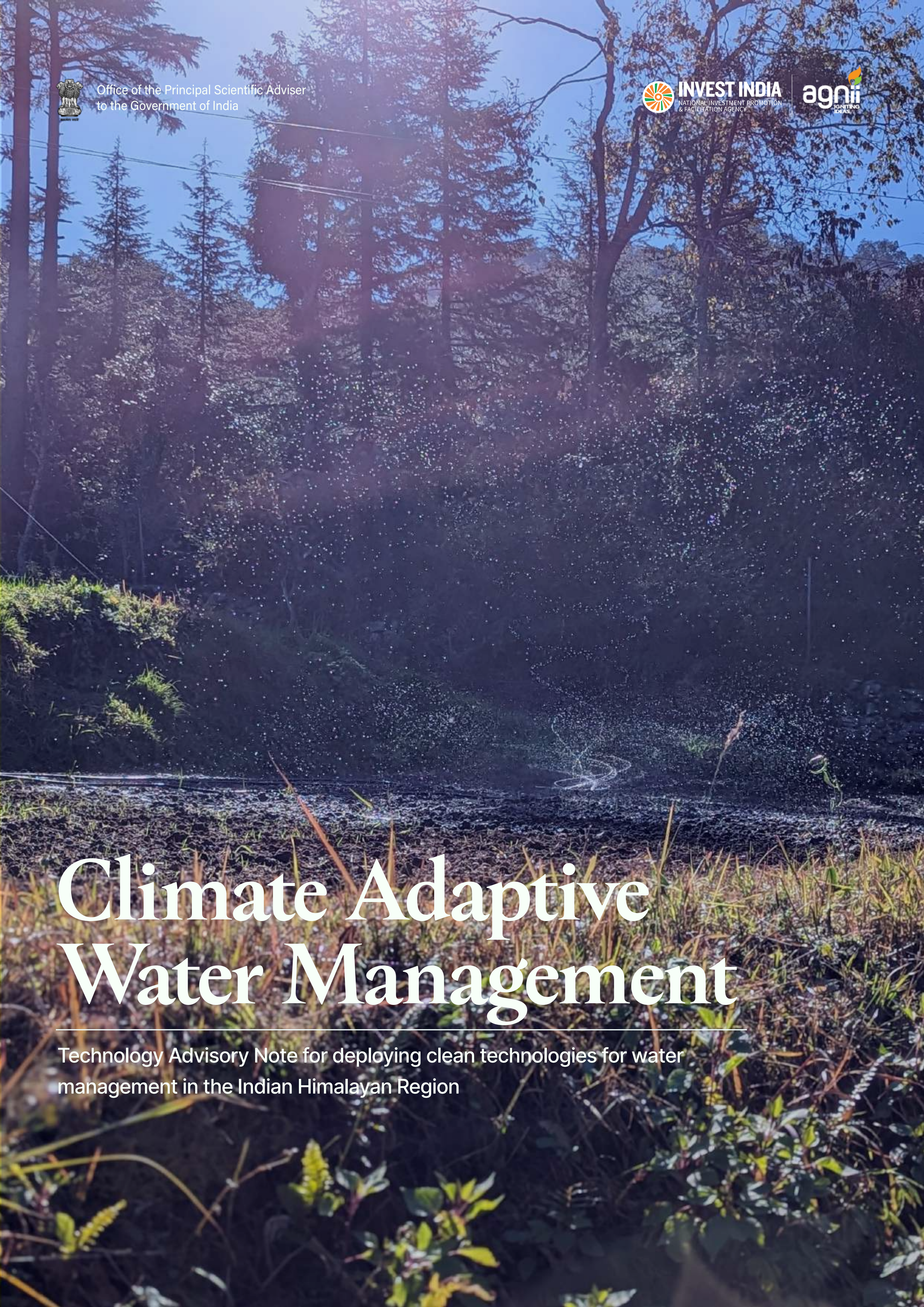

Office of the Principal Scientific Adviser
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agnii
IGNITING IDEAS

Climate Adaptive Water Management

Technology Advisory Note for deploying clean technologies for water management in the Indian Himalayan Region

Climate Adaptive Water Management

Technologies for water management in the Indian Himalayan Region

Technology Advisory Note
June 2023

AGNIi Mission
Office of the Principal Scientific Adviser to the Government of India
Conducted in collaboration with Uttarakhand State Council for Science and Technology

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Title: Climate Adaptive Water Management - Technology Advisory Note for deploying technologies for water management in the Indian Himalayan Region | Issue date June 2023.

Recommended citation: AGNIi. 2023. Climate Adaptive Water Management - Technology Advisory Note for deploying technologies for water management in the Indian Himalayan Region

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Acknowledgments

This Technology Advisory Note elaborates the work undertaken by AGNIi Mission under Project Climate Adaptive Water Management to develop a scalable pioneering example of how Indian technological innovation can enable climate adaptive water management; and will subsequently support administrative action. The project was conceptualized and executed by the AGNIi Mission (from the Office of Principal Scientific Adviser, Government of India executed in partnership with Invest India) in collaboration with Uttarakhand State Council for Science and Technology (UCOST), Department of Information and Science Technology, Government of Uttarakhand.

At the onset, we extend our gratitude to the Office of the Principal Scientific Adviser to the Government of India for their guidance and support. We sincerely thank Prof. Ajay Kumar Sood, Principal Scientific Adviser to the Government of India for his encouragement and vision. Our gratitude to Dr. Parvinder Maini (Scientific Secretary, Office of the Principal Scientific Adviser to the Government of India) for her guidance and oversight during the projects. We are very grateful to Dr. Preeti Banzal (Adviser/Scientist 'G', Office of the Principal Scientific Adviser to the Government of India) for her consistent advice, direction, and support.

As Uttarakhand emerges as a pioneer state for implementing technologies to tackle climate change, we extend our gratitude to the Hon'ble Chief Minister of Uttarakhand Shri Pushkar Singh Dhami for entrusting AGNIi Mission to enable technology enabled interventions for climate resilience, which will help develop Champawat as an Adarsh Zilla under the Uttarakhand@25initiative under the guidance of UCOST; which can also be emulated and scaled across the other Indian Himalayan states. We acknowledge and extend our gratitude to Prof. Durgesh Pant (Director General, UCOST), Dr. Piyush Joshi (Sr. Scientific Officer, UCOST), and Mr. Prahalad Adhikari (Coordinator, Adarsh Champawat) for their guidance and support during the Project.

We express our sincere gratitude to Ms. Jyotsna Sitling (Principal Chief Conservator of Forests – Van Panchayats, Uttarakhand during the project) for sharing of her experience and advice about community behaviour and helped facilitate AGNIi Mission's fieldwork among rural hill communities in different Van Panchayats across Champawat district.

We express our sincere thanks to Mr. Narendra Singh Bhandari, IAS (District Magistrate, Champawat), Mr. Rajendra Singh Rawat (Chief Development Officer, Champawat), Mr. Ramesh Chandra Kandpal (Divisional Forest Officer, Champawat) and representatives from various line departments for their unstinting support in the field.

We are especially grateful to Padma Bhushan Dr. Anil Joshi (Founder, HESCO), Dr. K.V. Ramana Rao (Principal Scientist and Head, Irrigation and Drainage Engineering Division, ICAR-Central Institute of Agricultural Engineering, Bhopal), Dr. Nitin Maurya (Scientist E, National Innovation Foundation - India) and Dr. Lal Singh (Director, Himalayan Research Group) for their expert inputs primarily with respect to technology evaluation furnished to AGNIi Mission during the Technical Session (Pioneering Climate Adaptive Innovations for the Himalaya: Uttarakhand as an Exemplar) organised by the Mission under the aegis of the Rural Science Congress, Dehradun.

Also, we acknowledge and extend our gratitude to community collaborators - Dr. Dinesh Raturi (Project Officer, BAIF Research Development Foundation), Dr. Himani Purohit (Himalayan Environmental Studies and Conservation Organisation [HESCO]), Dr. Ravish Joshi (HESCO/Kumaon Agriculture and Greenery Advancement Society), Ms. Ruth Joanne D'Costa (Hai Jalo), Ms. Pratibha Krishnaiah (Himalayan Blooms), and the citizens of Champawat, especially its women for giving us their time and sharing in detail the various problems that afflict the water mangement practices of the hill.

Finally, and importantly, we deeply appreciate all the innovators who overcame significant logistical and weather challenges to showcase their innovations that can significantly help rural communities residing in the Indian Himalayan Region develop resilience in the face of the challenges climate change poses.

FOREWORD

Pushkar Singh Dhami

Hon'ble Chief Minister, Uttarakhand

पुष्कर सिंह धामी

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संदेश

मुझे यह जानकर अत्यन्त प्रसन्नता हो रही है कि भारत सरकार के मुख्य वैज्ञानिक सलाहकार कार्यालय द्वारा उत्तराखंड विज्ञान एवं प्रौद्योगिकी परिषद (UCOST) के साथ मिलकर **'आदर्श चम्पावत'** के अन्तर्गत दूरस्थ ग्रामीण क्षेत्रों सहित सम्पूर्ण चम्पावत जिले के सर्वांगींण विकास एवं आजीविका संवर्धन हेतु देश में उपलब्ध अत्याधुनिक तकनीकी हस्तक्षेपों के अनुप्रयोगों में प्रयासरत है।

मा0 प्रधानमंत्री जी की विराट सोच के आधार पर उत्तराखण्ड को हिमालयी क्षेत्र के लिए **'आदर्श राज्य'** के रूप में स्थापित करने की दिशा में प्रदेश सरकार अति महत्वाकांक्षी उत्तराखंड @ 25 पहल पर बहुत संवदेनशील है। आदंर्श चम्पावत इस विराट मुहिम की एक प्रयोगशाला है, जिसके माध्यम से हम जिले के दर्जनों रेखीय विभागों, केंद्र सरकार के संस्थानों, स्थानीय स्तर पर कार्यरत विभिन्न स्वयं सहायता समूहों तथा नागरिकों को एक मंच पर लाकर विज्ञान एवं प्रौद्योगिकी के सही इस्तेमाल से सतत् एवं एकीकृत विकास की रूपरेखा बनाने में अग्रसर हैं। चम्पावत का जनप्रतिनिधि और प्रदेश का मुख्य सेवक होने के नाते आदर्श चम्पावत के क्रियाकलापों, खासकर विज्ञान आधारित समाधानों में मेरी विशेष व्यक्तिगत रूचि भी है।

मुझे ज्ञात हुआ है कि मुख्य वैज्ञानिक सलाहकार के कार्यालय के अन्तर्गत अग्नि मिशन के दल द्वारा चम्पावत जिले के दूरस्थ ग्रामीण इलाकों का भ्रमण कर रोजमर्रा के जीवन की चुनौतियों का सघन अध्ययन किया जा रहा है। इस अध्ययन के आधार पर पहले चरण में देश भर से करीब एक दर्जन चुनिंदा स्टार्ट–अप कम्पनियों को साथ लेकर नरसिंह डांडा में स्थानीय लोगों के समक्ष जल एवं कृषि आधारित चुनौतियों से निपटने में सक्षम तकनीकों का भी प्रदर्शन किया गया। इस कार्यक्रम से सम्बंधित लोगों की प्रतिक्रियाओं, विभिन्न हितधारकों एवं प्रशासनिक अधिकारियों के सुझावों का संज्ञान लेते हुए गहनता से तकनीकियों का अध्ययन करने के उपरान्त अग्नि मिशन द्वारा संकलित यह तकनीकी सलाह पुस्तिका **(टेक्नोलॉजी एडवाइजरी नोट)** एक गुणवत्तापूर्ण दस्तावेज है जो आदर्श चम्पावत के साथ–साथ प्रदेश के सतत् विकास के क्रियान्वयन के लिए भी अत्यन्त महत्वपूर्ण सिद्ध होगी।

मैं इस तकनीकी सलाह पुस्तिका के प्रकाशन तथा राज्य को हस्तांतरण के लिए UCOST एवं अग्नि मिशन के पूरे दल सहित इस तकनीकी प्रदर्शन में उपस्थित सभी स्टार्टअप और स्थानीय नागरिकों को बधाई और हार्दिक शुभकामनाएँ प्रेषित करता हूँ।

(पुष्कर सिंह धामी)

FOREWORD

Prof. Ajay Kumar Sood

Principal Scientific Adviser to the Government of India

अजय के. सूद
भारत सरकार के प्रमुख वैज्ञानिक सलाहकार
Ajay K. Sood
Principal Scientific Adviser to the Govt. of India

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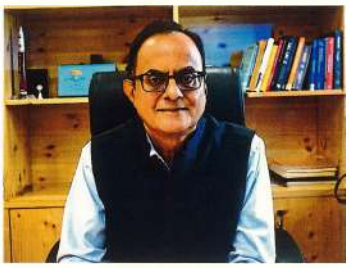

Message

The Office of the Principal Scientific Adviser (PSA) to the Government of India is committed to advise and facilitate solving pressing socio-economic challenges with the intervention of science and technology. We believe that Indian technological innovation can, under the aegis of Aatmanirbhar Bharat, help better public service delivery, governance of schemes and welfare of the society.

Office of PSA is glad to work via our AGNIi Mission, with the Government of Uttarakhand via Uttarakhand State Council for Science and Technology (UCOST), on technological innovation for climate-sustainable development in the region.

For the Himalayan States, covering approximately 18% of India's geographical area and home to about 5% of her population, climate change is a crucial challenge. climate change can potentially affect agriculture, livelihood, water, ecology, and the wider citizenry of the region. UCOST's with the Office of PSA's support, intends to explore how technological innovation can help Uttarakhand's Mountain communities adapt and acquire resilience to these challenges. This partnership has identified, assessed, and demonstrated examples of technological interventions to meet out Himalayan State's climate resilience needs.

The results of this exercise, captured in this Technology Advisory Note, could support decision-making by public agencies on leveraging such innovation. Further, this initiative can offer important examples for wider emulation across India's Himalayan States.

I extend my sincere appreciation for the support and cooperation extended by UCOST, and State and District agencies; and look forward to touching further milestones through this important partnership.

