Household survey was conducted by the local field-investigator in the local language for the convenience of the household members. The basic information about the project and its objectives were conveyed to the household members. We assured that their data will only be used for research purpose and the privacy will be maintained. Only after their approval the survey was conducted. They were free to deny to answer any questions during survey.

3.5. Details of Field Survey arranged:

Our field survey locations are South district of Sikkim and Darjeeling district of West Bengal.

South Sikkim

South Sikkim is one of the four districts of Sikkim. Namchi and Ravangla are the two sub-divisions of the district. Different sites selected under these sub-divisions are:

Sites from Namchi sub-division:

1) Assangthang: It is located in the outskirts of Namchi Bazar. Assangthang is surrounded by Jorethang towards west, Sumbuk towards East, Kaluk towards North, Sikkip towards North. There are only few water sources and they are at difficult locations.

2) Damthang: It is located 13 km away from Namchi and lies between Namchi and Ravangla. Damthang is surrounded by Temi Tarku towards East, Namchi towards South, Ravangla towards North, Kaluk towards west. It lies within dense forest and the average temperature is low.

3) Melli: It is a town located in Sikkim-West Bengal border. Teesta river originates from high altitudes of Cho Lhamu Lake and flow in southern direction till it reaches Melli. Melli lies at an elevation about 330 and the temperature is higher compared to other places in South Sikkim.

4) Temi: It is located 26 km away from Namchi district headquarter. There are about 300 houses. The only tea estate in Sikkim is located in Temi. It has few perennial water sources at the inner dense forest.

5) Phalidara: Phalidara village is situated in Namchi, District South District. Total geographical area of Phalidara village is 328.86 Hectares. Gram Panchayat name of the Phalidara village is Maniram Phalidara. Namchi sub-district headquater distance is 8 Km from the village.

Ravangla sub-division:

1) Kewzing: It is located 10 km south-west of Ravangla and 35 km away from district head-quarter Namchi. It is at an altitude of 4600 ft. with a total geographical area of 260 hectares. There are seasonal as well as perennial water sources situated in the village of Kewzing.

2) Yangang: It is located in South District of Sikkim. It is located 39 KM towards South from District head-quarters Namchi. Yangang Rangang is surrounded by Temi Tarku Tehsil towards South, Khamdong Tehsil towards East, Ravong Tehsil towards west, Sikip Tehsil towards west.

3) Neya Mangzing: It is situated 25km away from sub-district head-quarter Ravangla and 51 km away from district head-quarter Namchi. Singtam is the nearest town to Mangzing which is approximately 18 km away.

4) Ben Namphrik: It is situated 12km away from sub-district headquarter Ravangla and 38km away from district headquarter Namchi. Ben Namprik is the gram panchayat of Namphrik village. The total geographical area of village is 546.34 hectares.

Darjeeling

1) Kurseong: It is a town in Darjeeling district of West Bengal. It is the headquarter of the Kurseong subdivision. Located at an altitude of 1,482.55 metres and 32 km from Darjeeling, the region has a pleasant climate throughout the year. Bagdogra is the nearest airport while New Jalpaiguri railway station is the nearest railway station.There are very few water sources and a majority of the public depend on commercial water tanker for their daily use.

2) Sukhia: It is a town in the Jorebunglow Sukhiapokhri block in the Darjeeling Sadar subdivision of the Darjeeling district. It is located 11 km from Ghum on the way to Mirik. Balasun river rises from the Jorepokhari, Sukhia (about 18 km from Darjeeling town) and flows towards the south east into the plains of North Bengal, where it joins the Mahananda River.
3) Sonada: It is 17 km from Darjeeling town and 16 km from Kurseong and lies on National Highway 110 connecting Darjeeling with Siliguri. It has an altitude of 6143 ft. and the winters are very cold.

4) Chimney: It is a village in Kurseong block in Darjeeling district. It belongs to Jalpaiguri Division, located 20 km towards South from district head-quarters Darjeeling.

3.6. Strategic Planning for each Activities

The time given to the project team to complete the objectives were 3 years starting from the 1st of March 2018 till 28th February 2021. Though this time duration seemed adequate at the start of the project, the team ran into several unforeseen roadblocks and some of the target deliverables could not be achieved. The precise problems faced by the team are detailed below –

1. South Sikkim and Darjeeling being in high altitude regions, the winters get very cold and foggy. Hence for around 4 months of winter, water source surveys could not be undertaken. Surveys also could not be done during the monsoon season when due to rainwater flowing down through different streams cannot be distinguished from the natural perennial spring sources. Thus, almost half of the year is unavailable for surveys.
2. We could not hire project staff for undertaking the survey quite easily. We did not get many candidates responding to our advertisements and many of the times candidates were found to be unsuitable for doing fieldwork. Thus, we could manage to go on the field only a few times in 2018 and 2019. Hiring of project scientist was even more difficult as we could not find suitable candidates and those candidates who were found to be good did not wish to relocate to Ravangla, Sikkim to work on the project.
3. In the year 2020, all our plans got cancelled due to the global pandemic Covid-19. The state of Sikkim did not allow outsiders into the state even after lockdowns were lifted from the country. We also could not hire project scientists or field investigators to continue the work after the Covid lockdowns were lifted.
4. We only received 40% of the amount sanctioned for the project in the first tranche and the next tranche was never released to us. One of the reasons cited to us was that we did not fully utilize the first tranche. However, we completely exhausted our budgets on some heads, and we could not continue to employ the project scientist.

Water source survey: (Duration: 6 months)
Water sources are identified and samples are collected in South Sikkim and Darjeeling district. Different types of water source such as perennial, seasonal and dry sources are identified.

Preparation of Questionnaire: (Duration: 5 months)
The questionnaire was prepared during the initial period of the project and was piloted in 2018.

Household survey: (Duration: 3 months)
Household surveys are conducted in different households of South Sikkim and Darjeeling district. Water samples are also collected from each household to conduct the water quality test.

Water sample testing: (Duration: on field / in lab immediately)

Water quality test is conducted in the site itself. pH, hardness, alkalinity, chloride, fluoride, nitrate, iron and turbidity tests are conducted for both household and water source data.

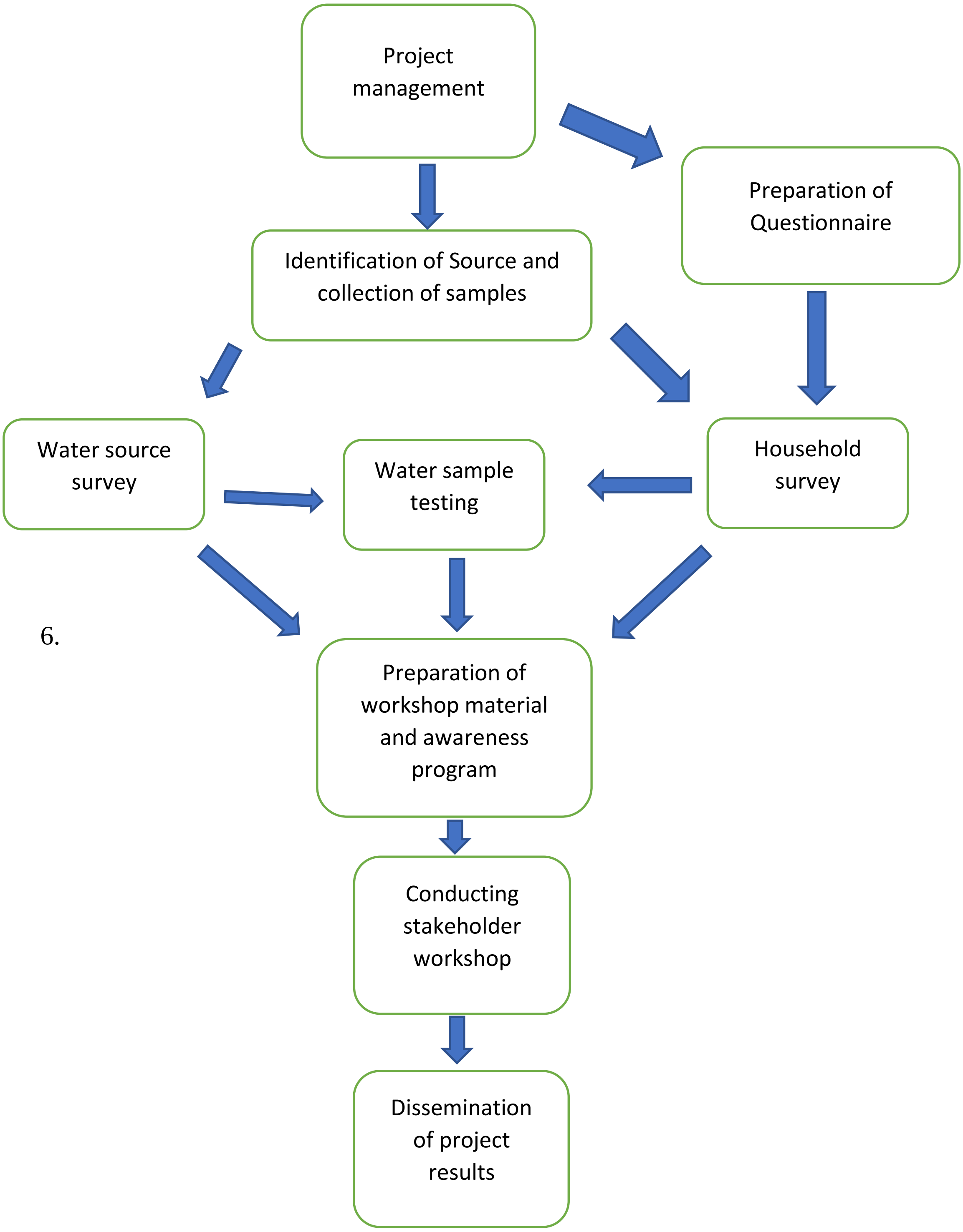
Preparation of workshop material and awareness program: (Duration: 0.5 months)
Two workshop-cum-awareness programs were conducted. The main objective of the workshop and awareness was to provide basic knowledge about water related diseases and water conservation.

Conducting stakeholder workshop: (Duration: 2 days)
Two stakeholder meet was conducted. Local panchayat and their representatives, government officials, NGO's and general public were invited to attend the workshop to raise the issue and discuss about water conservation and water related diseases.

Dissemination of project results: (Duration: 1 year)
We have identified the water source and water quality of source and household. All the information has been plotted in GIS map. The project information was disseminated through research papers in journals and conferences.

Project management: (Duration: 3.5 years)
The project is managed by project scientist, JRF and field investigator. The overall project is managed by the PI and co-PI.

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



6.

Fig. 3.7. Activity-wise time frame chart.

4. Key findings and results

4.1. Estimation of Water Quality Index

The calculated WQI values of five areas are shown in fig. 4.1 below. It can be observed from the graph that water is safe for drinking purpose for all five areas according to the water quality rating given in table 3.1. Relatively, Jorethang and Ravangla have better water quality than the other areas in the study.

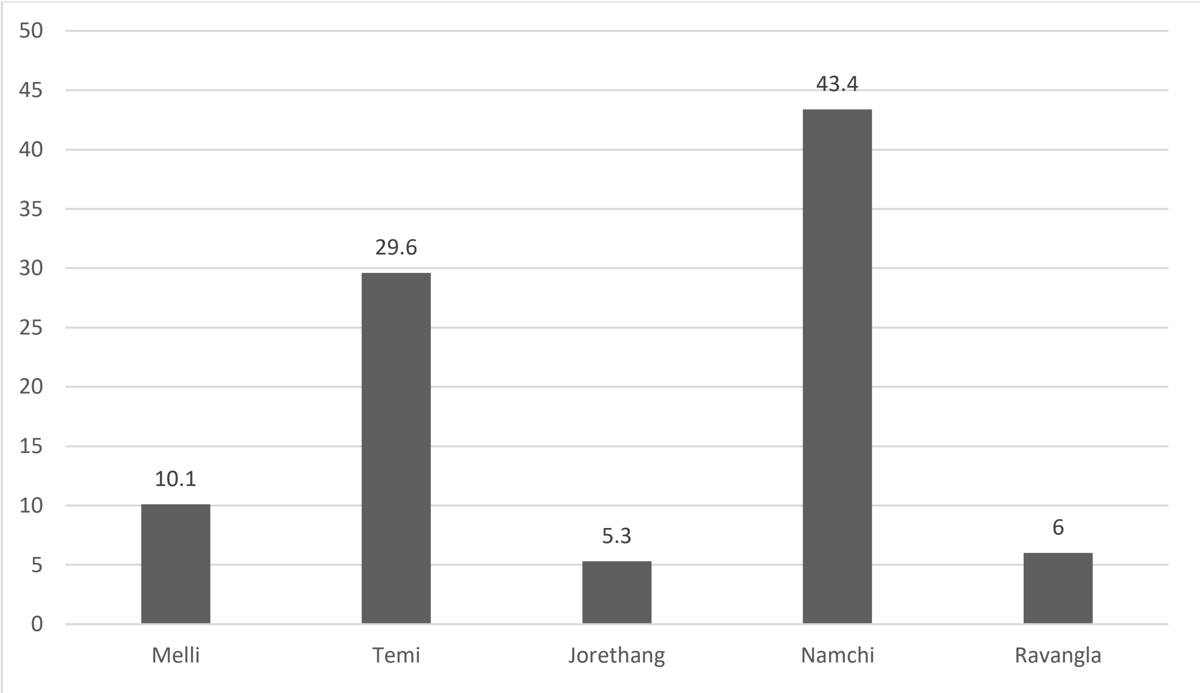


Fig. 4.1. WQI values for Melli, Temi, Jorethang, Namchi & Ravangla

4.1.1. Water Quality Parameters Spring water

- **pH:** We have collected large numbers of spring water data and also tried to find out the pH value of the spring water. All the values are in the ranges from 6.5 to 8. Hence, pH values of the spring water are in limit as per BIS guidelines (IS 10500: 2012), which 6.5 to 8.5.

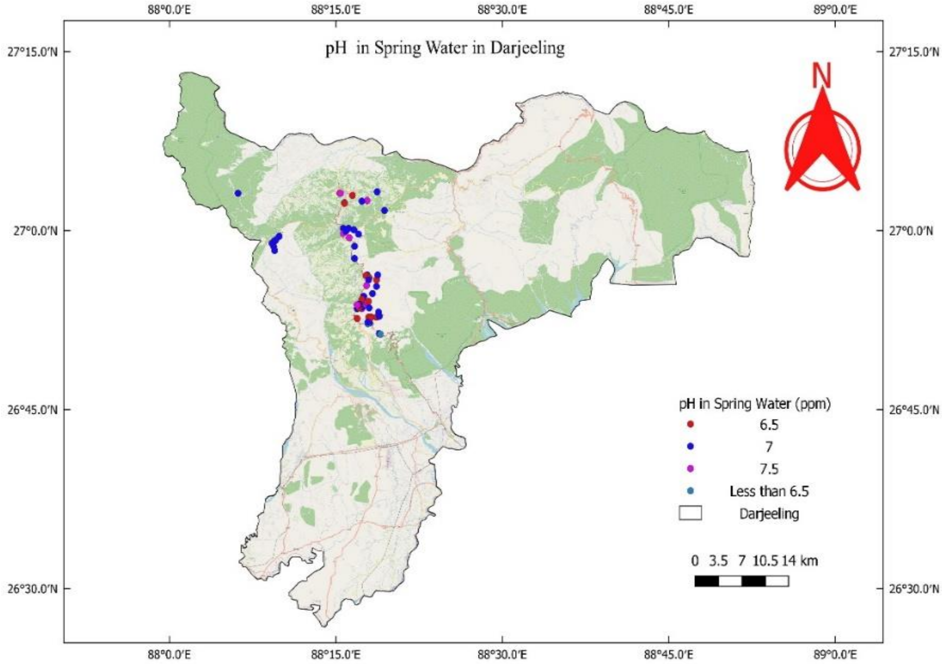


Figure 4.2. pH of spring water in Darjeeling.

