Office of the Principal Scientific Adviser
to the Government of India

Climate Adaptive Forest Management

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

Climate Adaptive Forest Management

Technologies for forest management in the Indian Himalayan Region

Technology Advisory Note
November 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 (UCOST)

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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 (Ex-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 (Ex-District Magistrate, Champawat), Mr. Navneet Pande 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.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.

Furthermore, we extend our thanks to a plethora of experts and participants who enriched the expert conusultations held at UCOST in September, 2023 with their diverse perspectives. These include professionals from governmental organizations, international bodies like the World Bank and UNDP, and academic institutions. Their contributions have been invaluable in shaping this Advisory Note, by extension, the future strategies for climate adaptive forest management and livelihoods in the Indian Himalayan Region.

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 सर्वांगीण 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। आदर्श 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 सम्बधित 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)

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(025 mission of Hon'ble 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 second sprint of Technology showcase covering climate adaptive livelihoods and forests held on 18th and 19th October March, 2023 at Dudhpokhra and Champawat 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 an 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 Uttaralchand@25 subsequently in near future. I extend best wishes to AGNIi and UCOST (ems 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 Hon'ble 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 Forests

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 forest management practices in the Indian Himalayan Region. This innovation includes Artificial Intelligence (AI), advanced sensing, Unmanned Ground Vehicles for forest monitoring and fire-lines creation, and traditional innovations to enable precise action against the impact of climate change on forest ecosystems.

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, advanced sensing, and others) can be leveraged to help address national priorities. Key among these is climate change. The Office's advisory is optimized 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 summarizes 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 organizations 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.

The guidance in the TAN was developed via Fieldwork, Technology Operational Scenarios, Expert Consultations, 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 Hon'ble Chief Minister of Uttarakhand Government to develop Champawat as an Adarsh Zila under the Uttarakhand @25 initiative of the state, with the guidance of UCOST.

The activities were undertaken in partnership and consultation with UCOST, and district administration. The Note and its advice aim to support practical, actionable administrative decision-making on technology engagement and acquisition for climate-adaptive forest management. 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 populace's 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.

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 Intergovernmental Panel on Climate Change (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 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.1 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.[1] 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 Pithoragarh have high vulnerability. Meanwhile, seven districts including Uttarkashi, Pauri Garhwal, Rudraprayag, 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 forest management, the state government[2] is continuously making efforts to create development models that balance ecology and economy. Livelihoods generation also remains priority of the state government.

To further its objectives, the Government of Uttarakhand, in collaboration with UCOST as the lead agency, is actively developing tech-driven operational frameworks to establish Champawat as an exemplary district. This effort is part of the state's Uttarakhand@25 initiative, aimed at enhancing the region within the unique setting of the Himalayan ecosystem.[3]

1 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)

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

3 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 abundance of 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.
- 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. Terai area is hot whereas 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 extremely high (about 20 cm. yearly). The climate of Shivalik is same but the lower region of Himalayas experiences hotter weather.

Forest Cover Variability.

The forests in Champawat range from 200-2,200 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]) [4]