Ajay K Sood

(Ajay K. Sood)

Dated: 15th June, 2023

FOREWORD

Prof. Durgesh Pant

Director General, Uttarakhand Council for Science and Technology (UCOST)

Prof Durgesh Pant
Director General

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MESSAGE

I am delighted to note that AGNIi team from office of Principal Scientific Advisor (PSA) to Government of India is working very closely with Uttarakhand State Council for Science and Technology (UCOST) in Adarsh Champawat initiative. Being a test bed for ambitious Uttarakhand@25 mission of Honorable Chief Minister Pushkar Singh Dhami Ji, Adarsh Champawat is an important and critical initiative not only for Uttarakhand state but also for all the states in Himalayan region.

It gives me pleasure to learn that a qualified, young and energetic team has been deputed on the ground which is working cohesively with UCOST to drive Science and Technology interventions in remote villages of Champawat. I am confident that the first sprint of Technology showcase covering climate adaptive Water and Agriculture held on 16th March, 2023 at Narsinghdanda has helped people from nearby areas to understand relevance and use of innovative technology solutions to address local challenges.

These initial efforts through field studies, rural immersion, interactions and showcases would not only help us in enabling holistic development of the state but also in ensuring value addition towards larger objective of creating a climate adaptive Technology Solution Architecture (TSA) for Himalayan ecosystem.

This Technology Advisory Note (TAN) is an important document for all of us. I believe this would provide much needed guidance in flawless execution of Adarsh Champawat now and Uttarakhand@25 subsequently in near future.

I extend best wishes to AGNIi and UCOST teams for the grand success of subsequent sprints of Technology showcases in Champawat which will help in driving both Adarsh Champawat as well as Uttarakhand@25 initiatives under the guidance of Honorable Chief Minister Shri Pushkar Singh Dhami Ji.

(Prof. Durgesh Pant)
Director General
Uttarakhand Council for Science and Technology, Dehradun

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Part A : Introduction | Objective and Method

SECTION 1

Technology for Climate Adaptive Water Management

This Technology Advisory Note (TAN) focuses on how emerging technology and innovation – capabilities for which exist in India's innovation ecosystems, startup, and laboratory – can support climate adaptive water management practices in the Indian Himalayan Region. This innovation includes artificial intelligence (AI), advanced sensing, and cyber-physical systems to enable precise action against the impact of climate change on water resources.

The Office of the Principal Scientific Adviser (PSA) to the Government of India, in partnership with national government agencies, identifies and advises on how Indian emerging technologies (such as AI, blockchain technology, nanotechnology, advanced sensing, and others) can be leveraged to help address national priorities. Key among these is climate change. The Office's advisory is optimised for relevance, supporting specific decisions; and for execution, providing decision-makers with guidance they can use in the field. This allows Government agencies with a usable basis for drawing on emerging technology and innovation. By shaping scaled Government engagement with Indian innovation: Office advisory, if executed by agencies concerned, will generate scaled opportunity for Indian startup and laboratory innovation.

The TAN summarises guidance developed in collaboration with the Uttarakhand State Council for Science and Technology (UCOST), Government of Uttarakhand acting as a Pioneer Agency. Pioneer Agencies are select organisations within the Government which are mandated to engage these national priorities; in doing so, they demonstrate a high degree of proactiveness and progressiveness in their engagement with innovation, technology, and new ideas; and share these priorities with a wider community of similar institutions – allowing scaled impact against these priorities to be assured by the emulation and adaptation of Pioneer Agencies' examples.

The guidance in the TAN was developed via fieldwork, Technology Operational Scenarios, Technology Capability Stacks, and Field Technology Showcases.

The Field Technology Showcase was held at Champawat, Kumaon Division, Uttarakhand. The choice of the showcase site is aligned with the vision of the Uttarakhand Government to develop Champawat as an Adarsh Zila under the Uttarakhand @25 initiative of the Hon'ble Chief Minister of the state under the guidance of UCOST.[1]

Its generating activities were undertaken in partnership and consultation with UCOST, and the district administration: the Note and its advice aims to support practical, actionable administrative decision-making on technology engagement and acquisition for climate adaptive agriculture. This in Uttarakhand – but also in other Himalayan states that bear similarities with respect to geography, demography, and climate change concerns. Aligned to the Government's Aatmanirbhar Bharat priority, the TAN focuses on Indian technological innovation.

Equally: The TAN – and the exercises that generate it (technology operational scenarios, stack development, field technology showcases, etc.) – are exercises in change management. They seek to support leadership in driving a wider technology-enabled transformation to improve the populaces' various parameters associated with human development, multi-dimensional poverty, and climate resilience. The analyses and output provide leadership with tools and levers with which to do so.

No part of any TAN should be construed as, or be interpreted or derived to generate, support for any individual vendor, startup, innovator, or private actor of any kind. The TAN features specific technologies – whose innovator startups and laboratories volunteered to participate in Field Technology Showcases – merely as examples of broader technological capabilities' existence and readiness within Indian innovation ecosystems, and of how Aatmanirbhar Bharat can be effectively advanced even while supporting key national priorities. At every stage, Government agencies must follow due process under competent authority in engaging, selecting, procuring, and deploying technology.

1 Presentation by UCOST at CM Review Meeting, Champawat held on 24th February 2023.

Scaled Impact: Are TAN and technologies applicable across the Himalayas?

Set at a diverse range of high-altitudes, the Himalayan geography has birthed a socio–economic paradigm attuned to its specific needs and distinct from the existent frameworks more widely and easily applicable to the plains where urban development is more convenient. The IPCC reports have specifically recognised the fragility of the mountains, with specific attention paid to the vulnerability that results from the loss of glaciers and more extreme events. The peculiar geographical conditions and the sheer diversity of it also means that the region is ecologically fragile and specifically more vulnerable to climate change, putting its population, especially the impoverished, at extreme risk.

The Indian Himalayan Region is a 2,500 km long arc, cutting across 13 states and Union Territories (UTs) of India. The region is home to approximately five per cent of the Indian population and covers 18 per cent of the geographical area of the country.[2] The entire Himalayan zone, including the foothills and the tarai region, constitutes an extremely fragile ecological zone. The diversity of the region divides the range into extremely small groups of distinctive socio-cultural regions and sub-regions, most of which have a slow pace of economic growth. The local communities derive their livelihood opportunities in the challenging terrain with a dwindling resource base.

Choosing Champawat as an Exemplar

Uttarakhand emerges as a state having low vulnerability to climate change in a relative sense with other Himalayan states. However, the vulnerability of the state to climate change in the absolute sense cannot be discounted[3]. At the district level, only two districts of Uttarakhand – Dehradun and Udham Singh Nagar have low vulnerability; however four districts of the state namely Haridwar, Tehri Garhwal, Bageshwar, and Pitthoragarh have high vulnerability. Meanwhile, seven districts including Uttarkashi, Pauri Garhwal, Rudra Prayag, Chamoli, Almora, Nainital, and Champawat have medium vulnerability.

Understanding that majority districts in the state either have medium or high vulnerability to climate change but also have immense potential with respect to agriculture and horticulture, the state government[4] is continuously making efforts to create development models that balance ecology and economy. Water conservation also remains priority of the state government.

To further its objectives, Uttarakhand government with UCOST as its Nodal Agency is proactively working on technology enabled operational models for developing Champawat as a Model District under the state government's Uttarakhand@25 initiative in the context of Himalayan ecosystem.[5]

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2 Status of Ecosystem Health In The Indian Himalayan Region, 2019

3 Department of Science and Technology 'Climate Vulnerability Assessment for the Indian Himalayan Region Using A Common Framework' available at https://dst.gov.in/sites/default/files/IHCAP_Climate%20Vulnerability%20Assessment_30Nov2018_Final_aw.pdf (Last accessed on March 29, 2023)

4 https://www.pressreader.com/article/281779927944826 (Last accessed on March 29, 2023)

5 Presentation by UCOST at CM Review Meeting, Champawat held on 24th February 2023.

The choice of Champawat in Uttarakhand is because the district shows a range of geographical and topographical markers, making it an ideal testbed to execute technology enabled operational models that can be replicated across Uttarakhand and subsequently across the Himalayan belt. Some of these features include:

Altitudinal range and topographical variability.

- The altitude in Champawat ranges from 200 – 2,200 mts. Champawat can be divided in three main parts:

- The 35 villages of Tanakpur (Purnagiri) Tehsil fall in Terai area and are important from the viewpoint of plain and agricultural land and a warm area of an average height of 200 to 250 meter, having abundant water and good soil.

- Shivalik which is situated at a height of 250 to 1,200 meter. It represents a sloping and uneven topographical land consisting of dense forests.

- The hilly area with average height of 1,500 mts (from 1,200 to 2,200 mts).

Climate variability. The climate of the district is very differential, and the temperature varies from one degree Celsius in the year to 35 degrees Celsius. The Terai area is hot whereas the hilly region is comparatively cold. High mountain ranges are covered with snow. The climatic condition of Terai and plains are similar, the seasonal rain is very high (about 20 cm. yearly). The climate of Shivalik is same but the lower region of Himalayas experience cold climate throughout the year.

Forest cover variability. The forests in Champawat range from 200-2,000 mts, making the operational models developed highly scalable across the montane sub-tropical forests and (1,000-1,500 mts (Pine forests)) and montane temperate forests (1,500 – 2,400 mts. (Himalayan temperate and Himalayan dry temperate)). [6]

Scalability of TAN across the Himalayan region

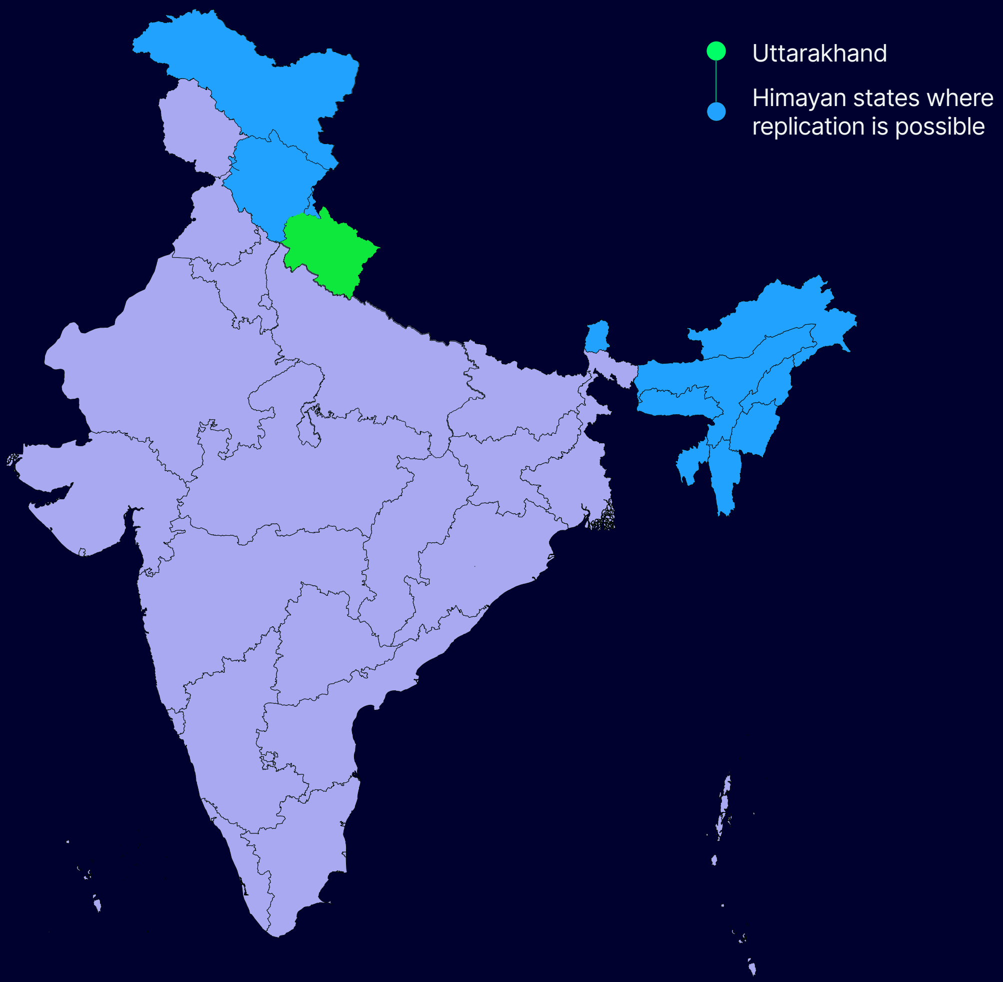
The state of Uttarakhand constitutes 10.02 per cent of the Indian Himalayan Region which is fourth highest among the Himalayan states. The commonalities of terrain and weather patterns present across the Himalayan states are evident. Uttarakhand represents the microcosm of the Indian Himalayan macrocosm given the altitudinal range and the resulting variability in the forest cover.

Thus, the technological capabilities that addresses the various pain points that are afflicting rural communities and reduce their vulnerability to climate change as proxied by various indicators can be

6 District Survey Report Champawat available at < https://cdn.s3waas.gov.in/s3eda80a3d5b344bc40f3bc04f65b7a357/uploads/2018/08/2018082543.pdf> last accessed 22 March 2023.

Box 1

Scalability of Adarsh Champawat project across Indian Himalayan Region^



^ Map not drawn to scale. For illustrative purposes only.