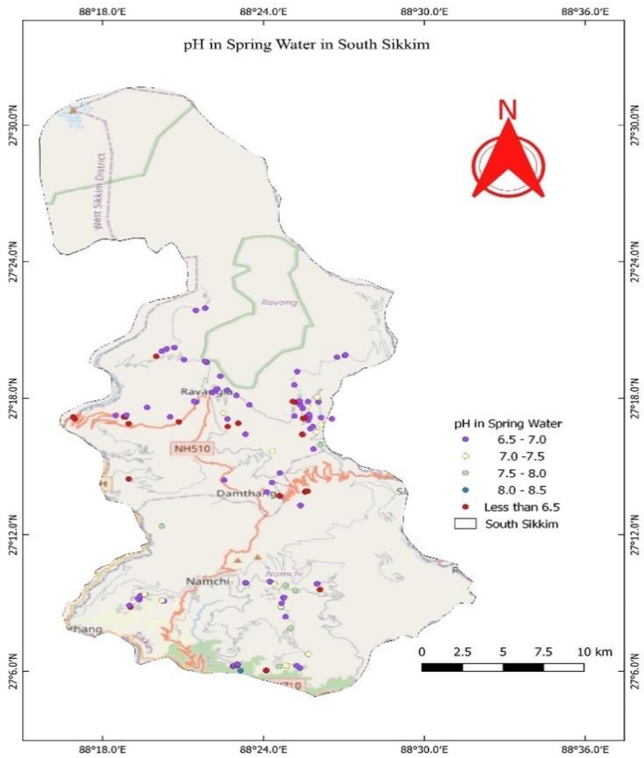


Figure 4.3. pH of spring water in Sikkim.

- **Total Hardness:** We conducted the total hardness testing using standard WHO recommended field testing kit. We found that the total hardness of spring water of different of Darjeeling and Sikkim are varies within the range of 20 ppm to 40 ppm. The values are well below from the standard value and hence, the water is fit for drinking.

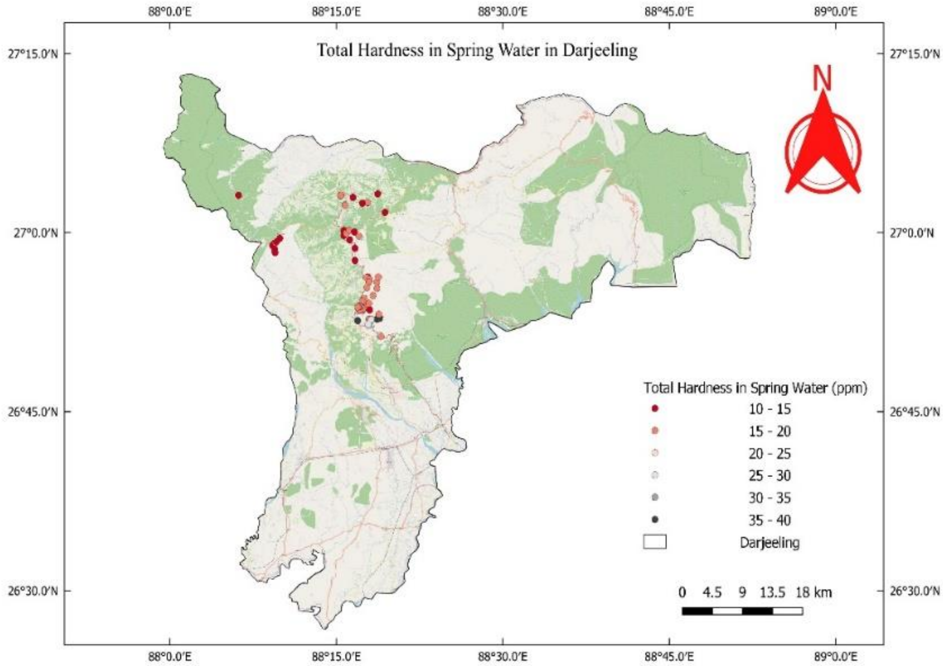


Figure 4.4. total hardness of spring water in Darjeeling.

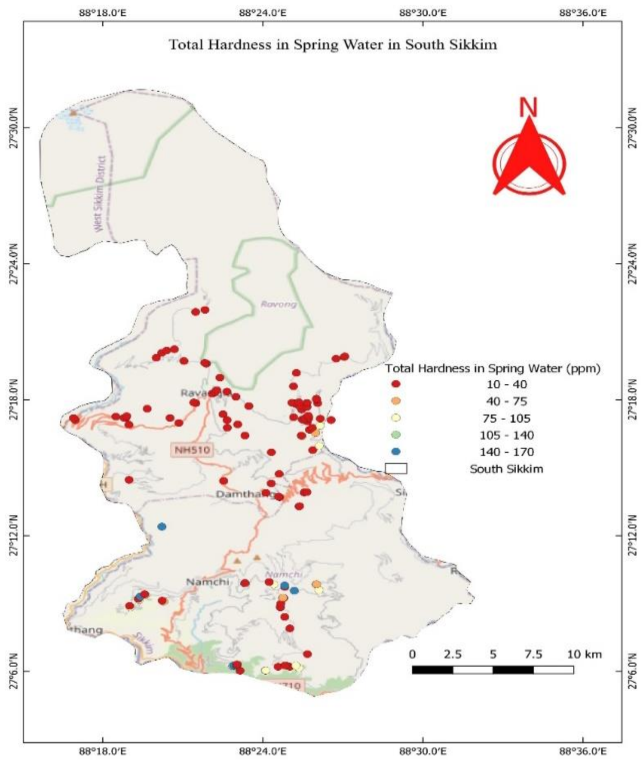


Figure 4.5. total hardness of spring water in Sikkim.

- **Alkalinity:** Alkalinity values are within the ranges from 10 ppm to 30 ppm but most of the cases alkalinity is less than 10 ppm except for 2 to 3 locations, where alkalinity is as high as 20 ppm or 30 ppm. All details have shown in GIS map for all the locations.

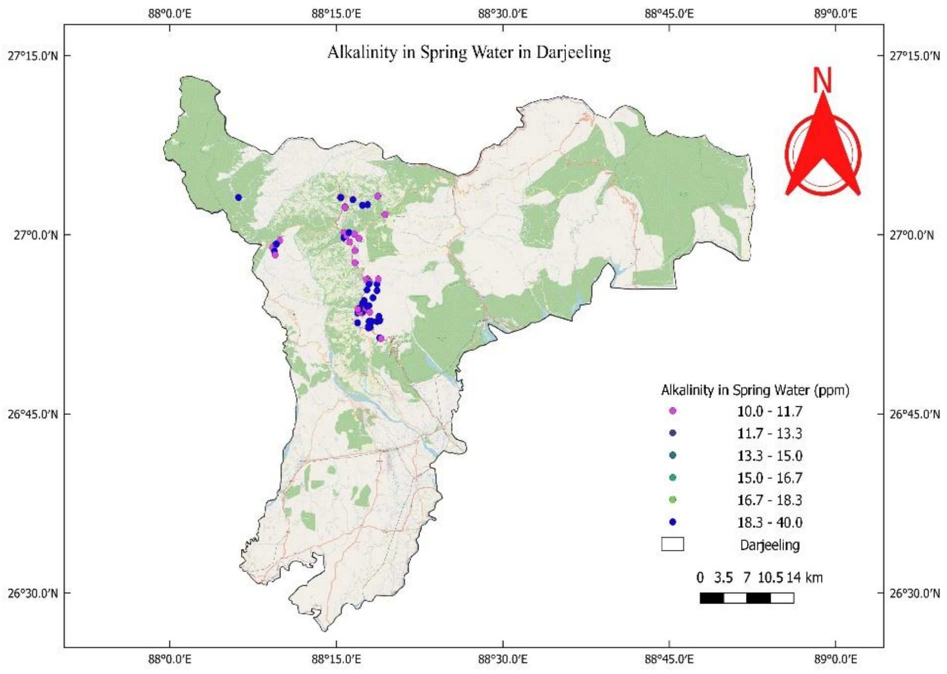


Figure 4.6. Alkalinity of spring water in Darjeeling.

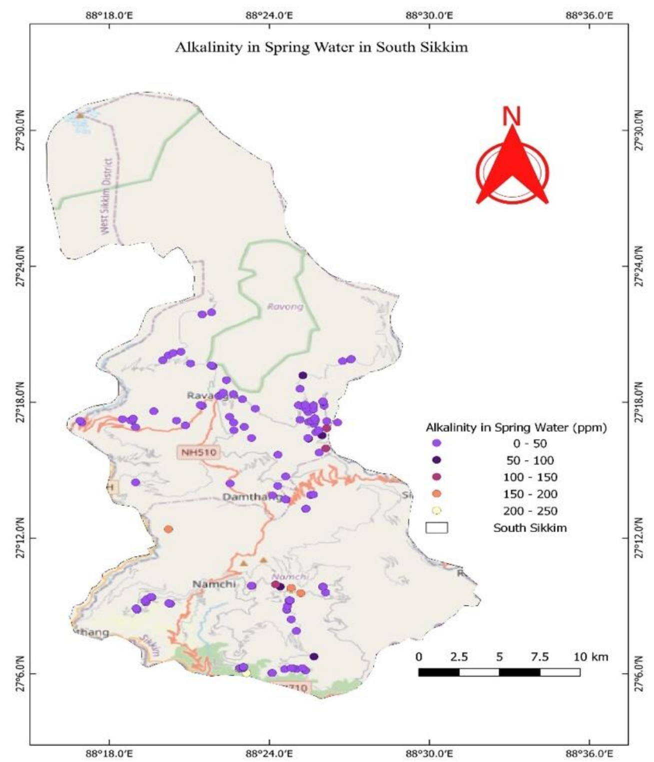


Figure 4.7. Alkalinity of spring water in Sikkim.

- **Chloride Content:** Chloride content of all the spring data were conducted and we found that the chloride content was within the limit. All the values are varying within the 25 to 60 ppm. Details of variation has been shown below by a GIS map.

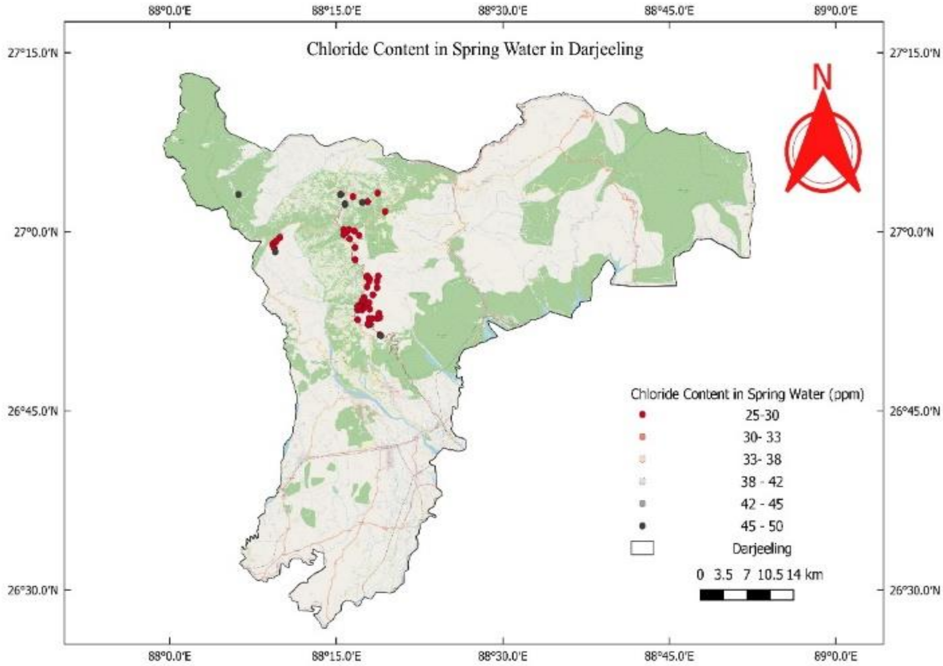


Figure 4.8. Chloride content of spring water in Darjeeling.

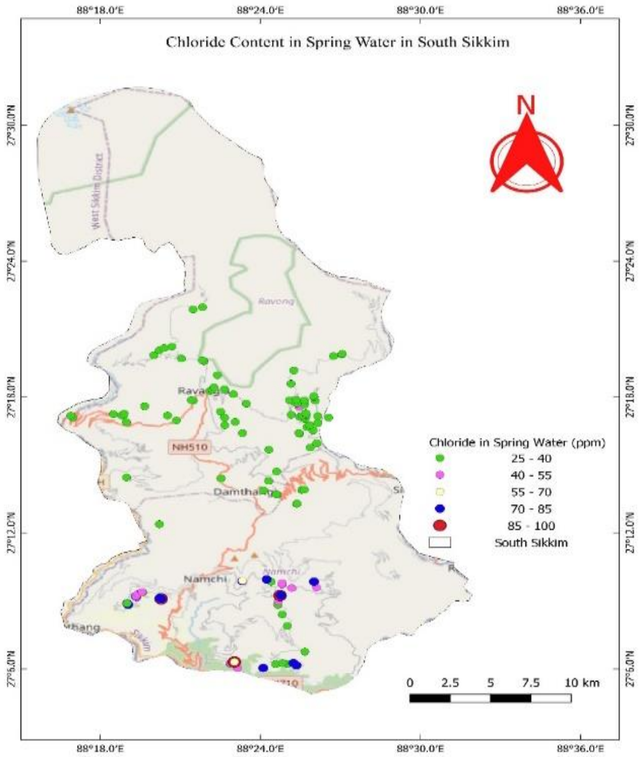


Figure 4.9. Chloride content of spring water in Sikkim.

- **Nitrate Content:** We did not find any stress of nitrates in most of the spring water throughout our survey but in Kurseong and Sonada we found nitrates in spring water, which is less than 10 ppm. Details are added in GIS maps given below.

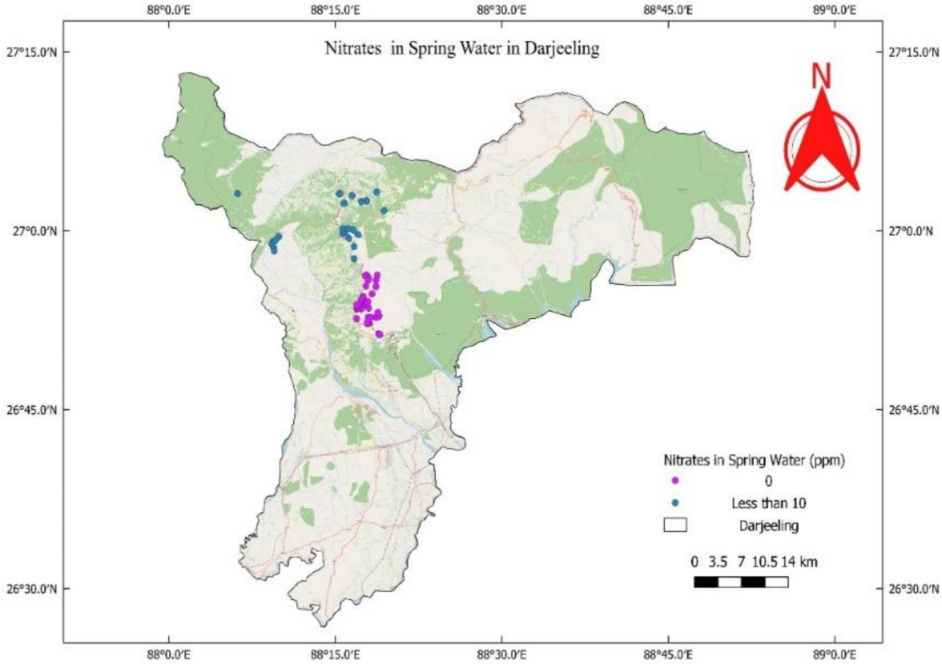


Figure 4.10. Nitrates of spring water in Darjeeling.