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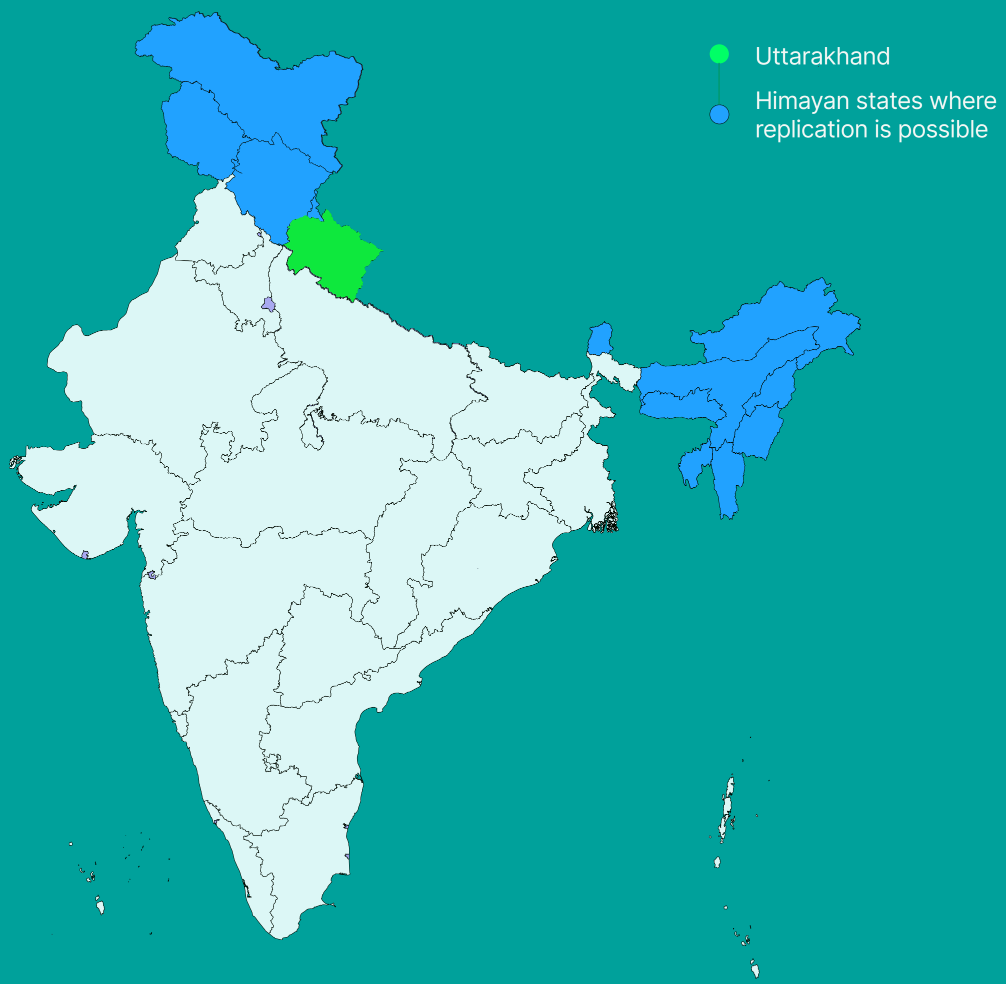
4 District Survey Report Champawat available at < https://cdn.s3waas.gov.in/s3eda80a3d5b344bc40f3bc04f65b7a357/uploads/2018/08/2018082543.pdf> last accessed 22 March 2023.

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://ecoursesonline.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

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.

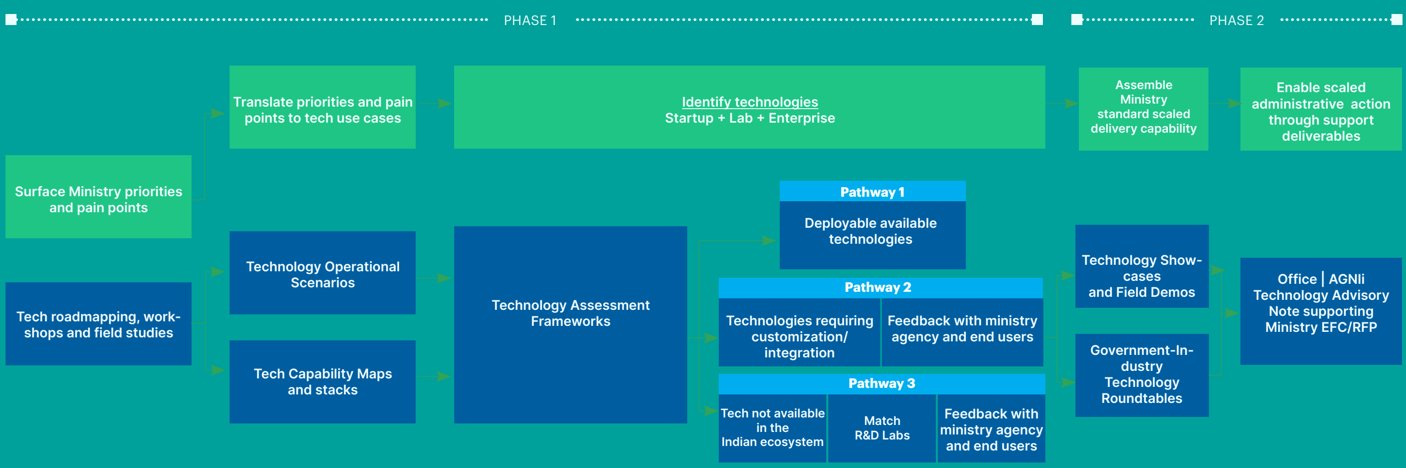
- To determine operational and strategic decision-making dimensions: the AGNIi Mission also consults, via a series of meetings, with Pioneer Agency representatives and the District Magistrate.