Table 1

Classification and Geographic Distribution of Indian Forests (Altitudinally)[1 2]

S.No	Broad Forest Classifications	Other areas of India where the broad forest type is found
Tropical Forests (up to 1,000 m)		
1	Moist Deciduous	Western Ghats; Manipur, Mizoram; Hills of Eastern Madhya Pradesh and Chhattisgarh; Chota Nagpur Plateau; Odisha; West Bengal; Andaman and Nicobar Islands
2	Dry Deciduous	Occur in an irregular wide strip running from the foot of the Himalayas to Kanyakumari except in Rajasthan, Western Ghats and West Bengaluru
Montane Sub-tropical Forests (1,000 – 1,500 m)		
3	Pine Forest	Jammu and Kashmir; Himachal Pradesh; Sikkim
Montane Temperate Forests (1,500 – 2,400 m)		
4	Himalayan Temperate	Kashmir, Himachal Pradesh, Darjeeling; Sikkim
5	Himalayan Dry Temperate	Ladakh, Lahul, Chamba, Kinnaur, and Sikkim
6	Sub-alpine	Jammu and Kashmir, Himachal Pradesh, Sikkim, Arunachal Pradesh
Alpine Scrub		
7	Moist alpine	Jammu and Kashmir, Himachal Pradesh, Sikkim, Arunachal Pradesh
8	Dry alpine	Jammu and Kashmir, Himachal Pradesh, Sikkim, Arunachal Pradesh

1 Sources: https://fsi.nic.in/isfr-2021/chapter-13.pdf ; http://wmduk.gov.in/ManualsUDWDP/TM/Forestry.pdf ; https://www.ceeindia.org/CEE-Academy-resouce/PDF/Forest%20ecosystem%20Forest%20Types%20of%20India.pdf;http://ecours-esonline.iasri.res.in/mod/page/view.php?id=14441; http://www.utrenvis.nic.in/data/classification%20forest.pdf ;

2 Forest types highlighted in Green are found in Champawat district of Uttarakhand

Table 2

Scaling Potential of the TAN across the Indian Himalayan Region[1]

Pain Points and Technology Use case	Vulnerability Factor	Indicators	Uttara-khand	Jammu and Kash-mir	Him-achal	Assam	Megha-laya	Mani-pur	Mizo-ram	Tripura	Arun-achal	Sik-kim	Na-galand	India Average
Pain point: • Lack of irrigation mechanisms for farmlands due to hilly terrain Technology use case: • Efficient water management • Water quality monitoring	Percentage of area under hilly terrain	Hilly Terrain#	100	100	100	24.2	100	100	100	100	100	100	100	18
	Net irrigated area to net sown area	Irrigation Intensity##	164	146	172	131	159	100	194	144	100	100	110	143
	Income diversification and per capita income	Ratio of average monthly household income to average monthly non-agricultural household income###	1.5	0.6	1.0	1.2	1.0	1.0	1.2	0.8	0.8	1.0	1.0	1.2
	Area under rainfed agriculture	Rainfed cultivated area (%)	Greater than 41%											50.9

1 Please note that for the present purpose the state of West Bengal has not been included in the table as the state has less than one per cent of share of geographical area in the Indian Himalayan Region (Source: http://gbpihedenvis.nic.in/him_states.htm [Last accessed on March 30, 2023]) & Jammu and Kashmir refers to undivided Jammu and Kashmir

Technology Use case	Vulnerability Factor	Indicators	Uttara-khand	Jammu and Kash-mir	Himachal Pradesh	Assam	Megha-laya	Manipur	Mizoram	Tripura	Arun-achal Pradesh	Sikkim	Na-galand	India Average
Pain point: • Drying of natural water springs: About 60-70% of the Himalayan population directly depends on springs to meet their domestic and livelihood needs Technology use cases: • Spring aquifer mapping and tracking • Water quality monitoring	Access to infrastructure: Living Standards - Drinking Water (MPI)	% habitations with provision of less than 40 lpcd of potable water#####	49.90	51.75	28.6	32.67	73.62	33.20	55.12	21.69	8.75	57.84	61.97	18.72
		% villages ^ reported 100% tap connection (potable water))^connection)#####	4.36	15.73	39.44	7.72	47.86	63.25	64.60	37.50	18.4	24.42	61.19	32.47

 # Source: https://fincomindia.nic.in/writereaddata/html_en_files/oldcommission_html/fincom14/others/29.pdf
Source: https://www.nabard.org/auth/writereaddata/tender/1710224557farmers-welfare-in-india-a-state-wise-analysis.pdf
Source: https://fsi.nic.in/isfr-2021/chapter-2.pdf
Source: https://www.nabard.org/auth/writereaddata/tender/1710224557farmers-welfare-in-india-a-state-wise-analysis.pdf
Source: https://www.nabard.org/auth/writereaddata/tender/1710224557farmers-welfare-in-india-a-state-wise-analysis.pdf
^ Source: https://www.nabard.org/auth/writereaddata/tender/1710224557farmers-welfare-in-india-a-state-wise-analysis.pdf

Methodology | Actionable Advice for Scaled Impact : Exemplar Projects

1. **Practicality: Ensuring Technology Decision-Making Support is Actionable.** To ensure that agency decision-makers receive technology and innovation advice that is actionable in the field: the Office's AGNIi Mission, under the Prime Minister's Science Technology and Innovation Advisory Council (PM-STIAC) develops this advice through

2. **Exemplar Projects**, executed in collaboration with a Pioneer Agency.

    - Exemplar Projects address pain-points identified by senior Government authorities in that sphere as comprising a major and scaled national priority.

    - Pioneer Agencies are select organisations within the Government which

        - are mandated to engage these national priorities;

        - in doing so, demonstrate a high degree of proactiveness and progressiveness in their engagement with innovation, technology, and new ideas; and

        - share these priorities with a wider community of similar institutions – allowing scaled impact against these priorities to be assured by the emulation and adaptation of Pioneer Agencies' examples.

3. **Ensuring Decision-Making Relevance: Technology Operational Scenarios.** AGNIi targets emerging technology innovation to support agency priorities and requirements, as follows:

    - The Exemplar Project analyses and characterises this pain-point, determining its dimensions and decision-factors:

        - Field Level, which have bearings for officers at directly dealing with rural communities on the field. In the present scenario, this would involve the District Magistrate/District Collector, line departments, officials at the block level, and Gram Panchayat level personnel;

        - Operational, which senior administrative tiers must resolve. In the district, this would include the District Magistrate, and Chief Development Officer;

        - Strategic, affecting leadership-tier decision-making. This would include the state level leadership (Chief Minister's Office and line departments) and Pioneer Agency - UCOST in the present scenario.

    - To ensure decision-making relevance: AGNIi executes that analysis and characterisation as follows:

        - To determine field level and operational decision-making dimensions: AGNIi team visits field locations – selected for representing the most challenging circumstances the Pioneer Agency faces – to research and characterise pain-points as they are experienced and determined the ground.

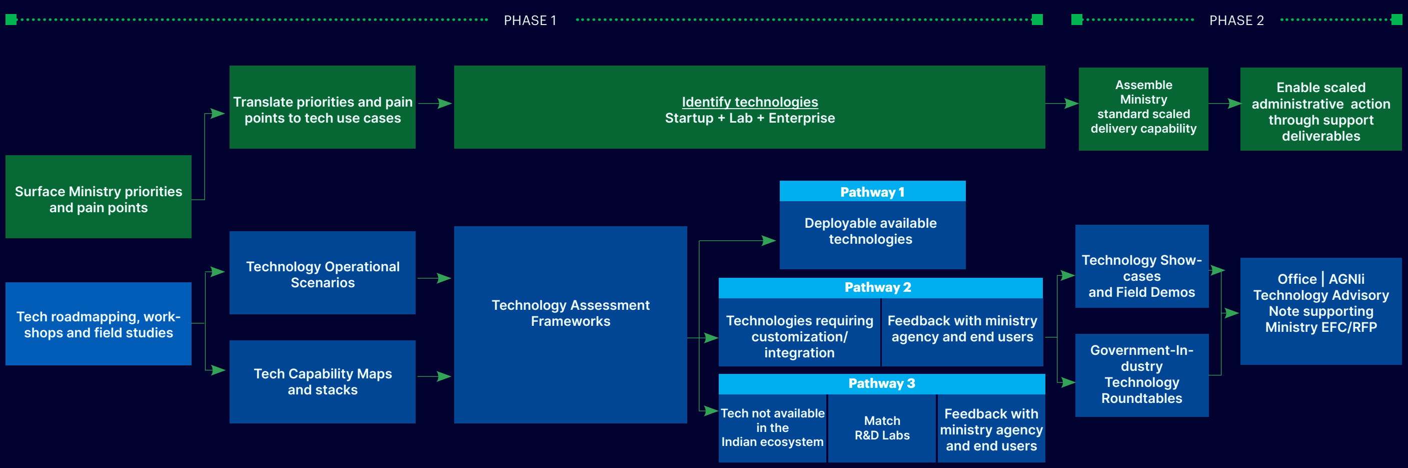
- To determine operational and strategic decision-making dimensions: the AGNIi Mission also consults, via a series of meetings, with Pioneer Agency representatives and the District Magistrate.

4. **Solving Challenges with Technology*:* The Technology Stack.** The Project then formulates a 'stack' of emerging technologies – within Indian startup and laboratory capability, demonstrated through specific examples – which can engage these challenges.

    - Technology Stacks integrate innovation across multiple technologies – for example, AI, Internet of Things (IoT), Satellite Imagery, Advanced Sensing, and Cyber-Physical Systems.
    - They position these technologies against operational capabilities required to address climate adaptive water challenges – for example water rejuvenation, irrigation, and water quality management.
    - Where these technologies and capabilities intersect – solutions are identified – for example, IoT based automated water pump for effective irrigation and water conservation.
    - For each of these solutions – examples of concrete Indian innovation are identified; in the form of startup or laboratory innovation. This offers the agency clarity that Indian innovation is available, under Aatmanirbhar Bharat objectives, to solve its challenges.

Box 2

AGNIi Work Flow



- Crucially, these examples (and the wider TAN) do not recommend or endorse any vendor.

- These technologies and capabilities are framed in terms of how they work together, to offer workable solutions to the broader operational challenge that the Technology Operational Scenario identifies and characterises.

5. **Demonstrating Workability and Options: Field Technology Showcases.** To demonstrate this innovation's practical potential – actual impact on the ground, for Government decision-makers, against these priorities – the AGNIi team conducts Field Technology Showcase (Field Technology Showcase) in locations representative of those where these priorities are encountered.

   - Hosted by the Pioneer Agency, startups and laboratories are invited to demonstrate how their innovation resolves these pain-points in the field.

   - The Showcases generate assessments for decision-makers on whether, and to what extent, innovation in its current form can resolve these pain-points.

   - The Exemplar Project consequently seek to represent the microcosm of the sphere they are working in. Pioneering Agency, one which deals with the 'microcosm' as a part of their regular functioning.

   - Importantly: Field Technology Showcase do not substitute technology evaluations conducted as part of the public tender process. Instead, they seek to help agency officers expand decision-making options in their quest to engage key priorities.

   - Crucially: Field Technology Showcase seek to support the actual adoption of relevant, effective innovation, by activating five crucial levers of innovation diffusion. First identified by innovation scholar Everett Rogers, in his development of the Diffusion of Innovation curve (or Rogers' Curve): these factors, if demonstrated, drive adoption decisions. Each Field Technology Showcase seeks to demonstrate these.

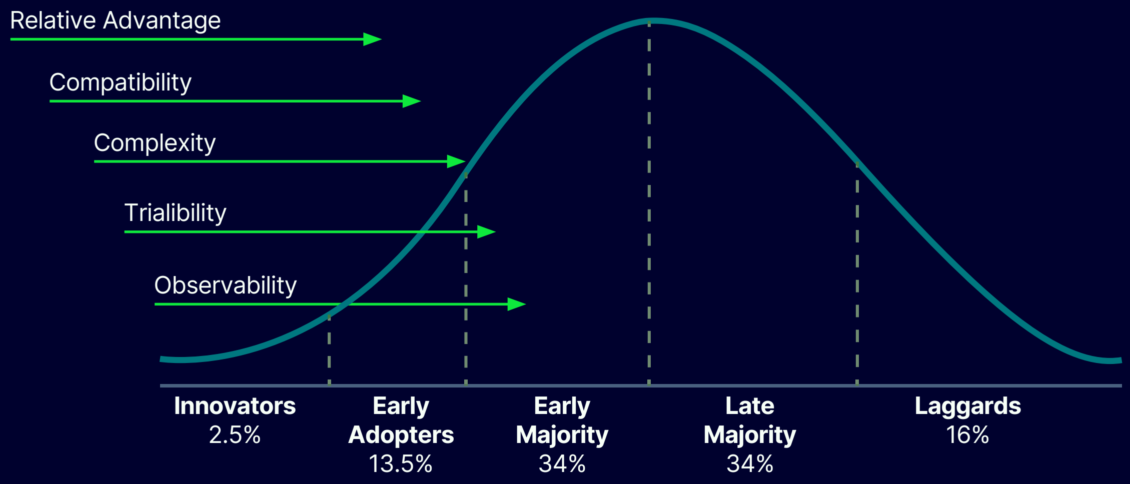
6. **Advice (and supporting analyses) are captured in Technology Advisory Notes:** Supporting specific administrative action to engage and leverage Indian emerging technology within Uttarakhand and across other Himalayan states facing similar challenges, in fulfilling national priorities at scale.

7. **Change Management: Supporting Agencies in Transformation through Innovation.** The Office of PSA's key objective, in its collaborations with agencies engage Indian emerging technology and innovation in answering national priorities – through the collaborative model outlined above. This embrace of innovation, with Office support, involves institutional change: with agencies upgrading their organisational capabilities through technology.

The AGNIi advisory project cycle described above supports this, activating eight change management level.

Box 3

Innovation Diffusion - Roger's Curve^



^ Rogers, Everett M, Diffusion of Innovations. New York, Free Press of Glencoe, 1962. Rogers, Everett M. Diffusion of Innovations.