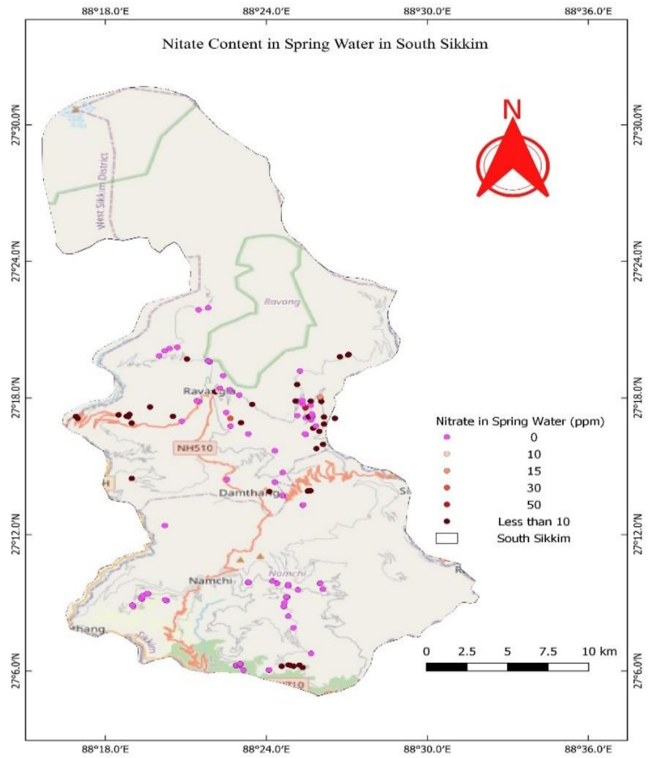


Figure 4.11. Nitrates of spring water in Sikkim.

- **Fluoride and Iron Content:** Fluoride values are within 0.25 to 0.5 and for iron the values are 0.15 to 0.30, which are well within the Limit of Indian Standard. All details are added in the GIS map.

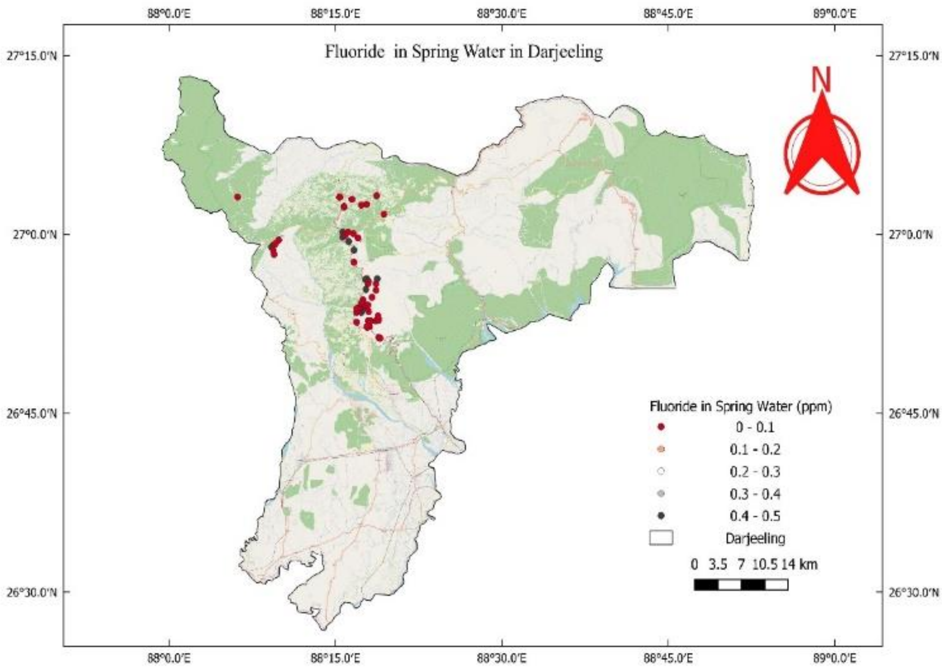


Figure 4.12. Fluoride of spring water in Darjeeling.

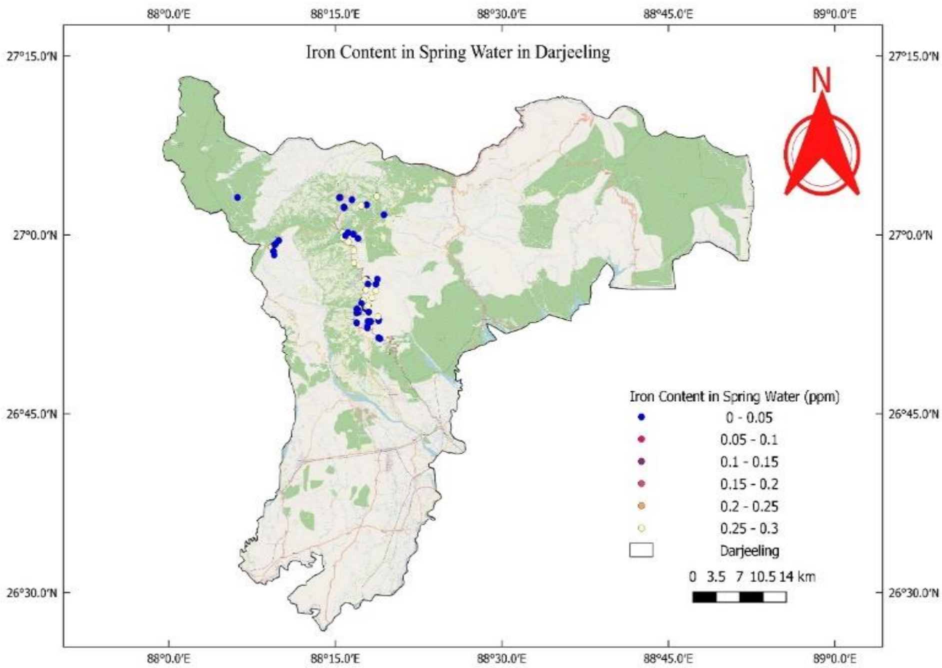
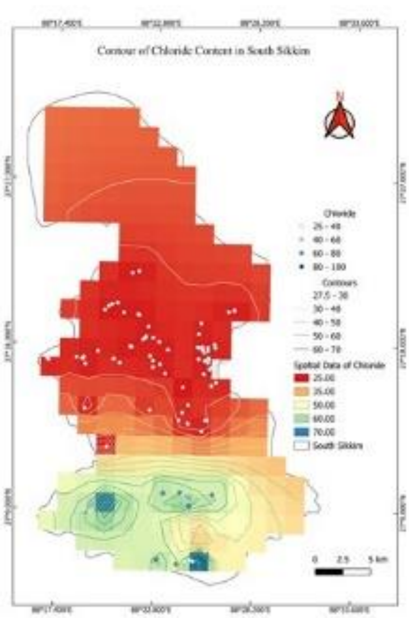
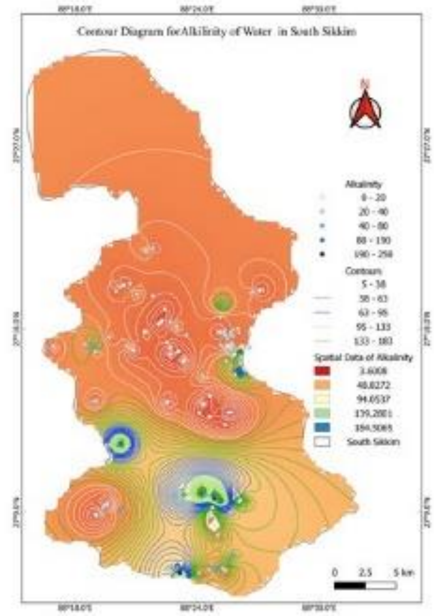


Figure 4.13. Fluoride of spring water in Sikkim.

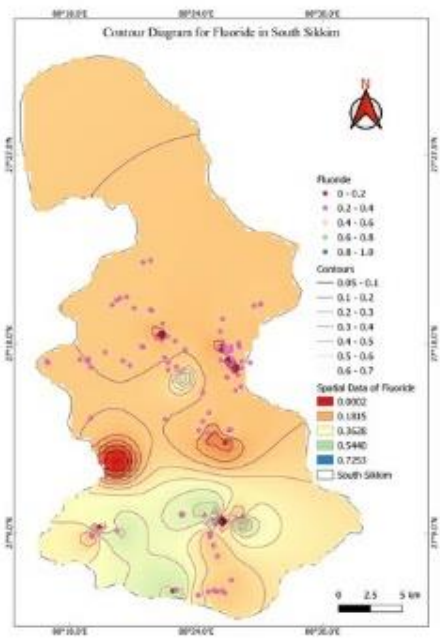
We have also analysed the spatial distribution of various spring water parameters throughout South Sikkim. We found that Chloride, Fluoride, alkalinity and hardness increases in southern part of South Sikkim as shown in Fig 9.



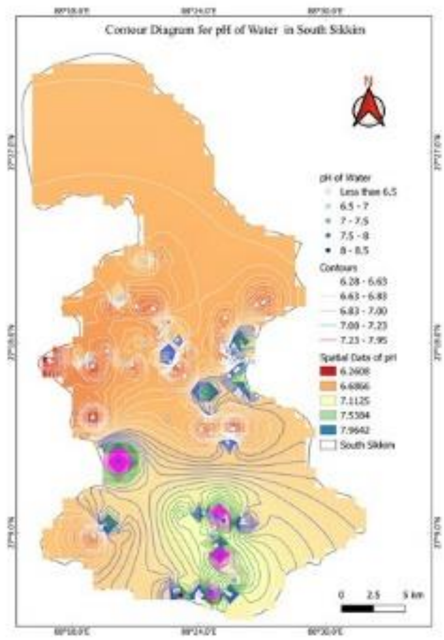
(a) The plot shows the spatial distribution of chloride content. It shows that the chloride content is higher in lower region.



(b) The plot shows the spatial distribution of Alkalinity. Alkalinity is higher in Namchi and Jorethang region, ie, in low altitude region.



(b) The plot shows the spatial distribution of Fluoride, and it is very low through south Sikkim



(d) The pH of the water in south part of Southern of South Sikkim compared to the middle part, i.e., Ravangla.

Figure 4.14. Nitrates of spring water in Darjeeling.

4.1.2 Flow Rate: We found the flow rates ranging from 0.016 to 90 liter/sec so huge variation was seen for the spring situated in South Sikkim but for Darjeeling the flow rates were within 0.1 to 6 liter/sec. The variation in flow rates for Darjeeling are not similar to that of South Sikkim. Details have been represented in GIS Maps.

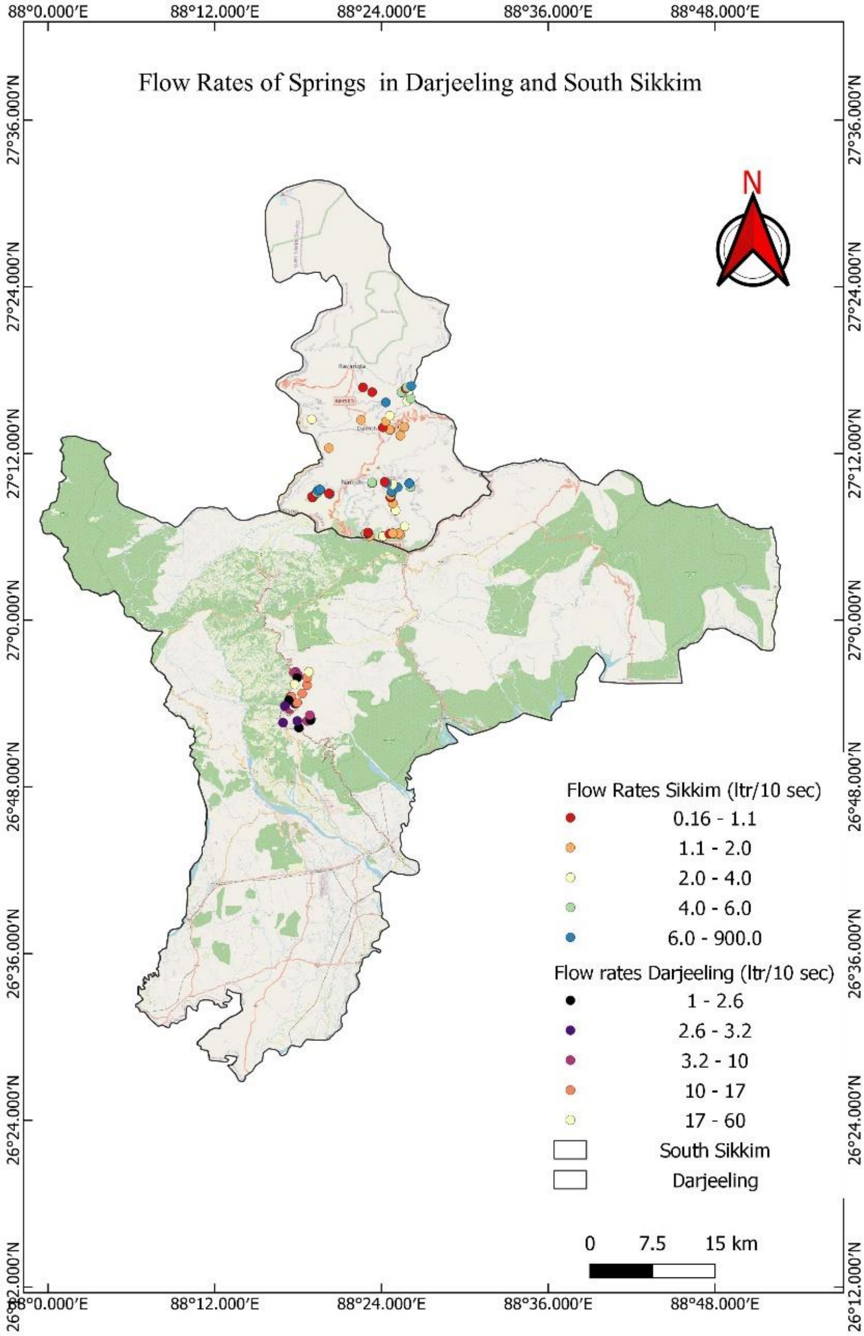


Figure 4.15. Nitrates of spring water in Darjeeling.

4.2. Water Quality Parameters of Household

We have conducted a household survey to find out water quality parameters. These have been done to identify the changes in water quality from the source if changes are present. All details data have been given below.

pH: In case of testing of household water quality, we found the pH of the water is 6.5 to 7.5, was well within limit. It can be concluded that pH of water is almost same that of the nearest source in Darjeeling and south Sikkim.

Total Hardness: Total hardness of household are similar to that of the source spring water from where the drinking water has been supplied. The ranges are 10 to 40 ppm and 10 to 190 ppm respectively for Darjeeling and South Sikkim. Details are also shown in GIS Map.

Alkalinity: Alkalinity for household drinking water are ranges from 10 to 20 ppm, which is slightly different from the source water.

Chloride Content: Chloride is very much important parameter in terms of the drinking water quality. Here for all the household, the chloride content is 25 ppm, which is slightly of less side than that of source.

Nitrate Content: In most cases the nitrate content is zero or less 10 ppm, which is similar to that of the source water. Details are shown in GIS Map.

Fluoride and Iron Content: Fluoride and Iron content are ranges from 0.25 to 0.5 ppm and 0.25 to 0.5 ppm respectively. Though fluoride content is high which has an adverse effect on health.

4.2.1. Dependence of water demand on Income:

In order to understand the quantity and quality drinking water, we have studied the studied the income elasticity of water demand. A range of commonly used summary statistics for the variables is presented in Tables below for 2019 and 2020 respectively. The results illustrate that the average price of the domestic pipeline connection to the household was Rs 14.72 per 100 litre in 2019 and Rs 15.72 per 100 litre in 2020 respectively. The quantity demands are 5,520 and 5,820 litres respectively. The maximum and minimum price for water is Rs 23 and Rs 10 in the year 2020 and 2020 respectively. Likewise, the average price ofcommercial pipeline connections, domestic water tankers, and commercial water tankers was Rs 32.28, Rs 39.56 and Rs 48.36 respectively, in 2019 and Rs 33.36, Rs 40.32, and Rs 49.96 respectively in 2020. The average quantity demand for consumption of water for the commercial pipeline, domestic water tanker, and commercial water tanker was 43,080, 3,153, and 31,840 l in 2019 and 47,880, 3,252, and 35,920 l respectively, in 2020. So, the total monthly revenue collected from the domestic pipe- line, commercial pipeline, domestic water tanker, and commercial water tanker is Rs 81,254.40, Rs 13,906.22, Rs 1,246.93, and Rs 15,397.82 respectively in 2019 and Rs 914.90, Rs 159,727.68, Rs 1,311.21 and Rs 17,945.63 respectively in 2020.