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 forest challenges – for manual ground truthing, forest fires, and sustained afforestation and reforestation.
   - Where these technologies and capabilities intersect – solutions are identified – for example, Unmanned Ground Vehicles for forest management and creation of fire lines.
   - 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.

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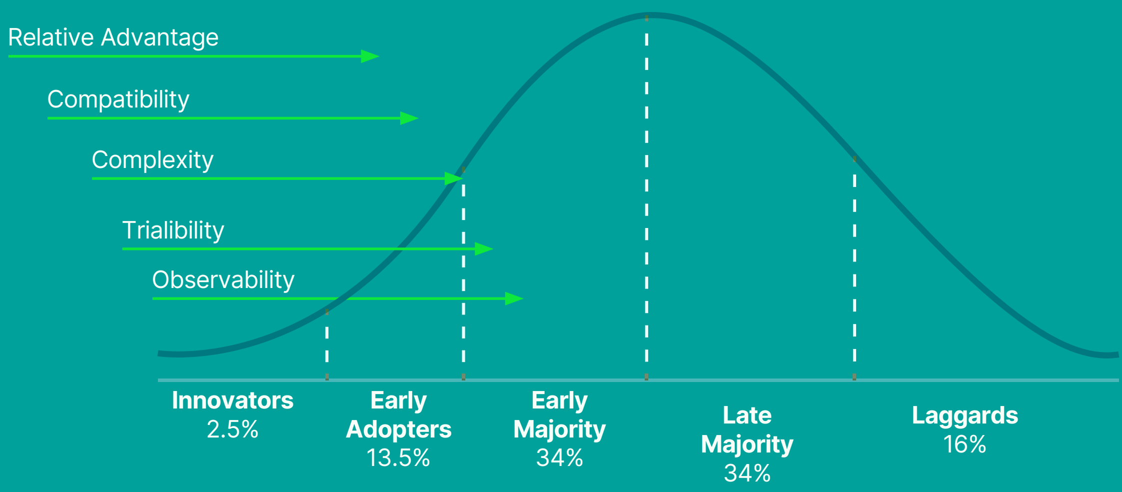
5. **Demonstrating Workability and Options: Field Technology Showcases.** To demonstrate this innovation's practical potential – actual impact on the ground, for Government decision-makers, against these priorities – the AGNIi team conducts Field Technology Showcase (Field Technology Showcase) in locations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

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 2

Change Management

Step	Change Manage-ment 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), Research & Development Labs, 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 Forest Management

SECTION 2

India's Vulnerability To Climate Change And Need For Adaptation

India is highly vulnerable to climate change with 65 percent of its geography being drought prone, 12 percent being flood prone, and 8 percent being susceptible to cyclones.[1] Over the past century, maximum temperatures in India have increased by 0.71 degree Celsius and mean minimum temperatures by 0.27-degree celsius.[2] In the pre-monsoon season, the frequency of hot days shows a gradual increase, while the frequency of chilly days shows a noticeable decrease.[3] 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

1 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)

2 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)

3 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)

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.[4] According to the latest report by United Nation's IPCC, the country has already lost 16 percent of its per capita Gross Domestic Product (GDP) because of rising sea levels and changing monsoon patterns.[5]

According to the Climate Transparency Report, 2022, India lost $159 billion or 5.4 per cent of its GDP, 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[6] . 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.[7] 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. [8]

Overview Of Forest Cover In India And Climate Change Impacts

India is in the top 10 countries in the world for forest coverage, with tropical and subtropical forests covering more than a fifth of the country. Being one of the most biodiverse countries, India contains 8% of the world's biodiversity and four recognised biodiversity hotspots. It is estimated that 47,000 plant species and 89,000 animal species can be found in the country with more than 10% of each thought to be on the list of threatened species.[9]

Forests provide important services in the form of absorbing carbon, preserving nutrients and providing timber and fuelwood. However, climate change impacts in the form of change in rainfall pattern, insect outbreaks, wildfires, invasive species etc. have led to major forest loss in India. These impacts can reduce forest productivity and change the distribution of tree species. According to the latest assessment done in FSI report 2021, nearly half of India's forest and tree cover (315,667 square kilometres, or 45 per cent) can emerge as 'climate hotspots' — areas expected to be affected by climate change. The report further indicated that by 2050, 448,367

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

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

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

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

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

9 https://www.sciencedaily.com/releases/2022/03/220324104524.htm

sq km or 64 %[10] of India's forest and tree cover is likely to face the 'high severity' (temperature rise between the range of 1.5 and 2.1 degree Celsius) of climate change.