Table 3

Change Management

Step	Change Management Lever	Collaborative Action	AGNIi Technology Advisory (Workflow Phase)
Step 1	**Establish and identify urgency**	Leadership consultations: Hon'ble Chief Minister, the Director General, UCOST, Himalayan Environmental Studies and Conservation Organisation (HESCO), District Administration aligned to priorities / guidance / values set by them. • Priorities on safeguarding rural communities against climate change • Profile, risk, capabilities of hilly communities: traditional practices, operational models of farming, livelihoods forest and water management • Terrain Analysis: terrain and geography, population distribution, infrastructure, market linkages	Agency Pain-Point Mapping Workshops / Consultations Field Visits
Step 2	**Form guiding coalition of authority**	Collaboration with leadership and field agencies intersecting operational and tactical interests and urgencies. Develop Technology Operational Scenarios with UCOST.	Agency Pain-Point Mapping Workshops / Consultations Field Visits Technology Operational Scenarios
Step 3	**Collaborate to surface Agency vision**	Develop Technology Operational Scenarios via focus group discussions and key informant interviews conducted among community members; and stakeholder consultations with the Chief Minister's Office and state line departments, Pioneer Agency (UCOST), district administration, and civil society organisations like HESCO and BAIF: describing baseline scenarios and target end-state. Develop Technology Stacks: reflecting functional requirements generated by Operational Scenarios. Collaborating with the Chief Minister's Office, Pioneer Agency (UCOST), district administration, civil society organisation like HESCO and BAIF, and rural communities to implement Field Technology Showcases: demonstrating how Indian innovation (representing Stack elements), in realistic field scenarios, delivers target end-state.	Technology Operational Scenarios Technology Stacks Field Technology Showcases

Step	Change Management Lever	Collaborative Action	AGNIi Technology Advisory (Workflow Phase)
Step 4	**Communicate the vision**	Demonstrate Indian innovation providing solutions – and alternatives to conventional decision-making options – in realistic field scenarios. Showcases demonstrated to • strategic leadership (District Magistrate, Heads of Line Departments, Community members) • representing solutions answering interests and imperatives across decision-making tiers.	Field Technology Showcases
Step 5	**Enable decision-makers to act on that vision**	• Evaluation (e.g., via UCOST and District Administration) of Field Technology Showcases: supporting further administrative action. • TAN supports scaled action in Uttarakhand and across other Himalayan states.	Field Technology Showcases Technology Advisory Notes
Step 6	**Build momentum via successful short-term action**	Advising the stakeholders like UCOST, District administration and the office of the Chief Minister for technology pilots. Formation of a Himalayan states Innovations committee with relevant members – AGNIi, UCOST, District Administration, etc. .	Field Technology Showcases Follow up meetings
Step 7	**Consolidate improvements for further change**	Feedback delivered from evaluations to Stack innovators (on product feature sets), UCOST, district administration and AGNIi (on technology functioning vs. Technology Operational Scenarios)	Technology Operational Scenarios Technology Stacks Technology Advisory Notes Field Technology Showcases
Step 8	**Support institutionalisation of new approaches**	Supporting administrative action .	Technology Advisory Notes

Part B : Climate Adaptive Water Management

SECTION 2

India's Vulnerability to Climate Change and Need for Adaptation

India is the third most vulnerable country to climate change impacts[7], with various regions already experiencing the adverse effects of extreme weather events such as heatwaves, floods, droughts, and cyclones. With a 1.4 billion population[8], 7500km vast coastline[9], and 58 per cent of the population with agricultural dependence[10], India is particularly susceptible to climate change.

7 XDI Gross Domestic Climate Risk, https://xdi.systems/xdi-benchmark-gdcr/

8 World Bank: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=IN

9 Achieving Aatmanirbharta in Agriculture, Nov 2022: https://pib.gov.in/FeaturesDeatils.aspx?NoteId=151185&ModuleId%20=%202#:~:text=It%20accounts%20for%20around%2019,is%20dependent%20on%20the%20sector.

10 National Portal of India: https://www.india.gov.in/india-glance/profile#:~:text=The%20total%20length%20of%20the,Nicobar%20Islands%20is%207%2C516.6%20km.

India is highly vulnerable to climate change with 65 percent of its geography being drought prone, 12 per cent being flood prone, and 8 percent being susceptible to cyclones[11]. Over the past century, maximum temperatures in India have increased by 0.71 degree Celsius and mean minimumtemperatures by 0.27-degree celsius[12]. In the pre-monsoon season, the frequency of hot days shows a gradual increase, while the frequency of chilly days shows a noticeable decrease[13]. As per Indian Meteorological Department, number of heatwaves in India has increased from 413 over 1981-1990 to 600 over 2011-2020. Increasing heatwaves, which can cause heat exhaustion, dehydration, and even death, are a common occurrence in the country.

Since 2005, extreme events have increased by almost 200 per cent in frequency and intensity in India[14]. According to the latest report by United Nation's IPCC, the country has already lost 16 percent of its per capita gross domestic product because of rising sea levels and changing monsoon patterns.[15]

According to the Climate Transparency Report, 2022, India lost $159 billion or 5.4 per cent of its gross domestic product, in the service, manufacturing, agriculture, and construction sectors due to extreme heat in 2021. 167 billion potential labour hours were lost, a 39 per cent increase from 1990-1999. Extreme events such as flash floods, cyclones, floods, and landslides caused crops damage in over 36 million hectares. This resulted in a $3.75 billion loss for farmers in the country, between 2016–2021. [16]As per the Ministry of Agriculture, hydro-meteorological calamities, including heavy rainfall and floods, have damaged 33.9 million hectares of India's cropped area between 2015-16 and 2021-22[17]. As per 2018 report by NITI Aayog, 50 per cent of the springs in the Indian Himalayan Region are drying up. This has further added to the drudgery of women since they need to manually carry water from springs located at other villages during the lean season.[18]

Impacts of Climate Change in the Indian Himalayan Region

Climate change poses a particular threat to the Indian Himalayan Region due to its unique geography, fragile ecosystem, and reliance on natural resources. The Indian Himalayan Region is an arc of 2,500

11 Project: Climate Smart Actions and Strategies in North Western Himalayan Region for Sustainable Livelihoods of Agriculture-Dependent Hill Communities, Implementing Entity: National Bank for Agriculture and Rural Development (NABARD)

12 Project: Climate Smart Actions and Strategies in North Western Himalayan Region for Sustainable Livelihoods of Agriculture-Dependent Hill Communities, Implementing Entity: National Bank for Agriculture and Rural Development (NABARD)

13 Project: Climate Smart Actions and Strategies in North Western Himalayan Region for Sustainable Livelihoods of Agriculture-Dependent Hill Communities, Implementing Entity: National Bank for Agriculture and Rural Development (NABARD)

14 Abhinash Mohanty and Shreya Wadhawan, 2010. Mapping India's Climate Vulnerability, A District Level Assessment, CEEW

15 Simrin Sirur, 2022. What the latest IPCC report on climate vulnerability & adaptation means for India, Article in The Print

16 Climate Transparency Report 2022, https://www.climate-transparency.org/g20-climate-performance/g20report2022

17 https://india.mongabay.com/2022/11/in-india-climate-impact-on-agriculture-is-already-a-reality-now/

18 https://www.downtoearth.org.in/news/water/crisis-in-the-himalayas-nearly-50-perennial-springs-in-the-region-have-dried-up-61482

km that traverses 13 states and UTs of India. It is inhabited by more than 52 million people, about 5 percent of India's population, and covers 18 per cent of the geographical area of the country.[19]

In the last decade, several climate change-related disasters have occurred in the Indian Himalayan Region, highlighting the urgent need for mitigation and adaptation measures. This region has witnessed various floods, landslides, and avalanches. The rivers of the Himalayas are some of the most important rivers in the world. The three great rivers of India – the Indus, the Ganges and the Brahmaputra collectively provide close to 50 per cent (320 km^3) of the total country's utilizable surface water resources (690 km^3). Contribution from snow and ice melt to the total annual river discharge has been estimated as 60 per cent, nine per cent and 21 per cent for Indus, Ganga and Brahmaputra basins, respectively.[20]

There are about 15,000 glaciers which prominently include Gangotri, Yamunotri, Khumbu, Langtang, Zemu among others. Since glaciers are contributing significantly to river flow, the impact of climate change on glacier is the most important from the point of view of water availability and ecosystem balance. Recent studies based on satellite imageries also indicate a continuing retreat of glaciers in Himalayas (refer Box 4).[21]

19 Status of Ecosystem Health In The Indian Himalayan Region, 2019

20 Dr. Shresth Tayal, 2019. Climate Change Impacts On Himalayan Glaciers And Implications On The Energy Security Of The Country

21 Dr. Shresth Tayal, 2019. Climate Change Impacts On Himalayan Glaciers And Implications On The Energy Security Of The Country

Box 4

Retreating Glaciers of the Himalayas

East Rathong Glacier

Retreat Rate (RR) : **15.1m yr-1**

Years : 1962-2011

Samudragupta Glacier

Retreat Rate (RR) : 18.4m yr-1

Years : 1963-2004

Gangotri Glacier

Retreat Rate (RR) : 19.9 +/- 0.3m yr-1

Years : 1965-2006

Dokriani Glacier

Retreat Rate (RR) : 16.6m yr-1

Years : 1962-1995

A region wide study conducted on seven of glaciers distributed across different basins shows retreating pattern for almost 77 per cent of the glaciers. Both, number of retreating glaciers and the extent of retreat are reported to be highest for western Himalayan glaciers.[22].

The Indian Himalayan Region has experienced an increase in maximum temperature up to one degree Celsius. Winter precipitation has declined over the years with shorter and warmer winters and reduced snowfall. The region has also experienced changed precipitation conditions such as reduced winter rains, delayed onset of monsoon rains, and increased frequency of intense rainfall events. These intense rainfall occurrences are coupled with sloping terrain and loose soil, deforestation, resulting in soil erosion, land degradation, and loss of fertile soil[23]. According to the IPCC, climate change impact in Indian Himalayan Region will range from glacial melt to reduced genetic diversity of species leading to increased flooding affecting water resources, within the next few decades.

Climate Adaptive Water Management: A Conceptual Primer

Water is essential to the sustainable functioning of ecosystems and human socioeconomic activities. Water enables agriculture, food production, energy generation, domestic and industrial use. The aquatic ecosystem also has a crucial role to play by providing essential services like flood mitigation, water purification, nutrient cycling among many others. Continued delivery of these ecosystem services is essential for the proper functioning and maintenance of ecosystems. Climate change is already affecting water access for people across the globe, causing severe droughts and floods.

India is currently facing a significant challenge in the form of fast-depleting and deteriorating water resources. Groundwater levels are receding at an alarming rate (almost 63 per cent of India's districts are threatened by falling groundwater levels[24]) in many regions of the country, resulting from over-extraction and changing seasonality and intensity of rainfall. Additionally, the impact of constantly rising temperatures and climate change in India is likely to be particularly severe on the economy, given the country's heavy reliance on agriculture. These factors are compounded by water scarcity and population growth, which are increasing demands for food, fresh water, and energy. Currently, the per capita availability of fresh water is estimated to be around 2,000 m^3 per year, but this is expected to drop to 1,000 m^3 by 2025[25] due to population growth and a lack of additional water resources.

Keeping this in mind, there is a critical need for adoption of adaptive strategies such as water harvesting, groundwater replenishment, modernization of irrigation facilities, desalination, and wastewater reuse, increase water storage capacity, among others. Deployment of indigenous technologies can also play a crucial role in helping India better manage its water resources in the face of rising climate change impacts. Around 74 per cent of natural disasters between 2001 and 2018

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22 Dr. Shresth Tayal, 2019. Climate Change Impacts On Himalayan Glaciers And Implications On The Energy Security Of The Country

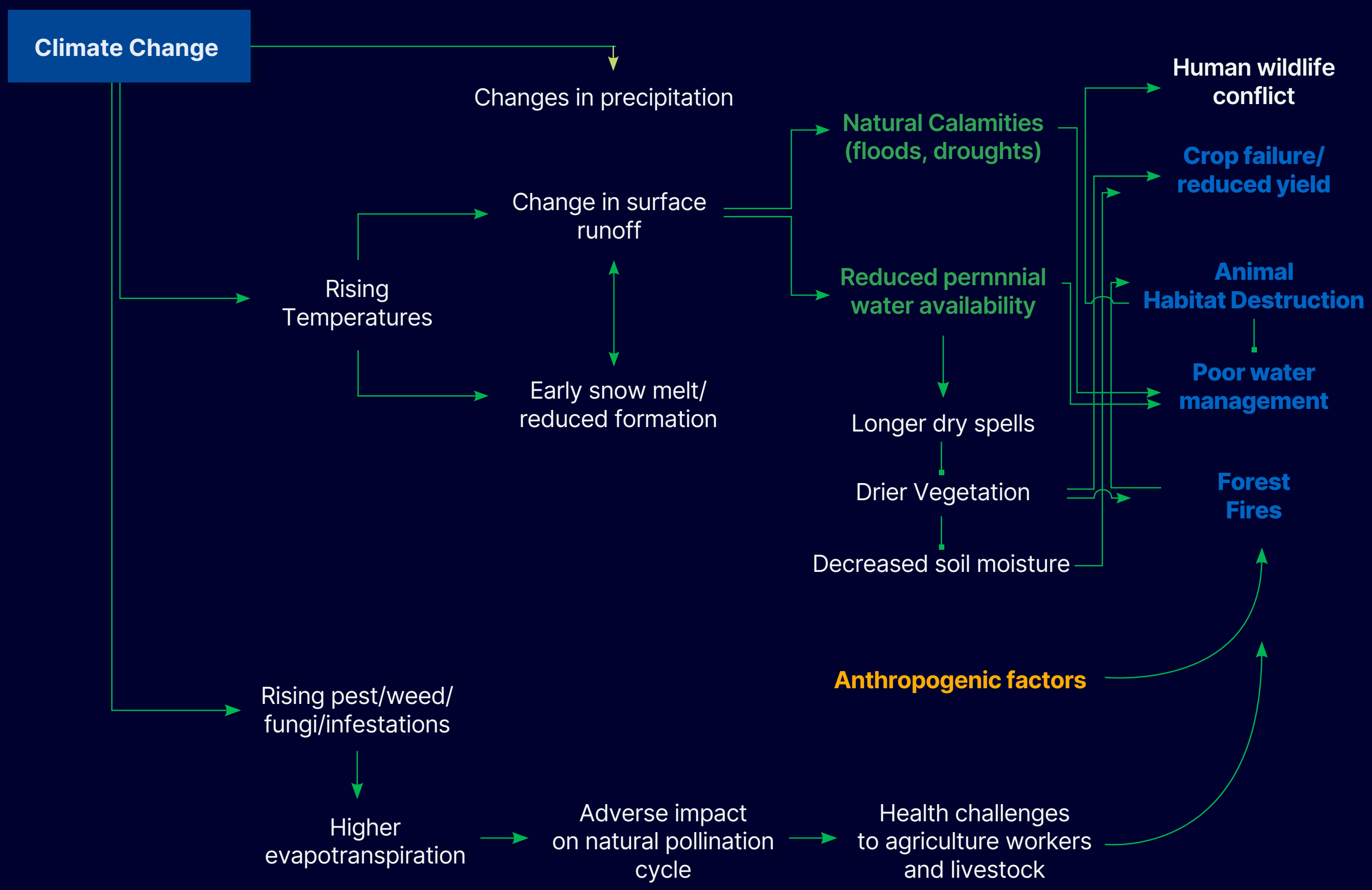
23 Project: Climate Smart Actions and Strategies in North Western Himalayan Region for Sustainable Livelihoods of Agriculture-Dependent Hill Communities, Implementing Entity: National Bank for Agriculture and Rural Development (NABARD)

24 https://blogs.worldbank.org/endpovertyinsouthasia/india-seeks-arrest-its-alarming-decline-groundwater

25 https://globalwarming.com/articles/climate-change-and-water-scarcity-in-india/ (Last Accessed on April 12, 2023)

Box 5

Impact Map of Climate Change on agriculture and water management



around the globe were water-related, including droughts and floods[26]. These extreme weather events are making water scarcer, more unpredictable, or more polluted. These impacts throughout the water cycle threaten people's access to water and sanitation, biodiversity etc.