Thus, in total, the revenue collected monthly by the private water supplier from 100 households of all four water sources is Rs 111,805.38 in 2019 and Rs. 179,899.42 in 2020. More specifically, the random samples of 100 households of Darjeeling town spends per annum Rs 1,341,664.55 and Rs 2,158,793.07 for 2019 and 2020 respectively. On the contrary, the municipality charges only Rs 500 per annum per household. This gap indicates that inequality between water demand and its price in Darjeeling.

Similarly, the descriptive statistics such as median, standard deviation, skewness, kurtosis, and Jarque-Bera tests are presented in Tables below for the years 2019 and 2020 respectively. In this context, we examine the price as well as income elasticity for the consumption of water. These are calculated considering the households' average price income.

Table 4.1. Descriptive statistics of price of water per 100 litre, monthly water demand and income of households for 2020

Variables	Mean	Maximum	Minimum	SD	Sk	Ku	JB
$DPPW_{it}$	15.72	23	10	4.76	0.24	1.54	2.44 (0.29)
$DPQD_{it}$	5820	11,000	3000	2197.91	0.40	2.48	0.95 (0.62)
TR1	914.904	2530.00	300.00	–	–	–	–
DPY_{it}	26680	55000	13000	10503.85	0.99	3.31	4.21 (0.12)
$DCPW_{it}$	33.36	55	23	9.50	0.77	2.70	2.56 (0.27)
$DCQD_{it}$	47,880	90,000	15,000	21793	0.26	2.02	1.28 (0.52)
TR2	159,727.68	49,500.00	3450.00	–	–	–	–
DCY_{it}	173,000	316,000	90,000	61,103.06	0.63	2.42	2.04 (0.36)
$DWPW_{it}$	40.32	57	30	9.26	0.49	2.01	2.05 (0.35)
$DWQD_{it}$	3252	6000	1500	1448.59	0.46	1.98	1.95 (0.37)
TR3	1311.2064	3420.00	450.00	–	–	–	–
DWY_{it}	23,960	42,000	12,000	7881.83	0.83	3.06	2.89 (0.23)
$CWPW_{it}$	49.96	76	31	13.31	0.43	1.95	1.91 (0.38)
$CWQD_{it}$	35,920	74,000	11,000	16380.68	0.44	2.56	1.00 (0.60)
TR4	17,945.632	56,240.00	3410.00	–	–	–	–
CWY_{it}	195,200	320,000	100,000	63,516.40	0.26	1.92	1.49 (0.47)
No. of households	100	100	100	100	100	100	100

Demand for Residential Water: New Findings. *J. Am. Water Works Assoc.*, 1978, **70**, 453–458.).

Thus, the study takes the average price and income of 100 households concerning average water consumption for both 2019 and 2020. Table 4 presents the results. It can be seen that the results show that the consumption of water from the domestic pipeline, commercial pipeline, domestic water tanker and the commercial water tanker is price elastic average price and income of 100 households concerning average water consumption for both 2019 and 2020. Table 4.2 presents the results. It can be seen that the results show that the consumption of water from the domestic pipeline, commercial pipeline, domestic water tanker and the commercial water tanker is price elastic.

Table 4.2. Descriptive statistics of price of water per 100 litre, monthly water demand and Income of households for 2019

Variables	Mean	Maximum	Minimum	SD	Skewness	Kurtosis	JB
$DPPW_{it}$	14.72	23	10	4.03	0.43	1.98	1.87 (0.39)
$DPQD_{it}$	5520	9500	3000	1888.78	0.26	2.27	0.83 (0.65)
TR1	81,254.4	2185.00	300.00	–	–	–	–
DPY_{it}	25,832	52,000	12000	10098.34	0.87	2.98	3.21 (0.20)
$DCPW_{it}$	32.28	53	23	8.71	0.71	2.69	2.20 (0.33)
$DCQD_{it}$	43,080	85,000	15,000	18151	0.52	2.97	1.14 (0.56)
TR2	13,906.224	45,050.00	3450.00	–	–	–	–
DCY_{it}	170,280	316,000	90,000	60,179.95	0.70	2.59	2.24 (0.32)
$DWPW_{it}$	39.56	56	30	8.43	0.46	2.00	1.92 (0.38)
$DWQD_{it}$	3152	5600	1400	1341.67	0.34	1.87	1.82 (0.40)
TR3	1246.9312	3136.00	420.00	–	–	–	–
DWY_{it}	23428	42000	12,000	8067.19	0.82	2.92	2.79 (0.24)
$CWPW_{it}$	48.36	72	31	11.91	0.50	2.16	1.78 (0.41)
$CWQD_{it}$	31,840	54,000	11,000	12766.1	0.01	1.93	1.18 (0.55)
TR4	15,397.824	38,880.00	3410.00	–	–	–	–
CWY_{it}	18,3040	320,000	100,000	61,216.47	0.49	2.21	1.68 (0.43)
No. of households	100	100	100	100	100	100	100

Table 4.3. Measurement of price and income elasticities from mid-point formula between the years 2019 and 2020

Domestic pipeline	
Price elasticity	–0.80529
Income elasticity	1.6385
Commercial pipelines	
Price elasticity	–3.20727
Income elasticity	6.6599
Domestic water tanker	
Price elasticity	–1.64124
Income elasticity	1.3910
Commercial water tanker	
Price elasticity	–3.70005
Income elasticity	1.8731

4.2.2. Estimation of Water Demand Index:

The summary statistics is presented in table 4.4. The average daily water consumption is 323 liter and the mid-value of the water consumption of the residential water demand of Ravangla is 250 lt. the standard deviation is 195.69 liter which implies that the deviation from mean is more. Further, the maximum value and the minimum value are 1000 and 100 respectively. The value of skewness (S_k) shows that the distribution is positively skewed and having leptokurtic. The Jarque-Bera (J-B) value clearly indicates that the distribution of water consumption is not normal. Similarly, the summary statistics of other selected variables are explained in table 4.4. In the next step, we have conducted the stationary test in order to avoid the problems of spurious relationship among them. We have used the augmented dickey fuller test and the result of stationary test is presented in table 4.5.

Table 4.4. Summary Statistics-Ravangla

Variables	Mean	Median	S.D.	Max.	Min.	Sk.	Ku.	J-B
WD (ltr)	322.54	250	195.69	1000	100	2.09	7.56	100.65 (0.00)
FSZ	5.00	4.00	1.48	8.00	1.00	0.41	2.91	1.79 (0.41)
A<16	0.88	1.00	0.88	3.00	0.00	0.50	2.13	4.60 (0.10)
A>18 <60	3.1	3.00	1.30	6.00	1.00	0.22	2.34	1.64 (0.43)

A>60	0.49	0.00	0.74	2.00	0.00	1.12	2.76	13.34 (0.00)
TL	1.79	1.00	1.15	6.00	1.00	2.00	7.28	90.31 (0.00)
TP	3.20	3.00	2.67	18.00	1.00	3.36	17.68	684.68 (0.00)
ME	14492	15000	6298.67	30000	4000	0.85	3.35	8.01 (0.02)
SC	2045.48	1000	2796.65	20000	15.00	4.68	29.03	2009.51 (0.00)

Note: Figure in parenthesis shows the p-value

The null hypothesis of the test is that a unit root is present in the series. It indicates that if the series is having unit root then the lagged value of the series cannot able to predict the change in present value of the series. The results show that all the variables are stationary at level form. Once we confirmed the form of stationary test of the variables we have used the ordinary least square model for establishing the relationship between the water consumptions with the selected variables. Before conducting the OLS model we have presented the Wald test. The null hypothesis of the test is there is no long run relationship among them. The result is presented in table 4.5.

Table 4.5. Results of Unit root test

Variables	Level	1st Order Difference	Inference on Integration
WD_t	-7.47 (0.00)	---	I(0)
FSZ_t	-7.51 (0.00)	---	I(0)
TL_t	-7.14 (0.00)	---	I(0)
TP_t	-7.43 (0.00)	---	I(0)
ME_t	-7.29 (0.00)	---	I(0)
SC_t	-7.61 (0.00)	---	I(0)

Note: Figure in parenthesis shows the p-value

We have compared the critical value of both Narayan et al. (2005) and Pesaran et al. (2001) for 1, 5 and 10 percent level of significance respectively. The result shows that the calculated F value is more than the critical value of both Narayan et al. (2005) and Pesaran et at. (2001). In this context we are able to reject the null hypothesis at 1 percent level of significance. In the next step we have used the OLS model and the results are presented in table 4.6.

Table 4.6. Results of Bound F-statistics

Region	F-statistics	Lag Length	Significance Level	Bound Critical Values by Narayan (2005)		Bound Critical Values by Pesaran et al. (2001)	
				I(0)	I(1)	I(0)	I(1)
Ravangala	14.58	1	1%	3.092	4.478	2.54	3.81
			5%	2.373	3.540	1.97	3.18
			10%	2.043	3.094	1.70	2.83

Note: Critical values borrowed from Narayan (2005) and Pesaran et al.(2001)

We find that the age of more than 18 years and less than 60 years variables is significant and positive. This implies that one percent change in such age categories leads to increase the daily water consumption of about 13 percent. More specifically, one person adds in between this age group leads to raise the water consumption per day of about 13 litre. Similarly, we find a positive and significant relationship between the age group of above 60 and daily consumption of water. This implies that one percentage change in the above age group of 60 lead to raise the consumption of about 11 percent. Therefore, altogether the age group of such kind of age group which leads to increase the daily consumption of water of about 25 percent. It is clear that over the time Ravangla of South Sikkim will definitely increase and this clearly indicates that the demand for daily per-capita consumption of water raise to 25 percent. Therefore, Government of Sikkim must ready to face to meet this demand in subsequent year. Similarly, due to unavailability of data of tourist due to Covid-19 pandemic period we can't able to add in our model. It is because Ravangla attract the population in such age category. Therefore, Ravangla needs sufficient level of water so that it can able to meet the basic need of the people. Our study did not find any significant relationship between below the age group of 16 years and daily water consumption. Further, our study shows the relationship between number of taps and the level of daily water consumption. It is because the more the water taps indicates the more the usage of water. Further, there are many side businesses such as tea shops, snacks point, and very small hotels. So, it indicates that more the water taps lead to more consumption of water. Further, people of Ravangla loves to have the domestic dogs and generally they have water taps outside of their home. By keeping into the importance of the variable we have included the variable in our model. We find that there is a positive and significant relationship between water taps and water consumption. It indicates that one more tap in their home leads to raise the water consumption of about 0.05 liter. As Ravangla is one of the important destinations point of tourist, over the time the flow of tourist increases and this will have spill over effect on those small business and increase the water taps. This leads to raise the daily consumption of water in Ravangla.

Table 4.7. Results of OLS model
Dependant variable- water demand per day (LWD)

Variables	Coefficients	t-test statistics
age> 18<60	0.13 (0.00)	3.19
age >60	0.11 (0.07)	1.84
age16	-0.12 (0.02)	-2.28
TL_t	0.09 (0.23)	1.19
TP_t	0.05 (0.10)	1.66
ME_t	8.3E-05 (0.32)	0.98

SC_t	1.54E-05 (0.07)	1.83
Constant	4.82 (0.00)	29.84
R-square	0.54	
Adj- R-square	0.48	
D-W statistics	1.75	
Jarque-Bera	0.52 (0.77)	
ARCH LM test	1.50 (0.22)	
Q(5)	0.87	
Q(10)	0.88	
Q(15)	0.91	
Q(25)	0.89	

Note: Figure in parenthesis shows the p-value; TL- Number of toilets; TP-Number of taps; ME-average monthly expenditure; SC- Storage capacity

The number of toilets is one of the important variables which influence the daily consumption of water. However, our study did not find any significant relationship between them. Similarly, the average monthly expenditure is not significantly influencing the daily consumption of water. Our study finds a positive and significant relationship between storage capacity of the household and daily water consumption. More specifically, one percentage increases the storage capacity of water leads to increase of about 1.54E-05 of the consumption of water. Finally, we have conducted residual diagnostic test such as normality, presence of heteroscedasticity and auto correlation in the model. The results clearly show that our model is robust and free from such problems. More specifically, our D-W statistics is about 1.75 and further we have conducted the correlogram and the different value of Q statistics are presented in table 4 and the results concluded that the model is free from the problem of auto correlation. In order to checked the normality and heteroscedasticity we have conducted the Jarque-Bera and ARCH-LM test respectively. The results show that the model is also confirm that our model stratify the normality condition as well as the homoscedasticity. Our R-square and adjusted R-square value are 0.54 and 0.48 respectively. This implies that our independent variables are explaining about 53 and 48 percentage levels to the dependant variable.

Based on the results from OLS model we have given weight and constructed the residential water demand index. We have taken into consideration those variables which are significant and influencing the water demand of Ravangla. We have presented it in the figure 1. The result shows that the water demand is highly volatile over the different household. Subsequently, we have constructed the long-term trend of the residential water demand index. It is presented in figure 2. The long-term result shows that the future residential water demand is highly increasing. In the next step we have conducted the ARDL model for robustness of our results. It shows that we find a similar kind of results and it is presented in table 5. Further, we have conducted the stability test by using Cusum and Cusum square test. It clearly shows that our model is stable.

Figure 4.16: Residential Water Demand Index

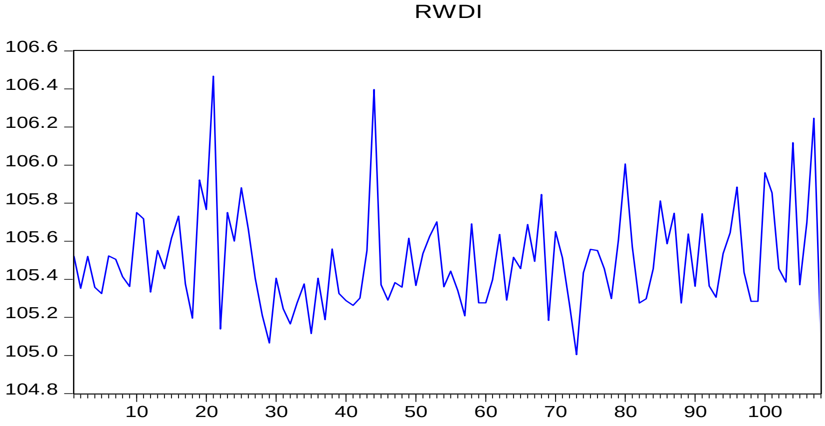
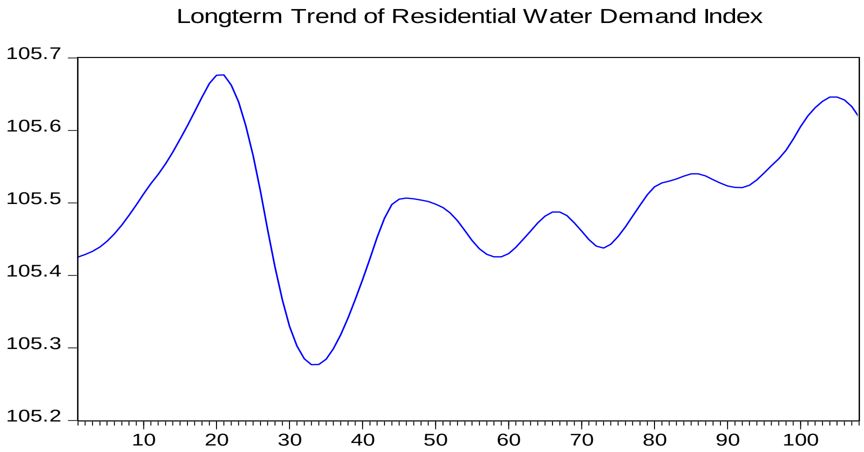


Figure 4.17: Long term Trend of Residential Water Demand Index by using HP Filter



Robustness Analysis

Table 4.8. Results of ARDL regression Model
Dependant variable- water demand per day (LWD)

Variables	Coefficients	t-test statistics
age> 18<60	0.14574 (0.00)	4.46
age >60	.10791 (0.07)	1.84
age16	-0.13306 (0.00)	-2.72
TL_t	0.079 (0.21)	1.26
TP_t	0.053 (0.06)	1.87
ME_t	0.5858E-5 (0.33)	0.98
SC_t	0.1833E-4 (0.23)	1.21
Constant	4.92 (0.00)	33.85
ECM(-1)	0.99 (0.00)	39.56
R-square	0.59	
Adj- R-square	0.53	
D-W statistics	1.95	
$\chi^2_{(Auto)}(2)$	0.028 (0.87)	
$\chi^2_{(Norm)}(1)$	0.029 (0.98)	
$\chi^2_{(Hetro)}(1)$	0.012 (0.91)	

Note: Figure in parenthesis shows the p-value; TL- Number of toilets; TP-Number of taps; ME-average monthly expenditure; SC- Storage capacity

4.3. Decision Support System:

4.3.1. DSS for water security in Sikkim

Our effort for preparing the decision support system is very limited as we are able to produce some static map instead dynamic computer-based system. Though our DSS is based on some static GIS based map, all locations have been included in the maps that will help the Government to take decision. All the maps have been given with an appropriate caption to explain the characteristics of the different parameter, which are directly dependent on household water demand.