The above impact map shows the direct and indirect interlinkages between climate change and the subsequent effects on agriculture and water resources.

- Rapid melting of glaciers and ice caps which feed many great rivers will lead to volatility in the cryosphere. This can affect the regulation of freshwater resources for people in lowland areas. Early snow melting due to rising temperatures leads to an increase in instances of floods, which can lead to water contamination, adversely affecting water quality.

- Drying up of perennial water sources due to change in surface run-off leads to high dependence on groundwater leading to increased water stress.

- Reduced availability of water due to drying up perennial water sources can also lead to poor water management practices in turn affecting water availability for households, industrial and agricultural purposes.

- Rising instances of wildfires lead to destruction of vegetation and tree cover which in turn exacerbates soil erosion and reduces groundwater recharge, increasing water scarcity and food security.

Strategic Factors Defining Technology Adoption : Scaled impact against a scaled challenge

This TAN describes how emerging technology and innovation – capabilities of which exist in India – can make water management in the Himalayan states climate resilient and help the rural communities adapt to the challenges posed by climate change. Developed in collaboration with UCOST, the TAN engages a scaled challenge.

The Himalayan states due to their mountain topography and higher than global average global warming are highly vulnerable on a continuum to the impacts of climate change[27]. The United Nations Framework Conventions on Climate Change defines vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity. Therefore, adaptation would also include any efforts to address these components."[28]

26 https://www.unicef.org/stories/water-and-climate-change-10-things-you-should-know (Last Accessed on April 12, 2023)

27 Department of Science and Technology 'Climate Vulnerability Assessment for the Indian Himalayan Region Using A Common Framework' available at https://dst.gov.in/sites/default/files/IHCAP_Climate%20Vulnerability%20Assessment_30Nov2018_Final_aw.pdf (Last accessed on March 29, 2023)

28 UNFCCC available at <https://www4.unfccc.int/sites/NAPC/Pages/glossary.aspx#:~:text=Vulnerability%20The%20degree%20to%20which,including%20climate%20variability%20and%20extremes.> (Last accessed March 22nd 2023)

Technology intervention answering its challenges – in use-case selection and solution deployment – be similarly scaled in impact.

To elaborate, the vulnerability of the Himalayan communities emanates from their 'sensitivity' i.e., 'susceptibility to harm' and 'lack of adaptive capacity' i.e., lack of capacity to adapt and cope[29]'. This sensitivity and lack of adaptive capacity of the Indian Himalayan Region primarily stems from the following factors:

- Fragile mountain ecosystems, where evidence suggests that the Himalayan region will experience higher level of climate change and its impact on both biophysical, and social and economic systems.

- High dependence on natural water sources, such as springs and rainwater for household needs.

- Climate sensitive rain-fed agriculture being the primary source of livelihood for hill communities.

- Infrastructural constraints pertaining to water distribution systems, water quality systems, and pumping infrastructure.

Development of adaptive capacities can play an instrumental role in reducing the susceptibility of the region to harm and making water ecosystem of the Indian Himalayan Region less vulnerable to the impacts of climate change. The technology stack will help achieve adaptability given a unique strategic context of the Indian Himalayan Region in the following manner (refer Table 4).

29 Department of Science and Technology 'Climate Vulnerability Assessment for the Indian Himalayan Region Using A Common Framework' available at https://dst.gov.in/sites/default/files/IHCAP_Climate%20Vulnerability%20Assessment_30Nov2018_Final_aw.pdf (Last accessed on March 29, 2023)

Table 4

Strategic Factors defining Technology Adoption

	Strategic Factor	Functional Implication	Technological Response: Consequences for Technology Stack Composition
1	**Hilly terrain and absence of plain and continuous agricultural land, which necessitates terrace farming.** • Infrastructural constraints for setting of water distribution and quality systems • Prevalence of flood irrigation • Implications for irrigation intensity, drinking water availability and quality	Real time monitoring of water resources along with assessment of various parameters that fall under the category of a water quality test aided with an automated water usage tracking and delivery system	Water quality: Sensors to detect physical, chemical and biological parameters for water sources Cloud based platform for online water management advisory, Mobile optimised web-based dashboards for advisory on efficient water management according to the location inputs from users IoT enabled water meters and pump controller with ROM to adjust for power losses
2	**High dependence on natural water sources such as springs and rainwater** • Implications for drinking water availability and quality for individual/ household, farming, and industrial needs	Using global multisource database to map and analyse existing water sources to identify rejuvenation potentials and keeping a real time check on the usage cycle of the same	Hyperspectral Imagery to collect hydrogeological maps, geophysical data, thermal data, gravitational field data, and magnetic fields data Geographic Information Systems (GIS) that blends the power of a map with the power of a database to allow people to create, manage and analyse information, particularly information about location AI to ingest; process; & normalise data points and provide analysis to identify, map, & analyse water sources IoT enabled smart water meters to track usage of water at a household level

Source: Authors analysis based on field work in Champawat, Uttarakhand in November and December 2022, stakeholder interactions with the state government, district administration, and civil society organisations like HESCO and BAIF with subsequent technology scouting

Strategic Context

SECTION 3

Pain Points: Surfaced through Fieldwork

Drying of natural water springs – Mountain springs are the primary source of water for most rural households in the Himalayan region. Springs provide stable habitat conditions as they often have high quality water and low seasonal thermal variability. Springs are also a natural part of complex ground-water dependent ecosystems that vary in terms of both the quantity and quality of the water. For example, Dharas, locally known mountain springs in the Himalayan region, are the natural discharges of groundwater from various aquifers. Rainwater finds its way into underground caves called aquifers that store water. Each aquifer has a recharge zone, where water seeps into the ground and recharges the spring. Climate change impacts, resulting in prolonged dry weather, give only a limited amount of time for water to seep in, which reduces recharges and loss of spring. According to a report released by Niti Aayog in 2018, about half of the perennial springs [30] (Out of a total of five million springs across India, three million are in the Himalayan Region alone) have dried up in the Himalayan region. This is directly affecting thousands of villagers that depend on natural spring water for domestic and livelihood needs such as drinking water and irrigation.

Bringing water from down the hill slopes to up the hill where families usually reside – The Himalayan Region heavily depends on water resources for food, irrigation, sanitation, and industry, as well as for the functioning of many important ecosystem services. Many major rivers such as the Ganges, Indus and Brahmaputra originate from snow and glacier-covered high mountains and provide adequate water supply. The undulated topography and terrain render these rivers inaccessible to a substantial portion of the population. Due to climate change impacts, leading to drying up of natural springs and shortage of water have placed an increasing burden on mountain communities, especially women. Increase in instances of natural disasters such as floods and droughts have led to loss of property and lives due to water-induced natural hazards. Climate Change impacts have certainly exacerbated the uncertainty about the future water availability and water security.

Lack of irrigation mechanisms for Farmlands - The Himalayan region is facing a dual challenge of the lack of proper irrigation mechanisms and the adverse impacts of climate change. Due to the region's rugged terrain and limited land availability, conventional irrigation methods are not easy to implement, and the high altitude and low rainfall make it difficult to grow crops without sufficient irrigation. However, the impact of climate change has further exacerbated this problem by altering the precipitation patterns, melting glaciers, and reducing the snowpack, affecting the water supply for irrigation. As a result, farmers are struggling to cultivate their crops, leading to reduced yields, food shortages, and economic instability. In regions such as Champawat in Uttarakhand, availability of water near households enables cultivation of vegetables such as Shimla Mirch (Capsicum), Cabbage, and Brinjal. Availability of water also takes care of the water needs and fodder, thus preventing the forest grazing of animals. Thus, innovative, and sustainable irrigation mechanisms need to be implemented in the region to enhance water conservation and improve crop yield.

Inability to utilize rainwater for drinking or farming needs – The adverse effects of climate change seen in the form of changing precipitation patterns resulting in prolonged dry spells or intense rainfall, have led to drying up natural springs in the Himalayan region. Additionally, the region's high altitude and unique geography make it particularly difficult to construct large water storage structures. These factors have consequently led to an inability to utilize rainwater for drinking or farming needs. Rainwater harvesting is currently not a pervasive activity in the region, exacerbating the challenge of utilizing rainwater. These challenges have severe implications for the livelihoods and well-being of the people of the region.

30 https://www.niti.gov.in/index.php/sustainable-development-indian-himalayan-region

Table 5

Pain Point mapping for Climate Adaptive Water Management in the Indian Himalayan Region

S.No	Pain Point	Operational Scenarios	Use Case	Functional Requirements
1	Drying of natural water springs	**Impact of changing weather conditions** • The natural water springs have dried up due to change in weather conditions and lack of preservation efforts **Geography** • The undulated topography and terrain render substantial number of natural springs and water reservoirs inaccessible. • Naturally, water infrastructure in the forests and otherwise includes Naulas & Gadheras. Drying of the water springs renders the Naulas redundant. **Technology Baseline** • Both the government and BAIF have undertaken initiatives for spring rejuvenation. • The existing Naulas are leveraged and re-connected to the springs. • Check dams to trap the water from the springs in the forests are made from the natural stones and blocks, indigenous to the ecosystem around	Spring/Aquifer mapping and tracking	Flow Rate Sensors: These sensors measure the flow rate of the water in the spring, providing information on the volume of water available. Temperature Sensors: These sensors measure the temperature of the water in the spring, providing information on the thermal characteristics of the spring. Level Sensors: These sensors measure the water level in the spring, providing information on the water availability and flow rate. Turbidity Sensors: These sensors measure the clarity of the water in the spring, providing information on the presence of suspended particles and organic matter in the water. Water Pressure Sensors: These sensors measure the water pressure in the spring, providing information on the water flow rate and the water storage capacity of the spring. Chemical Sensors: These sensors measure specific chemical parameters in the water, such as nitrates, phosphates, and other pollutants, providing information on the water quality and environmental impact of the spring

S.No	Pain Point	Operational Scenarios	Use Case	Functional Requirements
2	Lack of irrigation mechanisms for Farmlands	**Importance of Water Availability** • Availability of water allows cultivation of vegetables like Shimla Mirchi, Cabbage Brinjal • Availability of water near the household also takes care of the water needs & fodder of animals thus preventing the forest grazing of the animals • Scarcity of water creates drudgery for women & girls, who travel long distance for fulfilling daily water needs **Impact of changing weather conditions** • Unpredictable weather patterns which majorly includes erratic rainfall: short spells of high intensity • Scarcity of water and drying up of water natural reservoirs • The undulated topography and terrain render substantial number of natural springs and water reservoirs inaccessible • Natural water springs have dried up due to change in weather conditions and lack of preservation efforts **Geography** • Unavailability of large tracts of plain land • Collective Action Groups • Water committees operate and maintain the solar lift pumps **Technology Baseline** • Rainwater harvesting not a pervasive activity • Solar lift irrigation pumps installed with BAIF	Water efficient irrigation	IoT Enabled, timer-based pump controller which interfaces with all motors. It connects with the starter & operates the pump. It will switch the pump ON & OFF at the given / programmed time daily Water nutrient analysis: Helps determine the nutrient content of the water being used for irrigation. Irrigation efficiency: Allows for the application of only the necessary amount of water and nutrients, reducing waste and increasing efficiency. Crop growth and yield: Optimizes the nutrient content of the water to support healthy crop growth and improve yields. Water conservation: Supports the efficient use of water resources, reducing overall water usage and conserving this valuable resource. Fertilizer usage: Enables the precise application of fertilizer, reducing overuse and limiting potential environmental impact. Cost savings: By optimizing water and fertilizer usage, can reduce costs associated with irrigation and fertilizer application.

S.No	Pain Point	Operational Scenarios	Use Case	Functional Requirements
		• Dust and bird dropping reduce the efficiency of solar panels Villagers need to be sensitized about the operations and efficiency parameters of the technology		

User Persona Mapping

User persona mapping refers to the process of collating and segmenting information about potential decision makers and technology adopters[31]. The key objective of the process is to create archetypes of potential technology adopters and decision makers pertaining to procurement and financing. The creation of decision maker and technology adopter archetypes helps in making the process of technology scouting precise. This feeds into the larger goal of ensuring technology adoption by bringing the technology that solves the user problem most effectively. This section (refer Table 7) presents details of user persona mapping at the three different tiers - strategic, operational, and field, which involves decision makers and potential adopters for each layer in the climate adaptive agriculture technology stack.

31 Please note that in certain scenarios the decision makers and adopters of technology can be different.

Table 6

User Persona Mapping for Efficient Water Management

Decision-Making Tier	• Strategic • State Administration: Represented by UCOST (Nodal Agency for Uttarakhand @ 25) under the Department of Information and Science Technology, Government of Uttarakhand	• Operational • District Administration: District Magistrate | Line Departments | DFO | Allied Govt. Agencies	• Field • Gram Panchayat | Van Panchayat | Collective Action Groups | End adopters
Role and Key Priorities	• **Role:** • Facilitate deployment of innovative technological solutions across that help to effectively manage the available water resources of the state and balance the trade-off between the water needs of agriculture, industries, and households • Designing procurement and technology funding mechanisms • Key Priorities: Uttarakhand@25, Adarsh Champawat, science, and technology led development of Uttarakhand; effective water management in the state to ensure that citizens and those engaged in agriculture and other industries are not afflicted by water scarcity; natural spring conservation and rejuvenation efforts	• **Role:** • Incorporating mechanisms to deal with the impacts of climate change on water management for individual/ household purposes and farmland needs via district development plans • Operationalise procurement; sanction funds; Capacity building of local communities • Key Priorities: Adarsh Champawat; balancing the water supply and demand in the district for differential purposes, restoration of water table in the district, and rejuvenate natural water springs in the district	• **Role:** • Delivery & adoption of the technology for climate adaptive water management both for individual/ household purposes and farmland requirements • Funding and procurement; Awareness about modern technologies; Change Agents; Capacity building of local communities • Key Priorities: Availability of clean drinking water at the household level; Availability of sufficient water for irrigation purposes
Background	• Scarcity of water is a reality of the Uttarakhand hills. Ensuring water availability to different users (agricultural, industrial, and households) is an important priority for the strategic and operational tiers of stakeholders. • Similarly, given water scarcity, households also face trade-offs in water utilisation for farmlands and household purposes.		

Attitudes and Interests	• The administration understands the importance of leveraging emerging technologies for climate adaptive water management in hilly terrain. • Aligning initiatives of the district administration with the vision of the Chief Minister and national priorities.	• The district administration understands the importance of efficient water management and wants to resolve the problem of water shortages faced by the hill communities. • The district administration expressed that technological interventions for water management are required at both household and industrial level. • The district administration expressed concerns regarding the costing of smart pumps that detect water usage quantum.	• Representatives expressed their interest in adopting smart water pumps which are cost effective and address the problem of power cuts.
Behaviour and Decision Triggers	• The administration wants to regulate the water usage for industrial usage, household consumption as well as farming. • Their focus is to establish a balance between emerging technologies & frugal innovations which would facilitate faster adoption. • The administration focuses on solutions which are scalable across the state	• District Administration expressed concerns regarding the costing of smart water pumps that monitor usage against sanctioned limits. • The administration concurred that the smart water pumps could be deployed for group of three-four households given the costs involved	• Representatives were of the view that the smart water pumps would be useful for creating efficient irrigation systems for a group of farms at lower cost. • Representatives highlighted that the water usage monitoring pumps are expensive for individual adoption
Functional Requirements from Technology	• Portable smart technology solutions that can help keep track on the water usage of industrial players in the state. • Cost-effective solutions that can help rural communities engaged in agriculture to conservatively use water during flood irrigation of terraced slopes. • Possibility of leveraging the data generated through smart platforms for implementing	• District administration is looking for smart water pumps which are aligned to the needs of areas with substantial power-cuts. • The administration is looking for tamper-proof sensor-based pumps to monitor industrial water usage. • Possibility of leveraging the data generated through smart platforms to check for over-exploitation by certain users.	• Simple and not expensive technology aligned to the needs of areas with substantial power-cuts

Table 7

User Persona Mapping for Efficient Water Quality Management

Decision-Making Tier	• Strategic • State Administration: Represented by UCOST (Nodal Agency for Uttarakhand @ 25) under the Department of Information and Science Technology, Government of Uttarakhand	• Operational • District Administration: District Magistrate | Line Departments | DFO | Allied Govt. Agencies	• Field • Gram Panchayat | Van Panchayat | Collective Action Groups | End adopters
Role and Key Priorities	• **Role:** • Facilitate deployment of innovative technological solutions across that help to effectively manage the available water resources of the state and balance the trade-off between the water needs of agriculture, industries, and households • Designing procurement and technology funding mechanisms • Key Priorities: Uttarakhand@25, Adarsh Champawat, science, and technology led development of Uttarakhand; effective water management in the state to ensure that citizens and those engaged in agriculture and other industries are not afflicted by water scarcity; natural spring conservation and rejuvenation efforts	• **Role:** • Incorporating mechanisms to deal with the impacts of climate change on water management for individual/ household purposes and farmland needs via district development plans • Operationalise procurement; sanction funds; Capacity building of local communities • Key Priorities: Adarsh Champawat; balancing the water supply and demand in the district for differential purposes, restoration of water table in the district, and rejuvenate natural water springs in the district	• **Role:** • Delivery & adoption of the technology for climate adaptive water management both for individual/ household purposes and farmland requirements • Funding and procurement; Awareness about modern technologies; Change Agents; Capacity building of local communities • Key Priorities: Availability of clean drinking water at the household level; Availability of sufficient water for irrigation purposes
Background	• Scarcity of water is a reality of the Uttarakhand hills. Ensuring water availability to different users (agricultural, industrial, and households) is an important priority for the strategic and operational tiers of stakeholders. • Similarly, given water scarcity, households also face trade-offs in water utilisation for farmlands and household purposes.		

Attitudes and Interests	• The administration understands the importance of leveraging emerging technologies for climate adaptive water management in hilly terrain. • The administration focuses on ensuring quality water availability across the state. • Aligning initiatives of the district administration with the vision of the Chief Minister and national priorities • The administration focuses on solutions which are scalable across the state.	• The administration wants to bring down the time and cost expended by the farmers, especially small & marginal in ascertaining water quality parameters which has implications for crop yield and pisciculture. • District administration wants to test the water in natural reservoirs like springs which would aid the spring rejuvenation efforts. • District Magistrate has expressed interest to shift towards the smart & portable water sensing technologies.	• Representatives expressed interest in portable water testing technologies. • Representatives were of the view that some units of the portable water testing kits can also be bought at their level, which can then be utilized by certain trained community members to perform tests for farmers in two-three villages.
Behaviour and Decision Triggers	• Uttarakhand is state with hilly terrain with many small and marginal farmers and hence the administration is keen to adopt cost effective decentralised solution. • Their focus is to establish a balance between emerging technologies & frugal innovations which would facilitate faster adoption. • The administration focuses on solutions which are scalable across the state.	• The low-cost of water testing solutions are preferred by the administration. • Portable & instant water testing mechanism are highly sought for by the administration as it reduces the time & cost expended by rural communities as well as administration.	• Representatives' interests stemmed from the fact that farmers at present do not engage in testing as they are marginal and small. Such technologies will empower 'the last mile at the last mile' and help improve output from landholdings.
Functional Requirements from Technology	• Simple, portable, and cost-effective technologies that can be utilized by citizens to check water quality. • Smart systems that can also help the state gather data on water quality and leverage the same to ensure quality water to citizens.	• Simple, portable, and inexpensive technology that lucidly informs adopters of the quality of their water so that corrective actions can be taken accordingly. • Smart systems that can also help the state gather data on water quality and leverage the same to ensure quality water to citizens.	• Simple and inexpensive technology that lucidly informs adopters of the steps they need to take to enhance the quality of the water goes beyond monitoring to advisory.

Table 8

User Persona Mapping for Spring/aquifer Mapping and Tracking

Decision-Making Tier	• Strategic • State Administration: Represented by UCOST (Nodal Agency for Uttarakhand @ 25) under the Department of Information and Science Technology, Government of Uttarakhand	• Operational • District Administration: District Magistrate | Line Departments | DFO | Allied Govt. Agencies
Role and Key Priorities	• **Role:** • Facilitate deployment of innovative technological solutions that can help in discovering new perennial water sources and help in rejuvenation of old water springs • Designing procurement and technology funding mechanisms • Key Priorities: Uttarakhand@25, Adarsh Champawat, science, and technology led development of Uttarakhand; Spring rejuvenation and conservation efforts; ensuring availability of quality water in the state for drinking, agricultural, and industrial purposes	• Role: • Incorporating mechanisms to deal with the impacts of climate change on water management for individual/household purposes and farmland needs via district development plans • Operationalising procurement; Sanctioning Funds; Capacity building of local communities • Key Priorities: Adarsh Champawat; effective water management; water table rejuvenation; rejuvenation of natural water springs
Background	• Scarcity of water is a reality of the hills due to the drying of natural water springs, which cater to the water needs of a significant percentage of the hilly region population. Hence ensuring quality water availability to different users (agricultural, industrial, and households) is an important priority.	
Attitudes and Interests	• The administration understands the importance of leveraging emerging technologies for climate adaptive water management in hilly terrain. • The administration intends to address the state-level issue of drying up of perennial water sources. • Aligning initiatives of the district administration with the vision of the Chief Minister and national priorities.	• The administration understands that the district grapples with persistent drying up of natural water reservoirs because of climate change. • They are willing to leverage emerging technology for rejuvenation of natural water reservoirs like springs, Naulas

Behaviour and Decision Triggers	• Non-invasive technologies for mapping and analysing perennial water sources including aquifers would be less disruptive for the already sensitive ecosystem of the Himalayas. • The administration focuses on solutions which are scalable across the state.	• The administration is looking at emerging technologies solutions which could be integrated with the existing digital dashboard developed in coordination with Indian Space Research Organisation (ISRO). • The administration is exploring cost effective yet accurate mechanisms to map the natural water springs as well as perennial water sources.
Functional Requirements from Technology	• Using global multisource database to map and analyse existing perennial water sources across the state to identify rejuvenation potentials. • Assessing the qualities, flow rate and sustainability of the mapped water sources. • GIS that blends the power of a map with the power of a database to allow people to create, manage and analyse information, particularly information about location. • Monitoring and tracking the usage of the identified water sources	• Using global multisource database to map and analyse existing perennial water sources to identify rejuvenation potentials • Assessing the qualities, flow rate and sustainability of the mapped water sources • GIS that blends the power of a map with the power of a database to allow people to create, manage and analyse information, particularly information about location • Monitoring and tracking the usage of the identified water sources

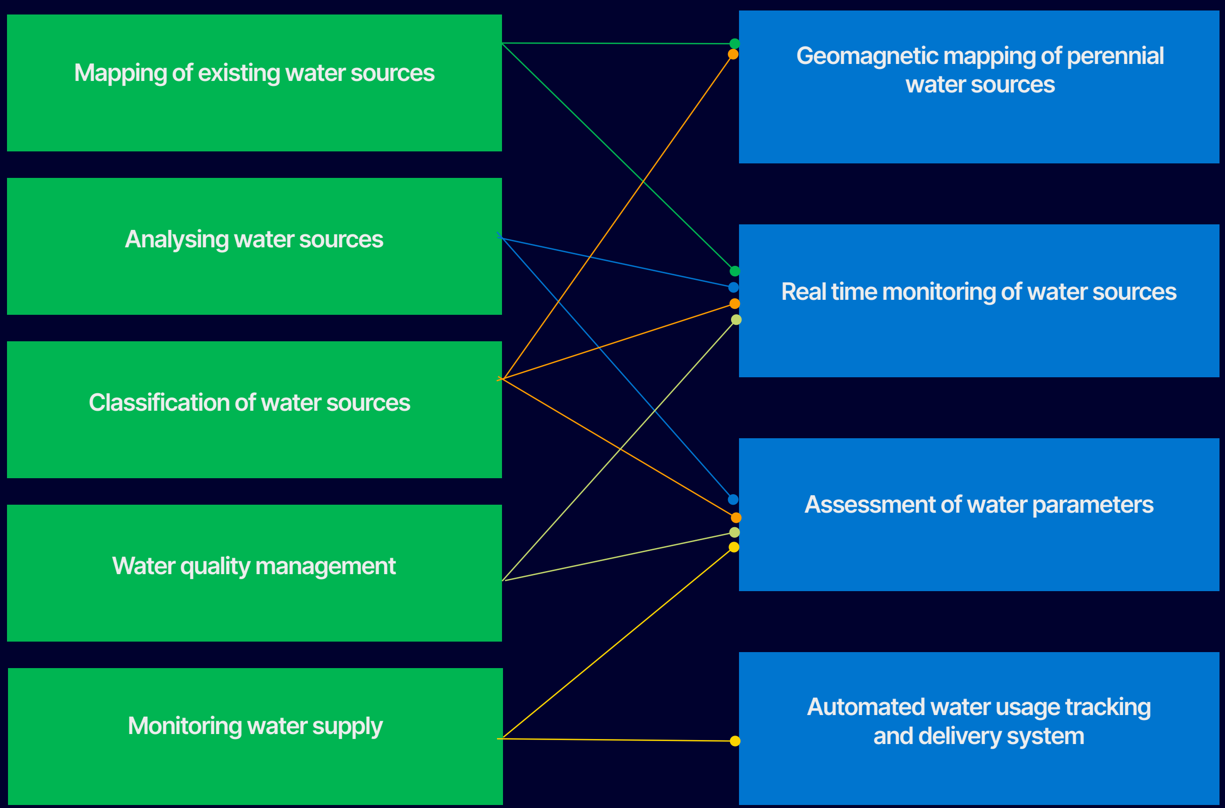
Need Feature Mapping

The pain-points and operational scenarios for climate-adaptive water management were surfaced via field work, which comprised focused group discussions and key informant interviews with relevant stakeholders (representatives of the state administration, district administration and rural communities).

Subsequently, the pain-points and operational scenarios were translated into technology functional requirements, which were utilised for scouting relevant innovators. The figure (refer Box 6) maps the pain-points and needs of end adopters with relevant technology use cases.

Box 6

Need Feature Mapping for Climate Adaptive Water Management for Indian Himalayan Region




Dhara Shakti
धरा शक्ति

Technology Stack

SECTION 4

The need for technological intervention is of utmost importance for successful implementation of climate adaptive water management practices. Based on the above-mentioned need-feature mapping, technological capabilities that have the capacity to address the needs, and their relevance to the end-user are mapped in the following figure (refer Box 7) and matrix (refer Table 8-11). The various layers of the matrix are:

- Feature and its description,
- technological capabilities and the specific layers that have the said features,
- relevance in terms of the end adopter to tie the need with the end user.