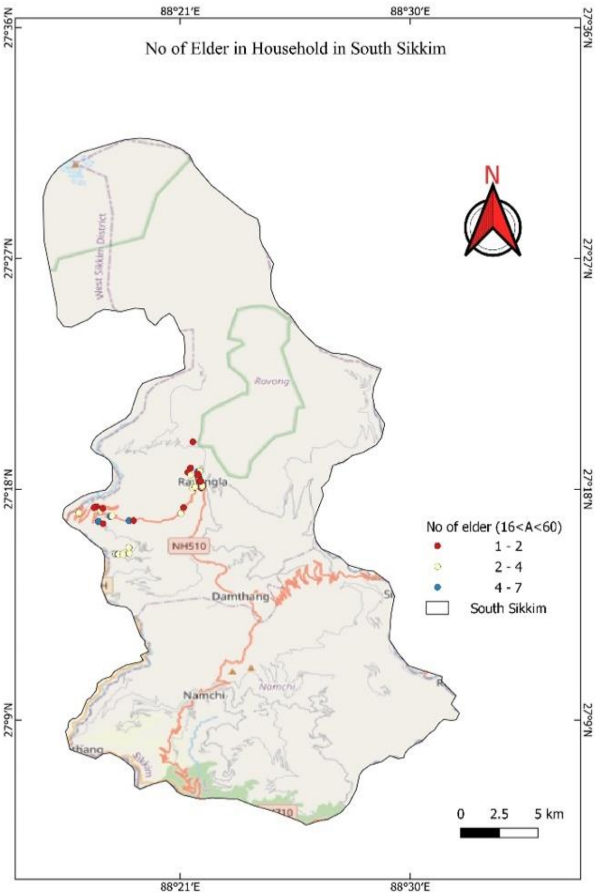


Figure 4.18. Number of young adults per household in Sikkim

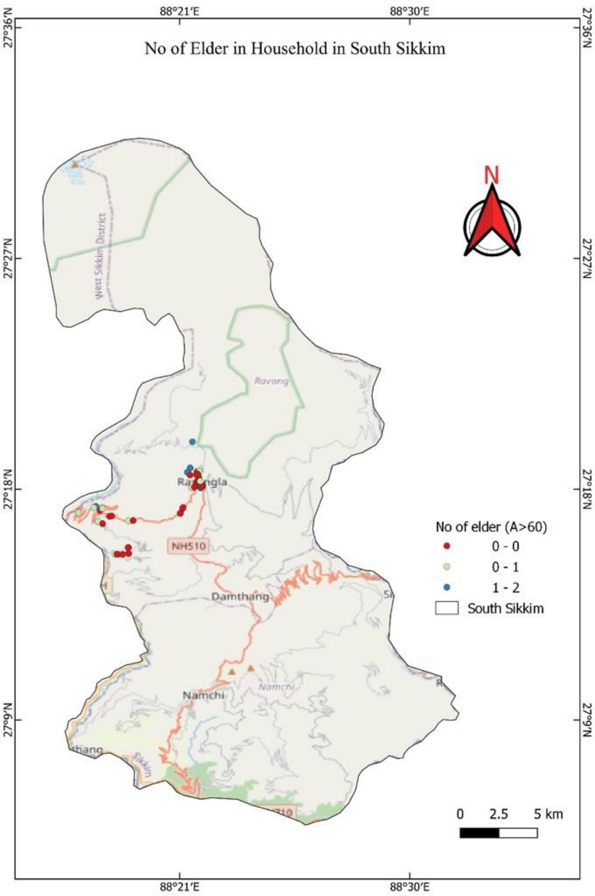


Figure 4.19. No of elders per household in Sikkim

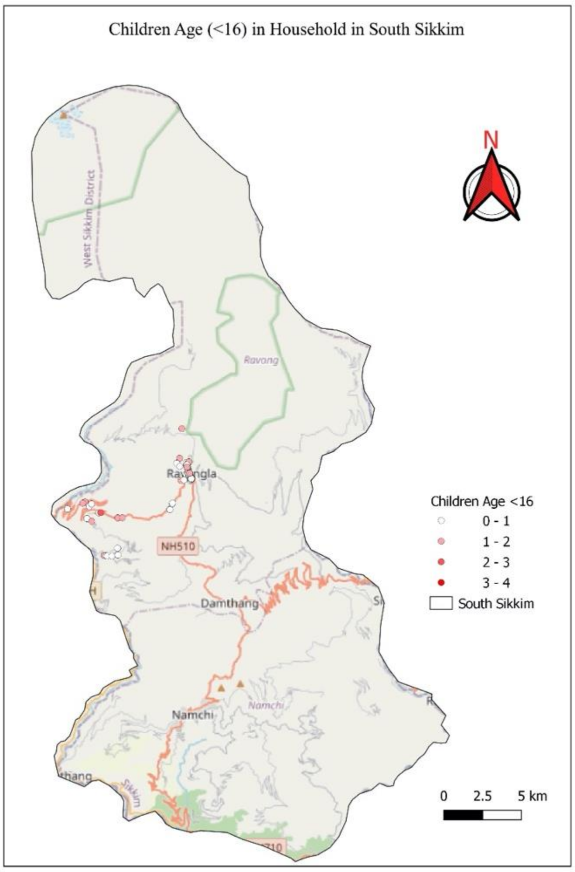


Figure 4.20. Number of children per household in Sikkim

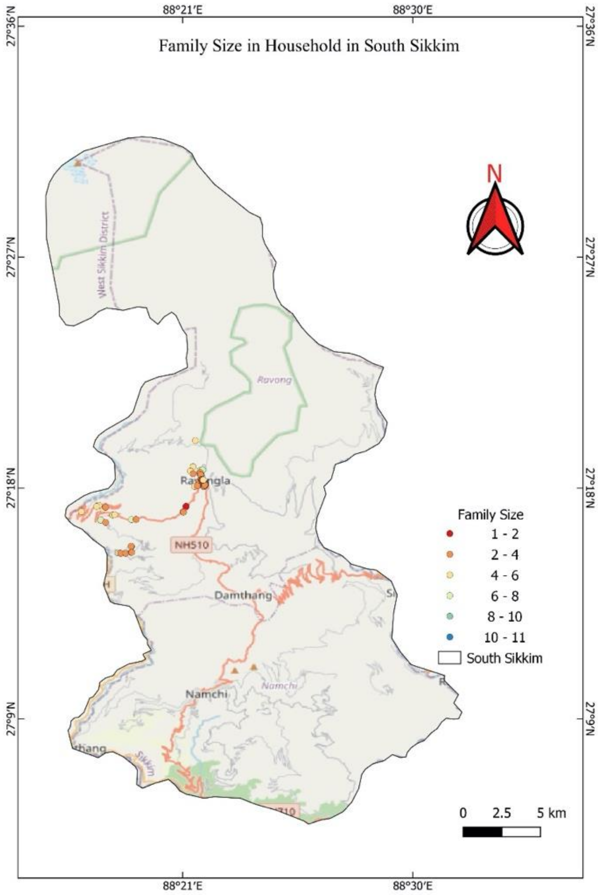


Figure 4.21. Family size of households in Sikkim

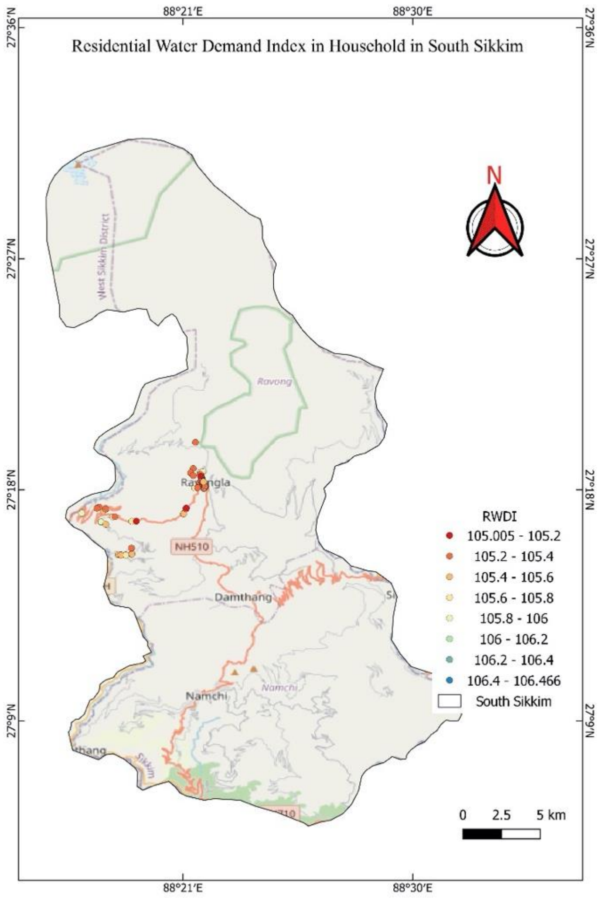


Figure 4.22. Water demand Index of households in Sikkim

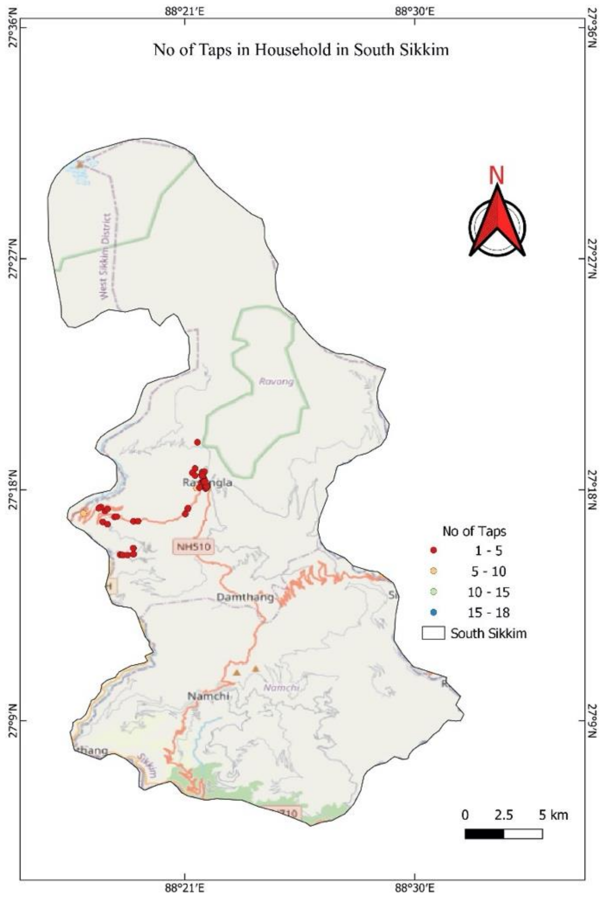


Figure 4.23. Number of water outlets in household in Sikkim

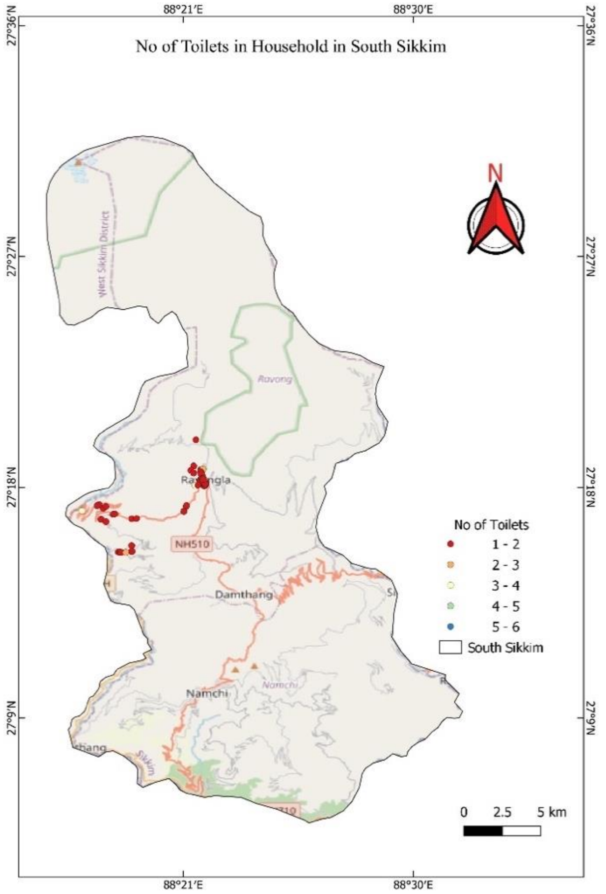


Figure 4.24. Number of toilets per household in Sikkim

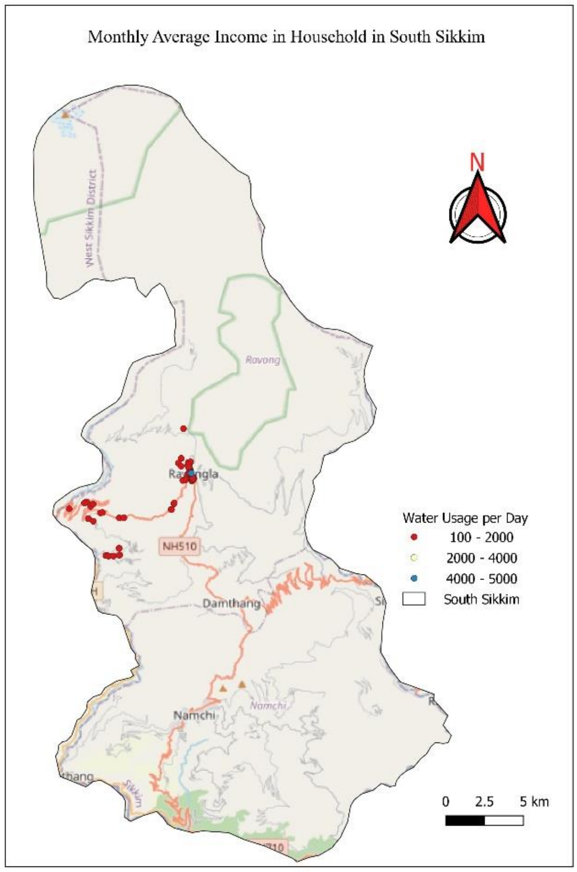
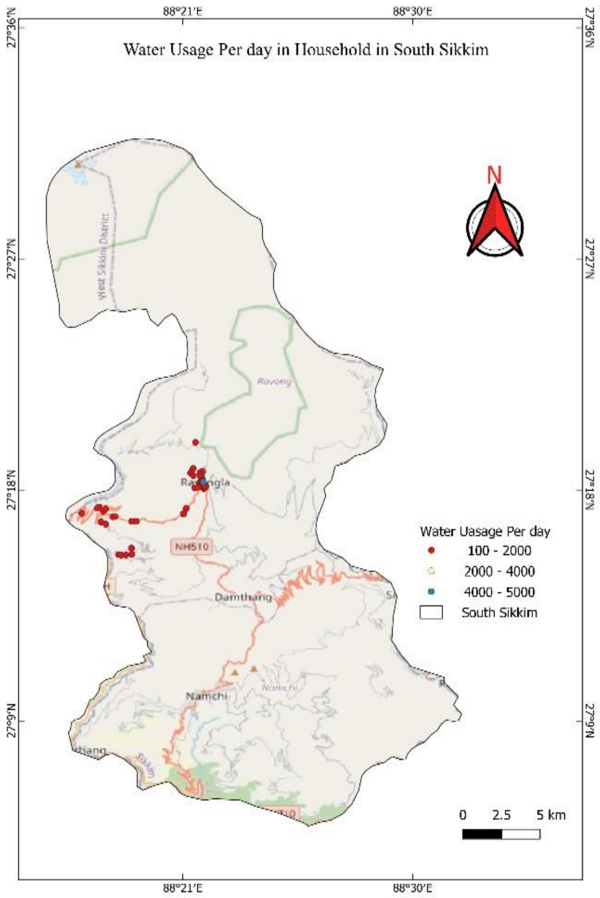