Box 7

Technology Stack for Climate Adaptive Water Management

	Assess	Analyse	Build
Sensors	Evapotranspiration (ET) Controllers Weather parameters captured: temperature, wind, solar radiation, humidity	pH, conductivity, turbidity, temperature, dissolved oxygen sensors, Discharge rate sensors, Moisture sensing, Ultrasonic sensors	Level Analyser
AI	Mapping of springs, streams, water catchment areas, and river channels	Water usage monitoring system	3D Models
Other technologies			Real–Time Monitoring and Control System

	Improve	Access
Sensors	pH, conductivity, turbidity, temperature, dissolved oxygen sensors, Discharge rate sensors Monitor, compare, evaluation of water usage	Monitor water usage
AI	Optimum asset utilisation, Local and Remote Control, Predictive Maintenance	Smart tamper detection, compare, evaluation of water usage
Other technologies		Leakage detectors

Table 9

Technology Stack for Climate Adaptive Water Management in the Indian Himalayan Region

Feature	Description	Capability					Relevance	
		Remote Sensing	AI & Big Data	Sensors	CPS/IoT	Digital Platform	Strategic Tier	Operational and Field Tier
Geo-magnetic mapping of perennial water sources	Using global multisource database to map and analyze existing water sources to identify rejuvenation potentials	Satellites with the capability for Hyperspectral Imagery to collect hydrogeological maps, geophysical data, thermal data, gravitational field data, and magnetic fields data	AI to ingest; process; & normalise data points (hydrogeology, seismology, magnetic fields, microwaves, satellite data, gravitational, & electric fields) and provide analysis to identify, map, & analyse water sources GIS that blends the power of a map with the power of a database to allow people to create, manage and analyse information, particularly information about location	-	-	Storing all the datasets in one dashboard along with displaying the data as per user requirement	• The administration is keen to resolve the state-level issue of drying up of perennial water sources • Non-invasive technologies for mapping and analysing the perennial water sources including aquifers would be less disruptive for the already sensitive ecosystem of the Himalayas	• The administration is looking at emerging technologies solutions which could be integrated with the existing digital dashboard developed in coordination with ISRO • The administration is exploring cost effective and accurate mechanisms to map perennial water sources

Table 9

Technology Stack for Climate Adaptive Water Management in the Indian Himalayan Region

Feature	Description	Capability					Relevance	
		Remote Sensing	AI & Big Data	Sensors	CPS/IoT	Digital Platform	Strategic Tier	Operational and Field Tier
Real-time monitoring of water sources	Monitoring the existing water sources in terms of flow, discharge, and other parameters	Upon identification of existing water sources, assessment of the same in terms of various parameters (depth, static level, flow rate, temperature)	AI to ingest; process; & normalise data points (hydrogeology, seismology, magnetic fields, microwaves, satellite data, gravitational, & electric fields) and provide analysis to identify, map, & analyse water sources GIS that blends the power of a map with the power of a database to allow people to create, manage and analyse information, particularly information about location	-	-	Storing all the datasets in one dashboard along with displaying the data as per user requirement	• State administrations wants to regulate water usage and keep a check on water supply vis-à-vis demand	• Smart water pumps could be deployed for group of three-four households via collective action groups • Smart water pumps would be useful for creating efficient irrigation systems for a group of farms at lower cost

Table 10

Technology Stack for Climate Adaptive Water Management in the Indian Himalayan Region

Feature	Description	Capability					Relevance	
		Remote Sensing	AI & Big Data	Sensors	CPS/IoT	Digital Platform	Strategic Tier	Operational and Field Tier
Assessment of various parameters to maintain water quality	Assessing the critical water quality parameters that play a crucial role in health and agriculture on a block level	-	Machine learning based optical analyser, which is connected to cloud, battery operated and is GPS enabled	Various sensors to test: 1. Physical parameters (turbidity, temperature, colour, taste & odour, total solids, EC) 2. Chemical parameters (pH, acidity, alkalinity, chloride, chlorine residual, sulfate, nitrogen, fluoride, Fe, Mn, Cu, Zn, hardness, DO, BOD, COD, radioactive substances) 3. Biological parameters (bacteria, algae, viruses, protozoa)	-	Mobile optimised web-based dashboards for advisory on efficient water management according to the location inputs from users	• Uttarakhand is state with hilly terrain with many small and marginal farmers and hence the administration is keen to adopt cost effective decentralised solution. • The focus is to establish a balance between emerging technologies & frugal innovations which would facilitate faster adoption	• Considering the socio-economic profile of the adopters and geography, low-cost and potable water testing solutions are preferred by the administration. • Portable & instant water testing mechanism reduces the time & cost expended by rural communities & administration

Table 11

Technology Stack for Climate Adaptive Water Management in the Indian Himalayan Region

Feature	Description	Capability					Relevance	
		Re-mote Sens-ing	AI & Big Data	Sensors	CPS/IoT	Digital Platform	Strategic Tier	Operational and Field Tier
Automated water usage tracking system	Keeping a check on the usage of the water re-sources by tracking the same on a supply and demand level	-	-	Various sensors that can monitor multiple parameters (pH, TDS, turbidity, EC, flow rate, temperature, & water volume consumption)	IoT enabled water meters; Smart and Complete Automated Irrigation System based on soil moisture sensors that irrigate the field if and only when necessary and only to an optimal level.	Mobile optimised web based or GSM/ GPRS activated dashboard to deliver real time updates and alerts to the end user	• State administrations wants to regulate water usage and keep a check on water supply vis-à-vis demand	• Smart water pumps could be deployed for group of 3-4 households via collective action groups • Smart water pumps would be useful for creating efficient irrigation systems for a group of farms at lower cost

Field Technology Showcase

SECTION 5

To demonstrate technology stack's practical potential – actual impact on the ground, for Government decision-makers, against these priorities – the AGNIi team conducted a demonstration, and a field showcase at Champawat. The first was conducted at Uttarakhand Rural Science Congress 2023 at Dehradun. In this demonstration, four innovators participated from across India. The primary objective of the demonstration was to gauge the level of response from the key stakeholders including the Hon'ble Chief Minister of Uttarakhand. After a successful demonstration, AGNIi organised a Field Technology Showcase in Champawat. In this, five innovators participated by demonstrating their technology capabilities in front of both the state and district administration. To enable adoption of these technologies by the decision makers, FTS focused on demonstrating Everett Roger's adoption levers for each technology.

Adoption Levers

Everett Rogers in his seminal work Diffusion of Innovations[32] stated that the perceived attributes of innovation (characteristics of innovations, as perceived by individuals) play a key role in determining the rate of adoption of innovation. According to Rogers, there are five important attributes of innovation, these include:

1. **Relative Advantage:** Refers to the degree to which an innovation is perceived as better than the idea it supersedes. The numerous factors by way of which the degree of relative advantage can be measure include – economic terms, social prestige factors, convenience, and satisfaction.

2. **Compatibility:** Refers to the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters.

3. **Complexity:** Refers to the degree to which an innovation is perceived as difficult to understand and use. Some innovations are easy to understand and hence, easily adopted. Meanwhile, others may not be very straightforward, which slows the adoption process.

4. **Trialability**: Refers to the degree to which an innovation may be experimented with on a limited basis.

5. **Observability:** Refers to the degree to which the results of an innovation are visible to others. The ease with which individuals can see the results of an innovation has a direct impact on the probable likelihood of their adoption.

The perceived attributes of innovation are instrumentally important. This is because end adopters are primarily rural communities and there exist information asymmetries with respect to both functionalities and the benefits of technology innovation. In this context, one of the key objectives of the Field Technology Showcase is to exhibit and contextualise the above attributes of innovation both to the decision makers and the end adopters.

The subsequent tables (refer Table 12-14) in the section enumerate the five important attributes of innovation and how each was conveyed to the decision makers and technology adopters by way the field showcase with reference to the different layers and technologies of the climate adaptive water management technology stack.

32 Rogers, E. M. (1962). Diffusion of innovations. New York, Free Press of Glencoe.

Table 12

Adoption Levers for Efficient Water Management

	Adoption Lever	Technology / Op Scenario Summary	How did Showcase achieve this?
1	Relative Advantage	• Farmer should be able to operate the smart water pumps even immediately after the power cuts. • Users should be able measure the quantum of water they are using a single pump without multiple retrofitting	• The farmers and the authorities could use the smart water pump immediately after the power was restored post the power cut without manual intervention. • The smart water monitoring pump displayed the quantum of water used in the field showcase
2	Complexity	• Processes for water management to control flow and usage needs to be simplified for rural hill communities • District administration should be able to remotely monitor water usage of industrial/large users situated in the foothill of the district (Tanakpur)	• Installation/Retrofitting of the smart water meters and smart pump controllers would require professional help (plumber was required at the showcase to make the setup in the case of the former, while in the case of the latter technology providers retrofitted a locally available pump with their smart pump controller • Operationally, the rural communities could understand the process of pre-setting time and taking readings
3	Compatibility	• District administration does deploy water monitoring devices for large/ industrial users. • Farmers use conventional water pumps in their farmlands	• The administration already deploys water monitoring devices hence the tamperproof water monitoring technologies would be an upgrade for them. • The farmers use conventional water pumps hence the automated pump controllers would be an impactful upgrade

	Adoption Lever	Technology / Op Scenario Summary	How did Showcase achieve this?
4	Trialability	• Farmers should be able to use smart water meters and water usage monitoring devices/pump controllers themselves with some initial land holding	• Community members could use the water pumps and water monitoring devices after the installation and retrofitting by the plumber
5	Observability	• Automatic switch-on and switch-off of the pump controller based on the availability of the electricity. • Measure of the water consumed during the field showcase	• Community members could witness the smart water pump operational after the power was restored post the power cut without manual intervention. • The smart water monitoring pump displayed the quantum of water used in the field showcase.

Table 13

Adoption Levers for Water quality Management

	Adoption Lever	Technology / Op Scenario Summary	How did Showcase achieve this?
1	Relative Advantage	• Rural communities should be able to test the quality of drinking water in-situ and take requisite measures like boiling, filtration, notification to authorities if the quality is not up to the mark. • These portable technologies should help the administration to monitor the quality of water in and around the water springs	• IoT based water testing solutions provided instant analysis and results on multiple channels of mobile devices to the community members who performed the test with the assistance of technology providers. • Farmers and officials concurred that portable water testing technologies are hassle free. • Further, the community members and officials found these solutions cheaper to adopt compared to the conventional labs (considering the logistics involved). • It was also iterated that cost per test would further reduce for an individual farmer if the technology were adopted by the district administration or collective action groups (Farmer Producer Organisations [FPOs] and Self-Help Groups [SHGs])
2	Complexity	• Water quality testing procedure needs to be simplified for both field officials and the farmers. • Rural communities cutting across income groups, gender, geography should be able to perform soil tests in-situ. • Field officials and rural communities should be able to understand the test results	• Local community members could use the water testing device with some initial training.
3	Compatibility	• The community members have not tried the water testing devices yet however the administration conduct water tests at longer intervals	• The farmers and community members have used the soil testing devices which are like water testing devices and hence it would be possible for them to adopt

	Adoption Lever	Technology / Op Scenario Summary	How did Showcase achieve this?
4	Trialability	• Field officials and communities should be able to use portable water testing technologies themselves with some initial handholding	• Community members could use the IoT based portable water testing devices. • District administration concurred that the low cost of the kits vis-à-vis the cost of setting up conventional labs also makes it easy for the administration to deploy
5	Observability	• The process of water testing as well as the results should be available instantaneously for the farmers and community members to see for themselves	• Results of portable water testing technologies were available to the community members and officials instantaneously

Table 14

Adoption Levers for Aquifer Mapping and Tracking

	Adoption Lever	Technology / Op Scenario Summary	How did Showcase achieve this?
1	Relative Advantage	• Integrated platform to identify, map and analyse the perennial water resources using non-invasive technological solutions which eliminate the complexity and cost of digging in hilly terrain.	• High level mapping of self-recharging aquifers in Champawat district was performed without any digging.
2	Complexity	• The user interface of the technology must be simple for the representatives from the administration. • The technological solution should be non-evasive without the need to deploy heavy machinery	• The high-level mapping was performed completely using emerging technology without any invasive technology.
3	Compatibility	• The technology should be compatible with the existing digital dashboard being developed by the district administration in association with ISRO.	• The technology can be plugged into majority of the platforms used by leading organizations like ISRO.
4	Trialability	• The administration should be able to map the reservoirs in a specified time with limited cost implication.	• The high-level mapping is done within a span of 24 hours in lesser cost.
5	Observability	• The administration should be able to see the analysis of the mapped natural resources instantaneously.	• The depth, qualities, flow rate and sustainability of the mapped water sources were mapped using the technology.

Performance Matrix[1]

This section summarises the idealised technological capabilities of the innovations vis-à-vis the performance and parameters of these innovations as assessed during the field technology showcase. The key objective of the performance matrix (refer Table 15) is to help the adopter in understanding the extent to which the technological capabilities tackle the adopter's pain points, thereby aiding in the deployment of climate adaptive water management practices.

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1 The technologies were showcased and tested within a frame of 16 hrs due to adverse weather conditions at the location and hence the performance assessment is limited by the time frame.

Table 15

Performance Matrix

Feature	Description		Capability					Performance Assessment
			Remote Sensing	AI & Big Data	Sensors	CPS/ IoT	Digital Platform	
Geo-magnetic mapping of perennial water sources	Using global multisource database to map and analyze existing water sources to identify rejuvenation potentials	Ideal Requirement	Satellites with the capability for Hyperspectral Imagery to collect hydrogeological maps, geophysical data, thermal data, gravitational field data, and magnetic fields data	AI to ingest; process; & normalise data points (hydrogeology, seismology, magnetic fields, microwaves, satellite data, gravitational, & electric fields) and provide analysis to identify, map, & analyse water sources GIS that blends the power of a map with the power of a database to allow people to create, manage and analyse information, particularly information about location	-	-	Storing all the datasets in one dashboard along with displaying the data as per user requirement	• The technology was able to identify, map and analyse perennial water sources within the specified geographical locations. It also provided various data points in terms of flow rate, depth, temperature, etc and display the same over a web-based dashboard
		Showcase Indication						

Table 15

Performance Matrix

Feature	Description		Capability					Performance Assessment
			Remote Sensing	AI & Big Data	Sensors	CPS/ IoT	Digital Platform	
Real-time monitoring of water sources	Monitoring the existing water sources in terms of flow, discharge, and other parameters	Ideal Requirement	Upon identification of existing water sources, assessment of the same in terms of various parameters (depth, static level, flow rate, temperature)					• The technology was able to identify, map and analyse perennial water sources within the specified geographical locations. It also provided various data points in terms of flow rate, depth, temperature, etc and display the same over a web-based dashboard
		Showcase Indication	The technology was able to capture the required data sets and provide analysis on porosity, storavity, electromagnetic field disruptions, transmissivity, fractures & discontinuities, hydraulic conductivity and permeability. This enabled the user to map & analyze water sources with an accuracy of 98%				Global data visualisation dashboard for data analysis, record, and prompt action	

Feature	Description		Capability					Performance Assessment
			Remote Sensing	AI & Big Data	Sensors	CPS/ IoT	Digital Platform	
Assessment of various parameters to maintain water quality	Assessing the critical water quality parameters that play a crucial role in health and agriculture on a block level	Ideal Requirement		Machine learning based optical analyser, which is connected to cloud, battery operated and is GPS enabled	Various sensors to test: 1. Physical parameters 2. Chemical parameters 3. Biological parameters		Mobile optimised web-based dashboards for advisory on efficient water management according to the location inputs from users	• The water testing device was able to test multiple parameters involved in a holistic water quality test and deliver the results within a turnaround time of 120mins. • The technology was used first hand by a local farmer with basic operational level knowledge of smart phones. The farmer was able to use the technology with ease and was also able to read the water quality reports
		Showcase Indication		The optical analyser had the following features: 1. Weight = 300gm 2. Battery operated = lithium ion (3000 mAH) 3. GPS = Uses hotspot to connect to the user's mobile device and uses the device coordinates to pinpoint location	The technology had the capability to test pH, nitrate, phosphate, ammonia, CO_2, alkalinity, salinity (EC) & hardness of water		The water quality data recorded on site was uploaded to the cloud and finally available on the web-based platform	