Figure 4.25. Monthly average income per household in Sikkim



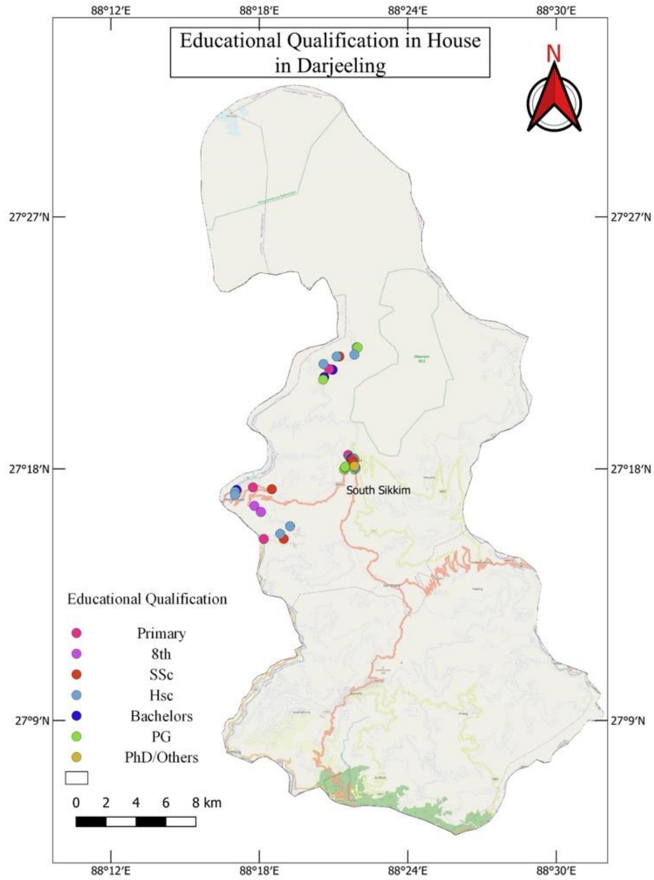
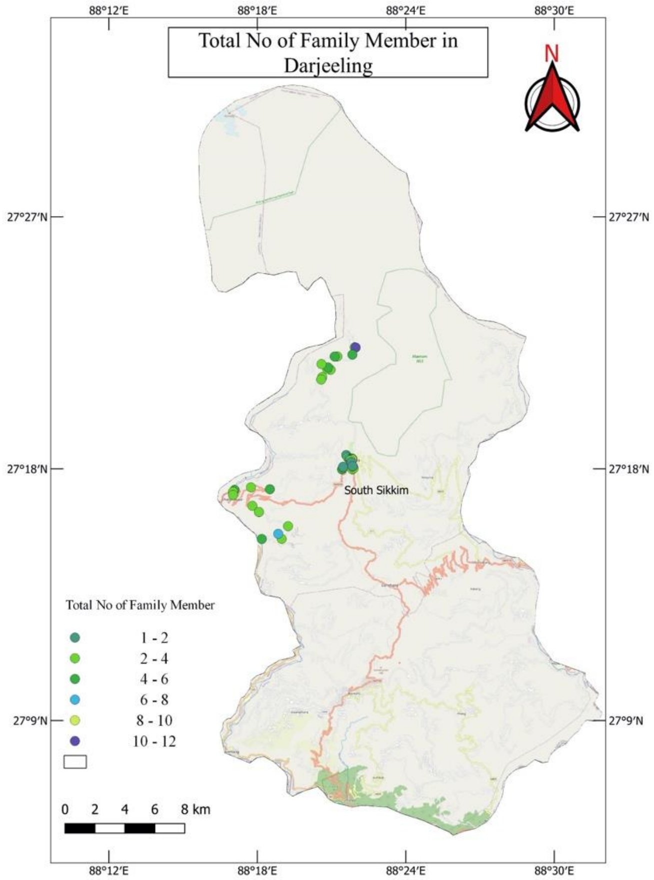


Figure 4.26. Water usage per household per day in Sikkim

Figure 4.27. Highest educational qualification in household in Sikkim



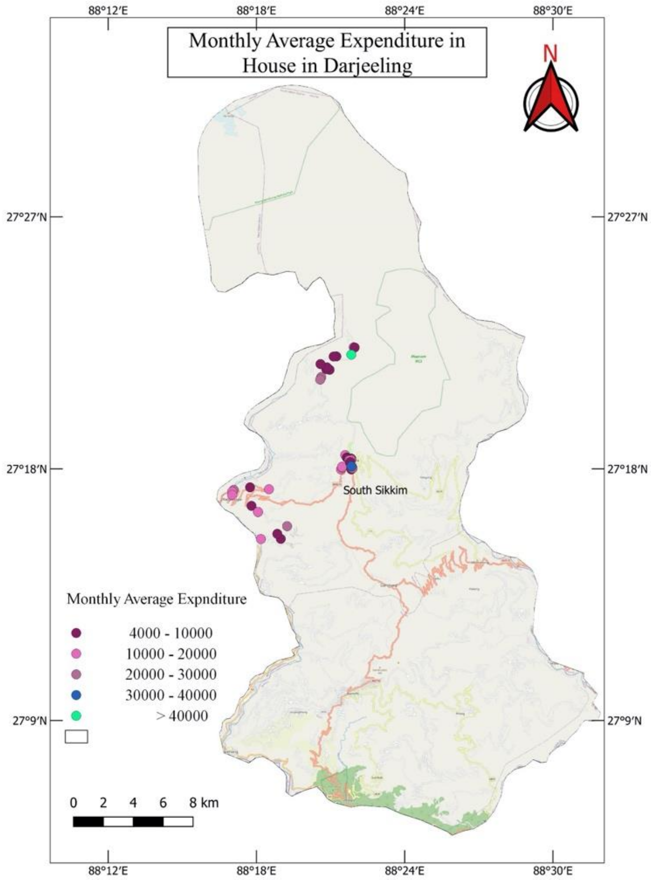


Figure 4.28. Total number of family members in a household in Sikkim

Figure 4.29. Monthly average expenditure per household in Sikkim

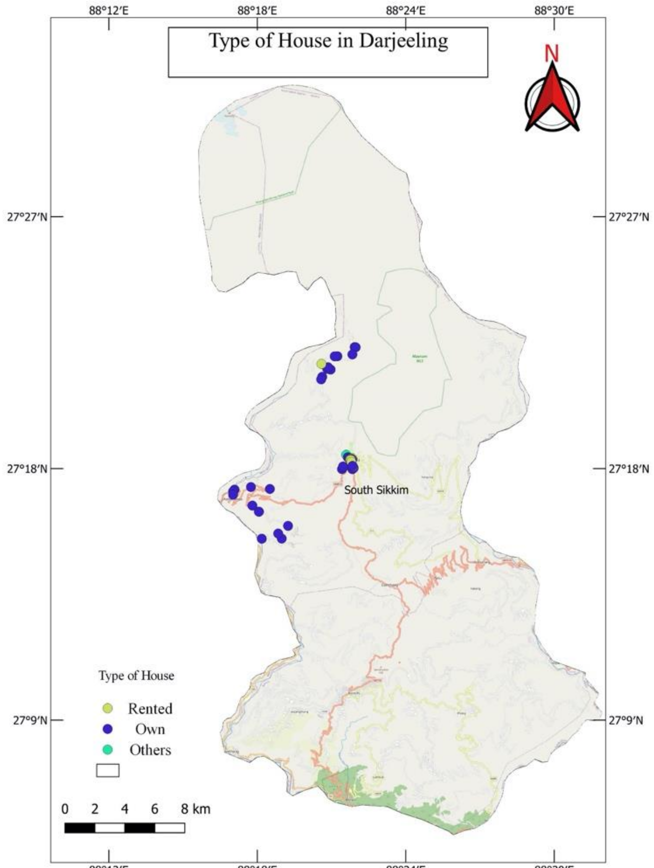


Figure 4.30. Type of house in Sikkim

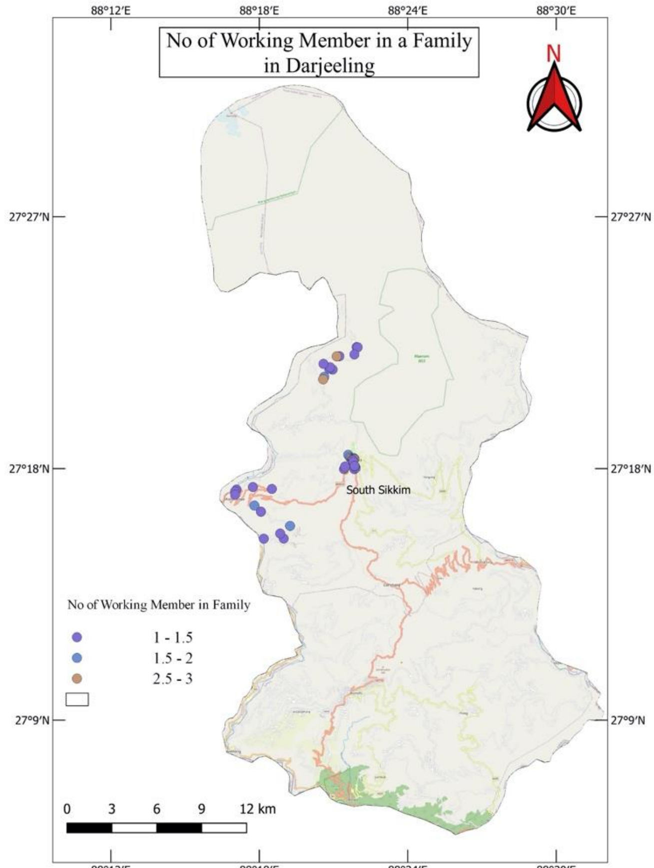


Figure 4.31. Number of working members per household in Sikkim

4.3.2. DSS for water security in Darjeeling

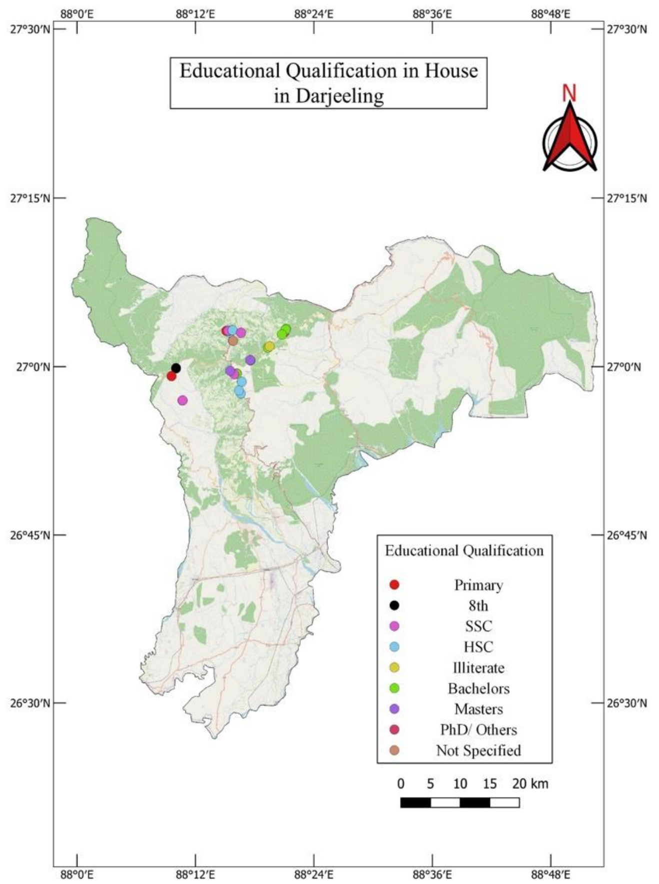


Figure 4.32. Highest educational qualification per household in Darjeeling

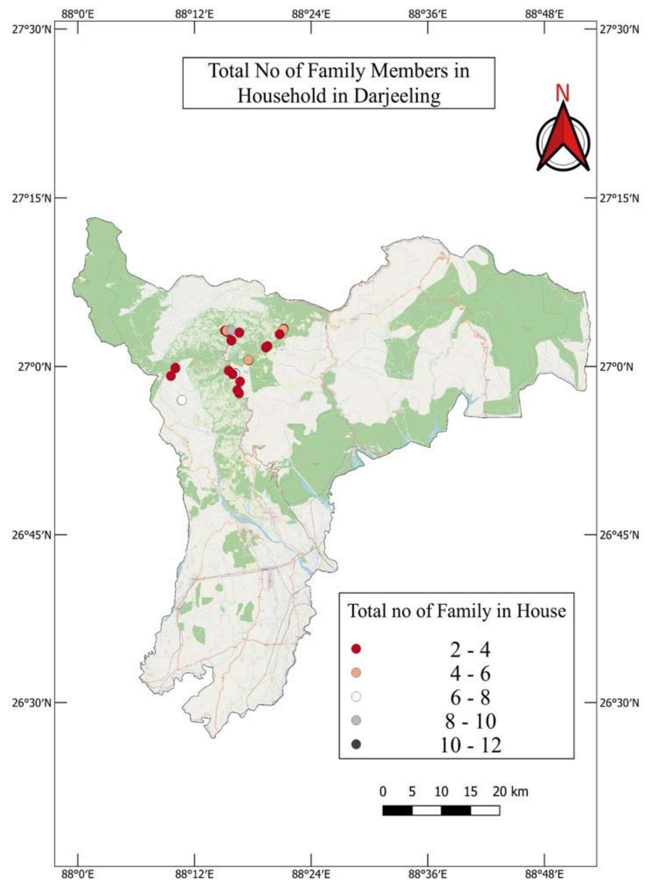


Figure 4.33. Total number of members per household in Darjeeling

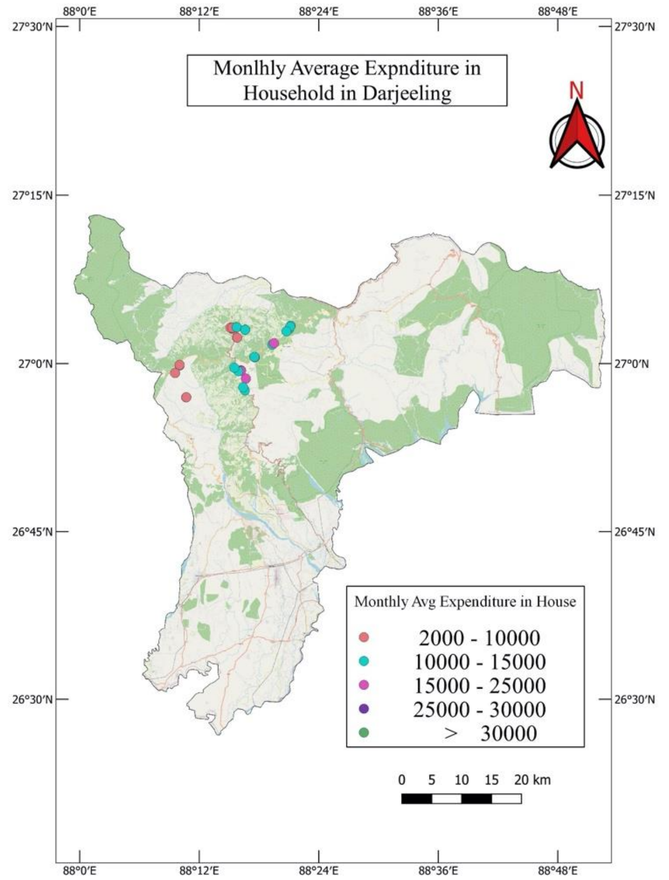


Figure 4.34. Monthly average expenditure per household in Darjeeling

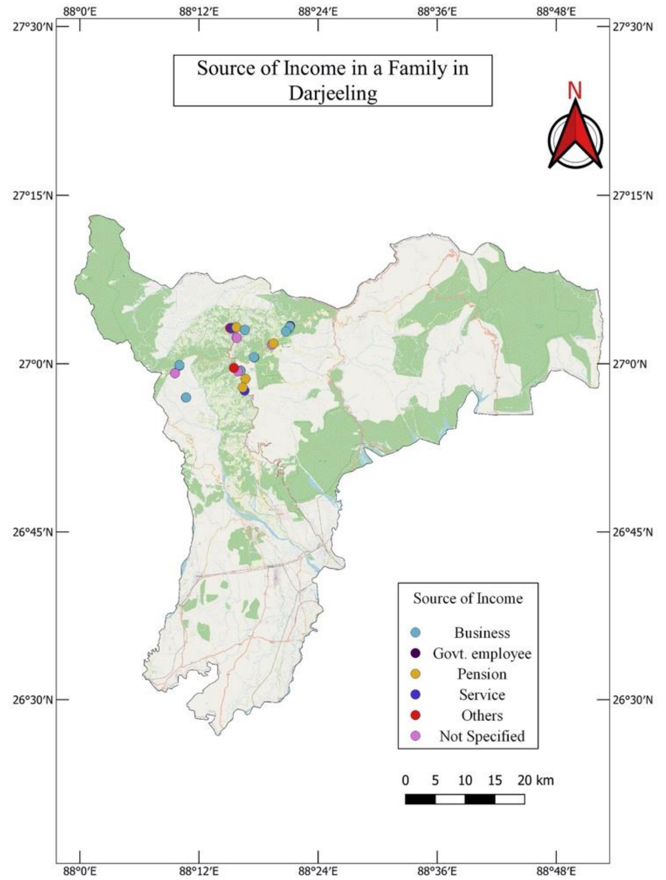


Figure 4.35. Source of income for households in Darjeeling

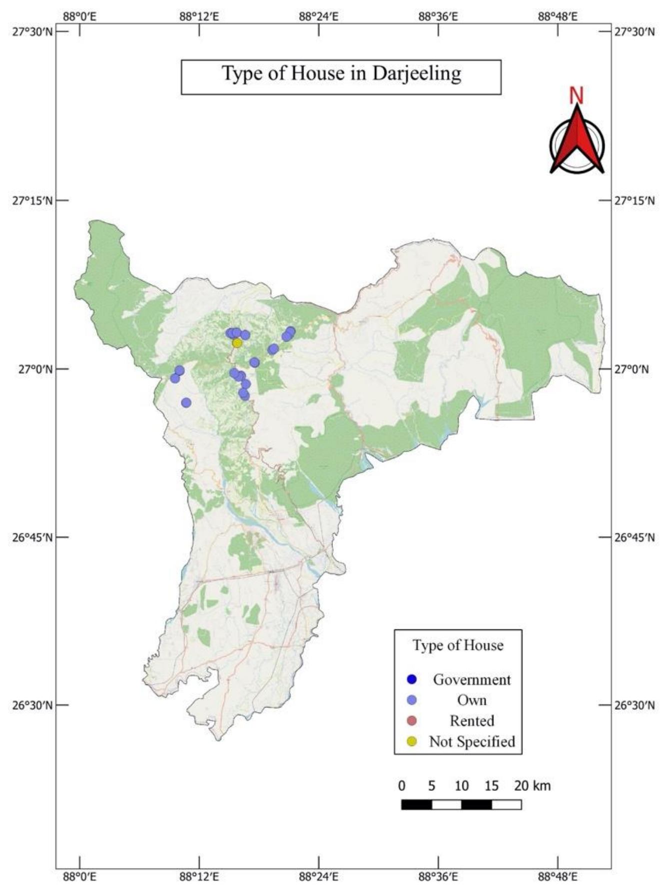


Figure 4.36. Type of house in Darjeeling

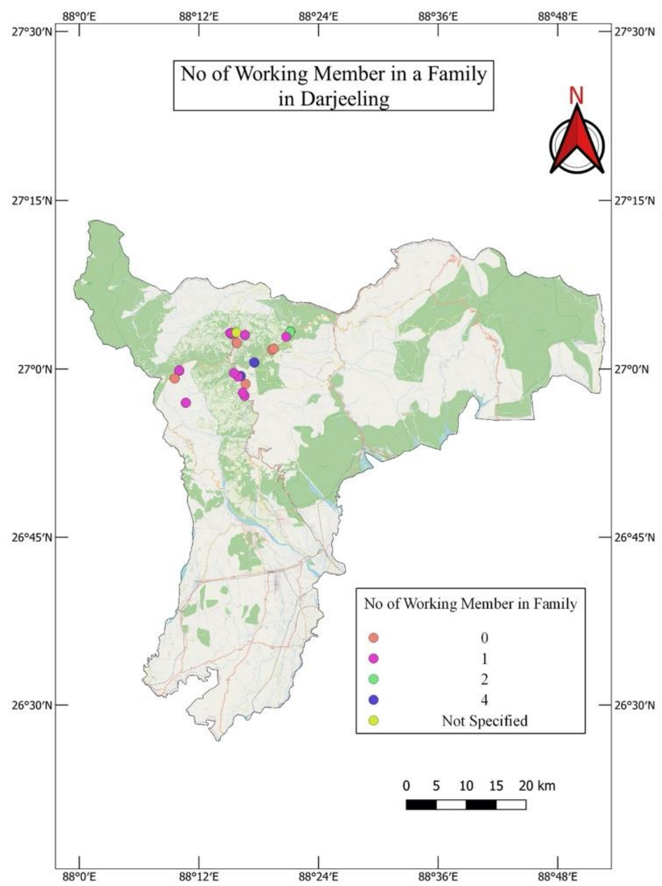


Figure 4.37. Number of working members per household in Darjeeling

4.4. Conclusion of the study

This study has analyzed the price and income elasticities for water demand in Darjeeling. We conducted a primary survey in 2019 and 2020. The results from descriptive statistics show that the demand for commercial water tankers is higher than that of other modes of water consumption. Next, we measure the price and income elasticities of all modes of water consumption. We concludedthat the consumption of water in commercial (water tanker and pipeline) purposes is relatively high elastic as compared to the domestic (water tanker and pipeline) usage. It indicates that the use of domestic water consumption is mainly price-driven. This means that if thegovernment can provide the subsidized water for the domestic purpose, then the utility of water can be maximized.

The result shows that income is less elastic in domestic water users. It indicates that income is one ofthe crucial factors which is pulling down to consume more water and being forced to rely on the use of thesame water for less important usage. The literature, suchas Metaxas and Charalambous[13], Marzano *et al.*[12] and Dhungel and Fiedler[20] concluded a similar kind of results. Hence, our results are robust and have suitable policy implications. By keeping the hygienic and health factors into consideration, the utility function for water can be maximized if the government can provide some alternative means of income, which can improve their level of income.

This study suggests that the municipality must try to minimize the dependency of water on private vendors through propermanagement of water supply. Further, outdated colonialpublic water supply systems still exist in the town, which need urgent repair, revitalization, and improvement.

This study confirms that currently the supplied water to community level in the district of South Sikkim is of good quality and can be used for drinking, cooking or other daily use purposes. According to WQI level; Melli, Jorethang, and Ravangla have a excellent quality of water. Remi and Namchi area have also good quality of water. Though, the district faces serious water shortage problem, being a most populated districts after East Sikkim. After exploring the various indices of water quality, it can be concluded that the purpose of WQI is to give a specific value to the water quality of the source and to reduce the number of parameters to a simple expression, which will result in an easy understanding of the water quality data analysis. During field visit, some of the serious issues are identified in the water supply distribution system like seepage problem storage reservoirs, use of old gravity main without air valves, frequent damages of pipelines due to landslides and heavy rainfall, water leakage, laying of water pipes haphazardly with drainage system, unmetered water connections and lack of maintenance. There is no existing strategy to promote the water conservation technology/methodology, re-use and re-cycle of the used water, rainwater harvesting using the emerging technologies like co-polymer based cross wave technology etc.

Overall, the study suggests that spring water is safe for consumption as all physical parameter tested are well within the limit. Quality of water is extremely good for health.

5 OVERALL ACHIEVEMENTS

5.1. Achievement on Project Objectives

Objective-1: To assess quality and quantity of water resources in the districts of South Sikkim and Darjeeling:

(a) We have assessed the quality of water from spring sources in South Sikkim.

(b) We also measured the flow rate of spring water wherever it was possible to observe and collect water from the source.

(c) The quality of water from springs in Darjeeling was assessed, and the flow rates of some springs, wherever possible, were recorded.

Objective-2: To establish drinking water security through a participatory approach:

(a) In addition to recording data from spring sources, we also measured water quality from households in South Sikkim and Darjeeling. We have collected more the 250-household data by conducting a survey.

(b) We conducted wo workshop cum awareness programmes through which we explained the rationale of our project objectives and also informed about the perils of poor quality water and harmful effects of different impurities like nitrates, e-coli, arsenic, iron, etc.

Objective-3: To estimate the social and economic cost of drinking water in the regions:

(a) To estimate the cost of drinking water in the region, we use the midpoint method to compute the price and income elasticity of water demand. This work was published with the title – “Estimation of price and income elasticity of water: a case study of Darjeeling town, West Bengal, India” in an issue of the journal – Current Science in the year 2021.

(b) We also evaluated the Water Quality Index (WQI) for the South Sikkim district to gain an estimate the cost of drinking water in the region. Based on WQI values, surface waterfalls under the projected area of South Sikkim district into two categories: excellent water and good water (ranging from 0 to 50). However, water scarcity continues to remain a major challenge.

Objective-4: To build a Decision Support System to support water demand:

(a) In order the build a decision support system that can aid local governance of drinking water, we look at the field survey details of 150 households randomly selected from five major areas of the district of South Sikkim - Ravangla, Melli, Temi, Jorethang, and Namchi. We have plotted our findings on GIS maps.

(b) Another objective was to build a dynamic system that updates the data from the baseline and shows the same on GIS maps. We were unable to complete that due to lack of time and resources caused by Covid-19.

Objective-5: To devise a long-term Policy Framework integrating all the stakeholders:

To devise a long-term Policy Framework integrating all the stakeholders, we engaged into Stakeholder meeting, Expert discussions and planning for future demand of drinking water. Taking above things into account we arrive a policy suggestion that should aim at SMART – an acronym that is formed of the actions briefly detailed below.

(a) Save and rejuvenate spring sources:

Water resource management can be a delicate political subject. As a result, basin management demands a significant voice in national policymaking. This entails establishing direct lines of communication with ministers and government bodies involved in the management of natural resources. Basin management is firmly on the planning and economic development agendas because to connections at top levels of government. Building the organisations, institutions, and management structures required for effective basin management systems requires high-level assistance. Although political leadership is important, if water management is completely top-down and excludes stakeholder input, an integrated approach cannot succeed. Integrated Water Resource Management (IWRM) means that basin management will engage individuals who have an interest in or who will be impacted by decisions about water resources and that information will be freely distributed. Finding effective solutions depends on having access to information. The IWRM approach is challenging to implement in situations when there is a lack of accountability or transparency, when individuals who are affected are left out, or when corruption is rampant. Therefore, there has to be a plan of action to rejuvenate the spring sources that are dead or dormant.

(b) Monitor water quality in sources:

Government representatives, lawmakers, representatives from non-governmental organisations, and laypeople who meet to discuss issues related to water management make up a basin council, which may be formal or informal. Typically, councils are formed to provide government with advice. A council lacks regulatory authority in contrast to a commission, another group of specialists. Basin associations or councils (also known as syndicates) may coexist with the formal administration and serve to represent various user groups, nongovernmental organisations (NGOs), or local community organisations. These organisations or councils can play a number of different roles, including advising, educating, and inspiring ownership of basin natural resource management, as well as fostering information interchange. They may also serve as watchdogs. Sometimes they are designed to address a particular issue or for a specific basin. Rejuvenating the spring sources is not only enough but they must be regularly monitored for their health and a spring or river basin monitoring council is the way forward.

(c) Awareness about drinking water quality:

Public education and awareness programmes for basins are used to keep residents and employees informed about basin issues and basin management. The target audiences are numerous and diverse, and they include residents of the basin, businesses operating both inside and beyond the basin, include water utilities, industries, tourist destinations, fisherman, and farmers. These programmes assist basin management by conveying concise communications regarding problems, solutions, and advancements. There has to be programs for school and college students that instil a basic responsibility towards managing the quality and quantity of springsheds in South Sikkim and Darjeeling. Awareness of the problems caused by different impurities in the water like nitrates and microorganisms like E.Coli are important to maintaining family health and workforce.

(d) Reduce Water Wastage:

During our study we found that there is a lot of unnecessary water wastage from households like washing of cars, vehicles, and courtyards with hose-pipes, flood irrigation in agriculture in some areas, and water wastage through hotels and restaurants. Awareness of the glaring issue of the quick depletion of the water sources due to the drying up of springsheds, lower glacier melt, and rising temperatures due to climate change are needed to be ingrained into the habits and behaviours of every households and hotels in the mountain state. Reducing water wastage is an imperative for arresting climate change.

(e) Treat Wastewater effectively:

Finally, wastewater must be effectively treated so that it does not cause harm to humans and the environment. This is further important considering the growth of industries be it in manufacturing or services. Different industries will require a different water usage plan along with a proper wastewater treatment plan so as to remove harmful effluents to be released into the downstream springs and rivers.

5.2. Establishing New Database/Appending new data over the Baseline Data

We have created a new database on the water quality and quantity of springs the regions of South Sikkim and Darjeeling. These details are available in the appendix.

6 PROJECT'S IMPACTS IN IHR

6.1. Socio-Economic Development

Effective water resources management can have a positive impact on socio-economic development in a number of ways. Some of the key ways in which water resources management can contribute to socio-economic development include:

Supporting economic growth: Water is a vital resource for many industries, including agriculture, manufacturing, and power generation. By managing water resources effectively, governments can ensure that there is a reliable supply of water for these industries, which can support economic growth and job creation.

Improving public health: Access to clean, safe drinking water is essential for public health. By managing water resources effectively, governments can ensure that there is a sufficient supply of clean water for drinking and sanitation, which can help to prevent waterborne diseases and improve public health.

Promoting environmental conservation: Water is a vital resource for the environment, and effective water resources management can help to protect and preserve water-based ecosystems. This can support biodiversity and promote the conservation of natural resources, which can have a positive impact on the environment.

Reducing poverty: Access to clean water and adequate sanitation is essential for reducing poverty and improving the quality of life for individuals and communities. By managing water resources effectively, governments can help to ensure that water is available for domestic use, agriculture, and other purposes, which can support economic development and reduce poverty.

Overall, effective water resources management is essential for supporting socio-economic development and improving the quality of life for individuals and communities. By managing water resources in a sustainable and equitable way, governments can help to ensure that water is available for the many different uses that are essential for human well-being and economic growth.

6.2. Scientific Management of Natural Resources In IHR

In addition to aiding socio-economic development in a region, effective water resources management can contribute to the scientific management of natural resources in several ways. Some of the key ways in which water resources management can support the scientific management of natural resources include:

Providing data and information: Water resource management involves collecting data and information about the availability and use of water resources. This data and information can be used to support the scientific management of other natural resources, such as by providing information about the relationship between water availability and the growth of crops or the health of ecosystems.

Developing and implementing management plans: Water resource management involves developing and implementing plans for the sustainable use and management of water resources. These plans can incorporate scientific knowledge and data to support decision-making and ensure that water resources are managed in a sustainable and equitable way.

Monitoring and evaluating the effectiveness of management strategies: Water resource management involves monitoring and evaluating the effectiveness of management strategies to ensure that they are achieving their intended goals. This can help to support the scientific management of natural resources by providing information about the effectiveness of different management approaches and identifying areas where improvements are needed.

Supporting research and innovation: Water resource management can support research and innovation in the field of natural resource management by providing funding and other resources for research projects. This can help to advance scientific understanding of the relationships between water and other natural resources, and to develop new and innovative approaches for managing natural resources.

Overall, effective water resources management is also essential for supporting the scientific management of natural resources. By collecting data and information, developing and implementing management plans, and supporting research and innovation, water resource management can help to ensure that natural resources are managed in a sustainable and equitable way.