Table 15

Performance Matrix

Feature	Description		Capability					Performance Assessment
			Re-mote	AI & Big Data	Sensors	CPS/IoT	Digital Platform	
Automated water usage tracking & delivery system	Keeping a check on the usage of the water re-sources by tracking the same on a supply and demand level	**Ideal Requirement**	-		Various sensors that can monitor multiple parameters (pH, TDS, turbidity, EC, flow rate, temperature, & water volume consumption)	IoT enabled water meters and pump controller with ROM to adjust for power losses. Smart and Complete Automated Irrigation System based on soil moisture sensors that irrigate the field if and only when necessary and only to an optimal level.	Mobile optimised web based or GSM/GPRS activated dashboard to deliver real time updates and alerts to the end user	• The various technologies were able to record the various parameters related to water flow and keep a real time check on the same. The smart IoT based systems enabled efficient water management and usage with the least amount of human intervention. The user was able to track all the metrics and take necessary actions with the use of the dashboard
		Showcase Indication	-		The technology mapped and recorded the above parameters	1. Battery-powered flow meter that uses ultrasonic technology to measure, capture, and report water flow. With built-in telemetry, the data can be accessed remotely on any computer or mobile device. IP68 Rating. 2. IoT Enabled, timer based (ROM) pump controller which interfaces with all existing motors. 3. Smart and Complete Automated Irrigation System based on Soil moisture sensors that irrigate the field if and only when necessary and only to an optimal level. This system can be monitored and controlled remotely	The technology delivered real time updates either to the web-based dashboard or directly to the end user's handheld mobile device	

Conclusions & Way forward

SECTION 6

The Field Technology Showcase conducted at Champawat, Uttarakhand has provided a platform for the development and sharing of innovative climate adaptive water management technologies and practices. These technologies and practices have the potential to establish robust water management practices in the region and to help the community adapt to the changing climate. The final deployment of the demonstrated technologies is ongoing, and the document will be updated once it has been shared with the AGNIi Mission. Till then, the indicative way forward is indicated in the table (refer Table 16).

Table 16

Assessment and Advisory Matrix

Strategic Context Factor	Operational Scenario	Emerging Technologies	Idealised Capability Requirement	Capabilities Indicated in Field Technology Showcase	Course of Action
Hilly terrain and absence of plain and continuous land. • Infrastructural constraints for setting of water distribution and quality systems. • Prevalence of flood irrigation • Implications for irrigation intensity, drinking water availability and quality	Real time monitoring of water resources along with assessment of various parameters that fall under the category of a water quality test aided with an automated water usage tracking and delivery system	1. AI 2. Sensors 3. IoT	1. Upon identification of existing water sources, assessment of the same in terms of various parameters (depth, static level, flow rate, temperature) 2. Satellites with the capability for Hyperspectral Imagery to collect hydrogeological maps, geophysical data, thermal data, gravitational field data, and magnetic fields data 3. AI to ingest; process; & normalise data points (hydrogeology, seismology, magnetic fields, microwaves, satellite data, gravitational, & electric fields) and provide analysis to identify, map, & analyse water sources 4. GIS that blends the power of a map with the power of a database to allow people to create, manage and analyse information, particularly information about location 5. Various sensors to test: 5.1 Physical parameters (turbidity, temperature, colour, taste & odour, total solids, EC) 5.2 Chemical parameters (pH, acidity, alkalinity, chloride, chlorine residual, sulfate, nitrogen, fluoride, Fe, Mn, Cu, Zn, hardness, DO, BOD, COD, radioactive substances) 5.3 Biological parameters (bacteria, algae, viruses, protozoa 6. IoT enabled water meters; Smart and Complete Automated Irrigation System based on soil moisture sensors that irrigate the field if and only when necessary and only to an optimal level.	1. The technology was able to capture the required data sets and provide analysis on porosity, storavity, electromagnetic field disruptions, transmissivity, fractures & discontinuities, hydraulic conductivity and permeability. This enabled the user to map & analyze water sources with an accuracy of 98% 2. The technology had the capability to test pH, nitrate, phosphate, ammonia, CO2, alkalinity, salinity (EC) & hardness of water 3. Battery-powered flow meter that uses ultrasonic technology to measure, capture, and report water flow. With built-in telemetry, the data can be accessed remotely on any computer or mobile device. IP68 Rating. 4. IoT Enabled, timer based (ROM) pump controller which interfaces with all existing motors. 5. Smart and Complete Automated Irrigation System based on Soil moisture sensors that irrigate the field if and only when necessary and only to an optimal level. This system can be monitored and controlled remotely.	The technology in its current form can be deployed across the 4 blocks of Champawat. However, the district administration may start deploying it in a phased manner as, initially, capacity building of farmers will be required too. As observed in the field, an individual farmer could learn to use the technology in 120 minutes. Hence, phased implementation of soil sensors initiated with a small pilot in an area of administration's discretion could be rolled out. Recommended course of action: Under competent authority, technology is ready to be deployed in both a pilot and full-scale deployment in Champawat, Uttarakhand.

Table 16

Assessment and Advisory Matrix

Strategic Context Factor	Operational Scenario	Emerging Technologies	Idealised Capability Requirement	Capabilities Indicated in Field Technology Showcase	Course of Action
High dependence on natural water sources such as springs and rain-water • Implications for drinking water availability and quality for individual/ household, farming, and industrial needs	Using global multisource database to map and analyse existing water sources to identify rejuvenation potentials and keeping a real time check on the usage cycle of the same	1. Remote Sensing 2 AI 3. IoT 4. Big Data	1. Upon identification of existing water sources, assessment of the same in terms of various parameters (depth, static level, flow rate, temperature) 2. Satellites with the capability for Hyperspectral Imagery to collect hydrogeological maps, geophysical data, thermal data, gravitational field data, and magnetic fields data 3. AI to ingest; process; & normalise data points (hydrogeology, seismology, magnetic fields, microwaves, satellite data, gravitational, & electric fields) and provide analysis to identify, map, & analyse water sources 4. GIS that blends the power of a map with the power of a database to allow people to create, manage and analyse information, particularly information about location 5. Various sensors to test: 5.1 Physical parameters (turbidity, temperature, colour, taste & odour, total solids, EC) 5.2 Chemical parameters (pH, acidity, alkalinity, chloride, chlorine residual, sulfate, nitrogen, fluoride, Fe, Mn, Cu, Zn, hardness, DO, BOD, COD, radioactive substances) 5.3 Biological parameters (bacteria, algae, viruses, protozoa 6. IoT enabled water meters; Smart and Complete Automated Irrigation System based on soil moisture sensors that irrigate the field if and only when necessary and only to an optimal level.	1. The technology was able to capture the required data sets and provide analysis on porosity, storavity, electromagnetic field disruptions, transmissivity, fractures & discontinuities, hydraulic conductivity and permeability. This enabled the user to map & analyze water sources with an accuracy of 98% 2. The technology had the capability to test pH, nitrate, phosphate, ammonia, CO_2, alkalinity, salinity (EC) & hardness of water 3. Battery-powered flow meter that uses ultrasonic technology to measure, capture, and report water flow. With built-in telemetry, the data can be accessed remotely on any computer or mobile device. IP68 Rating. 4. IoT Enabled, timer based (ROM) pump controller which interfaces with all existing motors. 5. Smart and Complete Automated Irrigation System based on Soil moisture sensors that irrigate the field if and only when necessary and only to an optimal level. This system can be monitored and controlled remotely.	The technology has been successfully used to map and analyse the perennial water sources in the Champawat district. These datasets can be used to tap the sources and access water from the veins underground. The district administration needs to ensure that the drilling to access the source is ecological and monitor the usage from the sources in a sustainable manner. The deployment of this technology is capital intensive. Recommended course of action: Under competent authority and with the aid of regular monitoring, the technology is ready to be deployed across Champawat, Uttarakhand.

Annexures

Annexure 1

Follow Through Operationalisation and Scale Up

The Field Technology Showcase conducted at Champawat, Uttarakhand has provided a platform for the development and sharing of innovative climate adaptive water management and practices. These technologies and practices have the potential to strengthen water management in the region and to help the community adapt to the changing climate.

To maximize the potential of these technologies and practices, the concept of Innovation Diffusion by Everett Rogers has been explored, to provide an understanding of how to further develop and diffuse climate adaptive water management in the Indian Himalayan Region. To do this in a structured way, a set of indicative next steps have been listed in the section below.

Creation of a District Innovation Fund for pilot projects

To ensure the successful implementation of climate adaptive agriculture in the Indian Himalayan Region, it is important to ensure that the necessary resources and infrastructure are in place. The District Innovation Fund should be established as soon as possible, to provide the necessary resources and infrastructure for deploying ad scaling of successful pilot projects in Champawat.

Once the technology achieves scale in Champawat, it could be scaled up in other districts of Uttarakhand followed by implementation throughout the Indian Himalayan Region. During Field Technology Showcase, the District Magistrate has already committed to set up this fund for Champawat district.

Creation of a Steering Committee

To monitor and scale up Climate Adaptive technologies in Uttarakhand, it is important to create a steering committee with the head being the Hon'ble Chief Minister, Uttarakhand. This committee should comprise of members from the agricultural, research and industry sectors, as well as members from the local government. In this committee, UCOST could act as the member convener.

This committee will be responsible for researching and developing innovative climate adaptive agriculture practices for the region. It will also be responsible for advocating for the implementation of these practices across the region. The committee will also direct the district administrations to ensure that the necessary resources and funding are available to support the implementation. Furthermore, the committee should be empowered to take decisions and implement strategies that are in line with the regional objectives.

The committee should meet regularly and provide the Chief Minister with updates on the progress of the projects. It should also be responsible for ensuring that the projects are implemented in a timely manner and that the outcomes are in line with the expected results. Overall, the steering committee with the Chief Minister at the helm will be instrumental in driving the implementation of climate adaptive water management in the Indian Himalayan Region

Capacity Building

To ensure successful implementation of climate adaptive agriculture in the Indian Himalayan Region, it is critical that local stakeholders are equipped with the necessary skills, knowledge, and resources to carry out activities related to climate adaptive water management. Capacity building of local stakeholders should include training on scientific and technological advancements in climate adaptive agriculture, community-led research and analysis, and the development of tools and strategies for monitoring and evaluation of climate adaptive agriculture initiatives.

Local stakeholders should also be empowered to undertake participatory planning and decision-making processes that enable them to identify their local needs and develop actions plans that incorporate climate adaptive agriculture solutions. The District Administration may undertake capacity building in close association with the technology providers.

Scouting for innovative technologies for new and existing use cases

As demonstrated in this TAN, the first step in deploying technology for climate adaptive agriculture in the Indian Himalayan Region, is to identify potential use cases for technology deployment. To do this, a comprehensive scouting exercise should be undertaken to identify suitable areas where the deployment of technology can have a positive effect on climate adaptive water management. This scouting exercise should involve a systematic process of data collection, analysis, and evaluation. The data collected should include information about the local climate and geographical conditions, the type of crops being cultivated, and the existing agricultural practices.

This data should be analysed to identify areas where the deployment of technology could help improve agricultural production, reduce the risk of crop failure, and increase the resilience of the local farming communities. Field exercises conducted by team AGNIi to populate this TAN could be used as a reference by the decision makers to produce a list of ready use cases and technologies to engage. It is important to note that during these exercises, relevant stakeholders should be engaged with to ensure the holistic view on use cases and technology options.

Scaling up of pilots in neighbouring districts of Champawat

To move forward with the development and diffusion of climate adaptive water management in the Indian Himalayan Region, it is recommended that pilots of the field technology showcase conducted at Champawat, Uttarakhand be conducted in other areas of the region. Based on the results of these pilots, successful technologies and practices should be identified and scaled across the region.

Furthermore, it is recommended that policy makers in the region consider the use of Everett Roger's Innovation Diffusion Model (described earlier in this TAN) to understand how to effectively spread the implementation of climate adaptive water management in the region.

Conclusion

Climate change is an undeniable reality that affects the livelihoods of millions of people, particularly in the Indian Himalayan Region. As a result of rising temperatures, unpredictable weather patterns, and shifting precipitation, farmers in the region are increasingly vulnerable to food insecurity, poverty, and other economic challenges.

Therefore, it is essential that the government take proactive measures to promote climate adaptive agriculture in the Indian Himalayan Region. Adopting the learnings and approaches outlines in this TAN will provide a solid foundation which the key decision makers could use to chart their way across these newer areas of emerging technologies in climate adaptive water management.

Annexure 2

Innovators Shortlisted by Pioneer Agency, UCOST for Field Technology Showcase

UTTARAKHAND STATE COUNCIL FOR SCIENCE & TECHNOLOGY

Department of Science & Technology
(Govt. of Uttarakhand)

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No. 23375/UCS&&T/RSC (USSTC)/2023 Dehradun,
Dated 10th March, 2023

TO WHOSOEVER IT MAY CONCERN

Sub: Invitation to attend field technology showcase at Champawat

Dear Sir,

This is to certify and inform that Uttarakhand Council of Science and Technology (UCOST) in conjunction with AGNIi Mission, Office of Principal Scientific Advisor to the Government of India is organising a Technology Showcase at Champawat, Uttarakhand from 15th – 16th March 2023.

The following Start-ups have been mutually shortlisted for the showcase at Champawat

The names of the shortlisted innovators are as follows:

1. Kalgudi Digital Pvt Ltd.
2. Aigroedge Technologies
3. Zone 4 Disaster Solutions Pvt. Ltd.
4. GasKon Engineers Pvt. Ltd.
5. Kyari Innovations Pvt. Ltd.
6. EmerTech Innovations Pvt. Ltd.
7. Kritsnam Technologies Pvt Ltd.
8. Intech Harness Pvt. Ltd.
9. WaterQuest Hydroresources
10. Navariti Innovation
11. CESTA Enterprise
12. Arogyam Medisoft Solution Pvt. Ltd.
13. Garuda Aerospace Pvt Ltd.

In case of any queries or concerns, please contact me at piyush@ucost.in.

(Dr. Piyush Joshi)

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