6.3. Conservation of Biodiversity and Protection of Environment in IHR

Some of the key ways in which water resources management can contribute to the conservation of biodiversity and the protection of the environment include:

Protecting water-based ecosystems: Water is a vital resource for many ecosystems, and effective water resource management can help to protect and preserve these ecosystems. This can support biodiversity by providing a habitat for a wide range of plant and animal species and can also help to protect the environment by maintaining the natural balance of these ecosystems.

Reducing pollution: Water resource management can help to reduce pollution by regulating the discharge of pollutants into water bodies and by enforcing standards for the quality of water that is used for drinking, irrigation, and other purposes. This can help to protect the environment and to support the conservation of biodiversity by ensuring that water bodies are free from pollution.

Supporting sustainable development: Effective water resource management can support sustainable development by ensuring that water resources are used in a sustainable and equitable way. This can help to protect the environment by reducing the over-exploitation of water resources and can also support the conservation of biodiversity by ensuring that water is available for the many different uses that are essential for maintaining healthy ecosystems.

Promoting public awareness and education: Water resource management can support the conservation of biodiversity and the protection of the environment by promoting public awareness and education about these issues. This can help to raise awareness about the importance of water for the environment and for human well-being and can encourage individuals and communities to take action to protect water resources and the environment.

Overall, by protecting water-based ecosystems, reducing pollution, supporting sustainable development, and promoting public awareness and education, water resource management can help to ensure that water resources are managed in a way that supports the health of the environment and the conservation of biodiversity.

7 EXIT STRATEGY AND SUSTAINABILITY

7.1. How effectively the project findings could be utilized for the sustainable development of IHR

An exit strategy for sustainable use of our project findings could involve several steps. First, it's important to share the findings with relevant stakeholders, such as local government agencies, community organizations, and environmental advocacy groups. This will help ensure that our findings are taken into account in decision-making processes related to water management and conservation in the region.

Next, the local government could consider partnering with local organizations to help implement conservation and management measures based on the findings. This could include working with local communities to develop sustainable water usage practices, or collaborating with government agencies to implement regulations or policies that protect water sources in the region.

Another important aspect of an exit strategy is to ensure that our findings are preserved and made accessible to future researchers and stakeholders. We have published our findings in journals and presented them to local stakeholders. Ultimately, the success of the program will depend on the specific goals and objectives of local government, as well as the needs and challenges of the communities in the Indian Himalayan region of Sikkim. By working closely with local stakeholders and partners, they can help ensure that our project findings are used to support sustainable water management and conservation in the region.

7.2. Efficient ways to replicate the outcomes of the project in other parts of IHR

We have discussed the ways in which we have carried out the work of data collection, analysis and dissemination. Any group of researchers can very easily replicate our methods and contribute to extending the database. We are also happy to collaborate with future group of researchers on their projects in other parts of the IHR.

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9 APPENDIX:

Appendix 1– Copies of Publications duly Acknowledging the Grant/ Fund Support of NMHS
Appendix 2 – List of Trainings/ Workshops/ Seminars with details of trained resources and dissemination material and Proceedings

Annexure-I

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

For the Period: 23.02.18- 30.11.2021

1.	Title of the project/Scheme/Programme:	Innovative and sustainable decision support system for drinking water security in Indian Himalayan region of Sikkim and West Bengal
2.	Name of the Principle Investigator & Organization:	Dr. Md. Nurujjaman, National Institute of Technology Sikkim
3.	NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand Letter No. and Sanction Date of the Project:	GBPNI/NMHS-2017/SG-01/543 dated 23/02/2018
4.	Amount received from NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand during the project period (Please give number and dates of Sanction Letter showing the amount paid):	Rs. 20,48,400/- Ref. No. GBPNI/NMHS-2017/SG-01/543 dated 23-02-2018
5.	Total amount that was available for expenditure (Including commitments) incurred during the project period:	Rs. 20,48,400/-
6.	Actual expenditure (excluding commitments) incurred during the project period:	Rs. 22,66,283
7.	Unspent Balance amount refunded, if any (Please give details of Cheque no. etc.):	Rs. -1,11,301.00/- (Rs. Minus one Lakh Eleven thousand Three hundred one only) The above amount has been taken from Institute.)
8.	Balance amount available at the end of the project:	**NIL**
9.	Balance Amount:	**NIL**
10.	Accrued bank Interest:	Rs. 106582/-

Certified that the expenditure of Rs._**Rs. 4,90,495.00 (Rupees four lakh ninety thousand four hundred ninety five only** mentioned against Sr, no.12 was actually incurred on the project/ scheme for the purpose it was sanctioned.

Date:

15/03/2022

(Signature of Principal Investigator)

(Signature of Registrar/ ~~Finance Officer)~~

(Signature of Head of the Organization)

Director
National Institute of Technology, Sikkim
Ravangla Campus, Sikkim-737139

OUR REF. No.

Accountant
Account Section
राष्ट्रीय प्रौद्योगिकी संस्थान सिक्किम
National Institute of Technology Sikkim

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALYAN STUDIES (GBPNIHESD)

EXPENDITURE STATEMENT

NATIONAL MISSION ON HIMALAYAN STUDIES

Statement showing the expenditure of the period from April 2021-NOV 2022
Sanction No. & Date: GBPNI/NMHS-2017/SG-01/543 Date: 23.02.2018

1. Total outlay of the project : Rs.49,30,200.00

2. Date of Start of the Project :24.04.2018

3. Duration :3 Years

4. Date of Completion :2021-22

a) Amount received during the financial year (2020-21): Rs.4,967.00 (Accrued Bank Interest)
b) Unspent amount carried forward from previous Financial year : Rs.3,74,227.00
c) Total amount available for Expenditure : Rs.3,79,194.00

S.No.	Budget head	Amount Carried forward (Rs.)	Amount received (Rs.)	Amount received+ amount carried Forward (Rs.)	Expenditure (Rs)	Amount Balance/ excess expenditure (Rs)
1	Salaries	-2,43,105.00	Nil	-2,43,105.00	2,10,744.00	-4,53,849.00
2	Permanent Equipment Purchased (Laptop)	3,12,094.00	Nil	3,12,094.00	0.00	3,12,094.00
3	Travel	1,98,784.00	Nil	1,98,784.00	0.00	1,98,784.00
4	Expenditure and Consumable	4982.00	Nil	4982.00	2,64,032.00	-2,59,050.00
5	Activities and other Project Cost	-954.40	Nil	-954.40	15719.00	-16,673.40
6	Contingencies	811.00	Nil	811.00	0.00	811.00
10	Institutional charges	Nil	Nil	Nil	Nil	Nil
11	Accrued bank Interest	1,01,615.00	4967.00	1,06,582.00	0.00	1,06,582.00
12	Total	3,74,227.40	4967.00	3,79,194.00	490495.00	-1,11,301.00
13	Amount allowed to be Carried forward to the next financial year	NA				**-1,11,301.00**

Certified that the expenditure of Rs._**Rs. 4,90,495.00 (Rupees four lakh ninety thousand four hundred ninety five only** mentioned against Sr, no.12 was actually incurred on the project/ scheme for the purpose it was sanctioned.

Date:

15/03/2022

(Signature of Principal Investigator)

(Signature of Registrar/ ~~Finance Officer)~~

(Signature of Head of the Organization)

Director
National Institute of Technology, Sikkim
Ravangla Campus, Sikkim-737139

OUR REF. No.

Accountant
Account Section
राष्ट्रीय प्रौद्योगिकी संस्थान सिक्किम
National Institute of Technology Sikkim

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALYAN STUDIES (GBPNIHESD)

FORM GFR 12 – A
[(See Rule 238 (1)]

UTILIZATION CERTIFICATE FOR THE YEAR 2021-22 in respect Of Recurring and Non- Recurring Grants

1. Name of the Project/Fellowships: National Mission on Himalayan Studies
2. Whether recurring and non-recurring grants: Both
3. Name of the Grantee Org.: NIT Sikkim
4. Grants position at the beginning of the financial year: 2021-22
   (i) Cash in Hand/Bank: Rs.3,74,227.00
   (ii) Unadjusted advances: 0.00
   (iii) Total: Rs.3,74,227.00
5. Details of grants received, expenditure incurred and closing balances:

Unspent Balances of Grants received years	Interest Earned thereon	Interest deposited back to the Govt.	Grant received during the year			Total Available funds (1+2+3+4)	Expenditure (excluding commitments)	Closing Balances (5-6)
1	2	3	4			5	6	7
			Sanction No. (i)	Date (ii)	Amount (iii)			
3,74,227.00	4,967.00	Nil	Nil	Nil	Nil	3,79,194.00	4,90,495.00	-1,11,301.00

Component wise utilization of grants:

Grant-in-aid– General	Grant-in-aid– Salary	Grant-in-aid–creation of capital assets	Total
46,422.00	2,10,744.00	2,33,329.00	4,90,495.00

Details of grants position as on -:30.11.2022
(i) Cash in Hand/Bank: -Rs.- 1,11,301.00
(ii) Unadjusted Advances: 0.00
(iii) Total: Rs.-1,11,301.00

Cont....

राष्ट्रीय प्रौद्योगिकी संस्थान सिक्किम
NATIONAL INSTITUTE OF TECHNOLOGY SIKKIM
(An Institute of National Importance, Ministry of Education, Govt. of India)

Certified that I have satisfied myself that the conditions on which grants were sanctioned have been duly fulfilled/are being fulfilled and that I have exercised following checks to see that the money has been actually utilized for the purpose for which it was sanctioned:

(i) The main accounts and other subsidiary accounts and registers (including assets registers) are maintained as prescribed in the relevant Act/Rules/Standing instructions (mention the Act/Rules) and have been duly audited by designated auditors. The figures depicted above tally with the audited figures mentioned in financial statements/accounts.

(ii) There exist internal controls for safeguarding public funds/assets, watching outcomes and achievements of physical targets against the financial inputs, ensuring quality in asset creation etc. & the periodic evaluation of internal controls is exercised to ensure their effectiveness.

(iii) To the best of our knowledge and belief, no transactions have been entered that are in violation of relevant Act/Rules/standing instructions and scheme guidelines.

(iv) The responsibilities among the key functionaries for execution of the scheme have been assigned in clear terms and are not general in nature.

(v) The benefits were extended to the intended beneficiaries and only such areas/districts were covered where the scheme was intended to operate.

(vi) The expenditure on various components of the scheme was in the proportions authorized as per the scheme guidelines and terms and conditions of the grants-in-aid.

(vii) It has been ensured that the physical and financial performance under has been according to the requirements, as prescribed in the guidelines issued by Govt. of India and the performance/targets achieved statement for the year to which the utilization of the fund resulted in outcomes given at Annexure – I duly enclosed.

(viii) The utilization of the fund resulted in outcomes given at Annexure – II duly enclosed (to be formulated by the Ministry/ Department concerned as per their requirements/ specifications.)

(ix) Details of various schemes executed by the agency through grants-in-aid received from the same Ministry or from other Ministries is enclosed at Annexure –II (to be formulated by the Ministry/Department concerned as per their requirements/ specifications).

Date:
Place:

15/03/2022
Signature
Name: Md Nurujjaman
PI

Signature
Name: Sahil Nanda
~~Finance Officer~~
Asst Registrar

Signature
Name:
Head of the Organization
Director
National Institute of Technology, Sikkim
Ravangla Campus, Sikkim-737139

Accountant
Account Section
राष्ट्रीय प्रौद्योगिकी संस्थान सिक्किम
National Institute of Technology Sikkim

राष्ट्रीय प्रौद्योगिकी संस्थान सिक्किम
NATIONAL INSTITUTE OF TECHNOLOGY SIKKIM
(An Institute of National Importance, MHRD, Govt. of India)

Ref: 477/NITS/Admin/Research Project-NMHS/2018 **Date: 22.03.2021**

Interest Earned Certificate

During the tenure of the Research Project – National Mission on Himalayan Studies (NMHS) the following interest has been accrued on the project account (Bank A/c- NMHS-NIT Sikkim 37665366546).

FY 2021-22 (Till 30th Nov 2021)	4,967.00
FY 2020-21	10,725.00
FY 2019-20	32,687.00
FY 2018-19	58,203.00
Total	**106582.00**

The total sum of **Rs.106582.00** (Rupees one lakh six thousand five hundred eighty two only) has been earned as an interest on the NMHS project account.

Project P.I **Finance Officer**

Accountant
Account Section
राष्ट्रीय प्रौद्योगिकी संस्थान सिक्किम
National Institute of Technology Sikkim

Ravangla, Barfung Block, South Sikkim - 737139 (India)
Tel.: +91-7479013172 | website: www.nitsikkim.ac.in

Annexure-III

Consolidated Assets Certificate

Assets Acquired Wholly/ Substantially out of Government Grants

(Register to be maintained by Grantee Institution)

Name of the Sanctioning Authority: "NATIONAL MISSION ON HIMALAYAN STUDIES" G.B. Pant National Institute of Himalayan Environment and Sustainable Development (GBPNIHESD)

Sl. No. ______________________________

1. Name of Grantee Institution: (a) National Institute of Technology Sikkim, (b) Flame University, Pune and (c) Birla Global University Bhubaneswar
2. No. & Date of sanction order: GBPNI/NMHS-2017/SG-01/ Date: 23-02-2018
3. Amount of the Sanctioned Grant: **Rs. 49,30,200/-**
4. Brief Purpose of the Grant: (a) To assess quality and quantity of water resources in the districts of South Sikkim and Darjeeling; (b) To establish drinking water security through a participatory approach; (c) To estimate the cost of drinking water in the region; (d) To build a Decision Support System to support water demand; and To devise a long term Policy Framework integrating all the stakeholders.
5. Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant-in-aid Sanction Order: NA
6. Particulars of assets actually credited or acquired: a Printer and a Laptop
7. Value of the assets as on (a) a Laptop- Rs. 84800/- On 30/01/2020. And a printer- of Rs. 23445/- 23/01/2019.
8. Purpose for which utilized at present: research activity in the department
9. Encumbered or not: No
10. Reasons, if encumbered: NA
11. Disposed of or not: NO
12. Reasons and authority, if any, for disposal: NA
13. Amount realised on disposal: NA

Any Other Remarks: NA

23/03/2022

(PROJECT INVESTIGATOR)

(Signed and Stamped)

(FINANCE OFFICER)

(Signed and Stamped)

(HEAD OF THE INSTITUTION)

Director
National Institute of Technology, Sikkim
Ravangla Campus, Sikkim-737139

(Signed and Stamped)

Accountant
Account Section
राष्ट्रीय प्रौद्योगिकी संस्थान सिक्किम
National Institute of Technology Sikkim

Annexure-IV

List or Inventory of Assets/ Equipment/ Peripherals

S. No.	Name of Equipment	Quantity	Sanctioned Cost	Actual Purchased Cost(Rs)	Purchase Details
1	Printer	1	480000.00	23445.00	HPFPM128fw Laser jet Pro Printer, date 23/01/2019
2	Laptop	1		84800.00	Laptop HP. Pav 15-cs3008TX-17 8th Gen/8G/1TB/4GR A/w10, batch 5CD938GWTT date: 30/01/2020

23/03/2022

(PROJECT INVESTIGATOR)

(Signed and Stamped)

(FINANCE OFFICER)

(Signed and Stamped)

Accountant
Account Section
राष्ट्रीय प्रौद्योगिकी संस्थान सिक्किम
National Institute of Technology Sikkim

(HEAD OF THE INSTITUTION)

Director
National Institute of Technology, Sikkim
Ravangla Campus, Sikkim-737139

(Signed and Stamped)

राष्ट्रीय प्रौद्योगिकी संस्थान सिक्किम
NATIONAL INSTITUTE OF TECHNOLOGY SIKKIM
(An Institute of National Importance, MHRD, Govt. of India)

Annexure-V

To,

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

Sub.: Transfer of Permanent Equipment purchased under Research Project titled "**Innovative and sustainable decision support system for drinking water security in Indian Himalayan Region of Sikkim and West Bengal**" funded under the NMHS Scheme of MoEF&CC – reg.

Sir/ Madam,

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

1. Printer
2. Laptop

Head of Implementing Organization: Prof. M.C Govil
Name of the Implementing Organization: NIT Sikkim
Stamp/ Seal:
Date

Director
National Institute of Technology, Sikkim
Ravangla Campus, Sikkim-737139

Copy to:

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