India's tropical dry deciduous forests, the top dominant type of forests, will be severely affected by climate change with a prediction of over 55% of these forests getting impacted. Tropical moist deciduous forests and tropical semi-evergreen forests, the second and third most prominent type of forests too are highly vulnerable. Some 47 per cent and 40 per cent of the tropical moist deciduous forests and tropical semi-evergreen forests respectively will be affected by climate change.

There are several geographical, demographic, and socio-economic factors responsible for forest degradation in India. In addition to the fragile ecosystems, increasing population with low agricultural production, degraded community forests and restricted means of livelihood constitute a vicious cycle of poverty, putting tremendous pressure on forests in the country. Some of these factors are discussed below –

- **Diversion of forestland for non-forestry purposes** - Forests are increasingly being diverted purposes such as hydel power projects, industry, road buildings, and mining. A total of 554.3 square kilometres of forest area in the country has been diverted for non-forestry purposes in the last three years (2020-2022).[11]

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10 https://www.downtoearth.org.in/video/forests/forest-survey-report-2021-over-45-of-india-s-forests-will-become-climate-hotspots-by-2030-81177#:~:text=By%202050%2C%20448%2C367%20sq%20km,SoFR%2C%202021)%2C%20 said.

11 https://www.deccanherald.com/national/554-sq-km-forest-area-diverted-for-non-forestry-purposes-in-last-3-

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

- **Unregulated grazing** - Grazing and trampling of regenerated seedlings by livestock is the biggest threat to regeneration of vegetation in all forested areas of the country. India had a requirement of 526 MT of dry fodder, 855 MT of green fodder, and 56 MT of concentrate fodder.[12] However, forests are unable to meet this demand and this gap is usually filled by unregulated grazing, illegal removal such as heavy looping of trees and cutting of saplings.

- **Forest Fires** - Uncontrolled fires have caused tremendous damage to the forest biodiversity of the country. Every year large areas of forests are affected by fires of varying intensity and extent. Based on the forest inventory records, 54.40% of forests in India are exposed to occasional fires, 7.49% to moderately frequent fires and 2.40% to high incidence levels while 35.71% of India's forests have not yet been exposed to fires of any real significance.[13]

Forests In The Indian Himalayan Region And Their Importance

The Indian Himalayan region is spread across 13 States/Union Territory (namely Jammu and Kashmir, Ladakh, Uttarakhand, Himachal Pradesh, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Assam and West Bengal), stretching across 2500 km.[14] The Indian Himalayas holds key to India's ecological security and is a major provider of various forest products and hydropower. The Himalaya is the store house of glaciers that provide perennial river systems for mountain inhabitants as well as people living downstream for settlement, agriculture and industries.

The Region consists of tropical deciduous forests in the foothills, temperate forests in the middle altitude, coniferous, sub-alpine, and alpine forests in higher altitudes followed by shrublands. The region also has a rich in biodiversity with 10,000 species of vascular plants, 13,000 species of fungi and 1100 species of lichens .Himalayan forests also serve as a habitat for 240 species of mammals, 750 species of birds and 270 species of fishes.[15]

Himalayan forests are an essential carbon sink and play a significant role in mitigating climate change impacts. The Himalayan region covers nearly 19% area and contributes to 33%[16] of the soil organic carbon stock of India largely due to dense forests. Apart from carbon sequestration, Himalayan forests also help in maintaining soil fertility, capture essential atmospheric moisture, regulate river flow, and reduce soil erosion and sedimentation downstream. Reduction in soil erosion further helps improve water quality by filtering pollutants from water.

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years-shows-govt-data-1128349.html

12 https://epashupalan.com/10961/animal-husbandry/current-availability-and-future-requirements-of-live-stock-feeds/#:~:text=India's%20Livestock%20Feed%20Demand%20by%202022&text=To%20meet%20out%20the%20requirement%20of%20livestock%2C%20India%20would%20require,Mt%20of%20digestible%20crude%20protein.

13 https://fsi.nic.in/forest-fire-activities

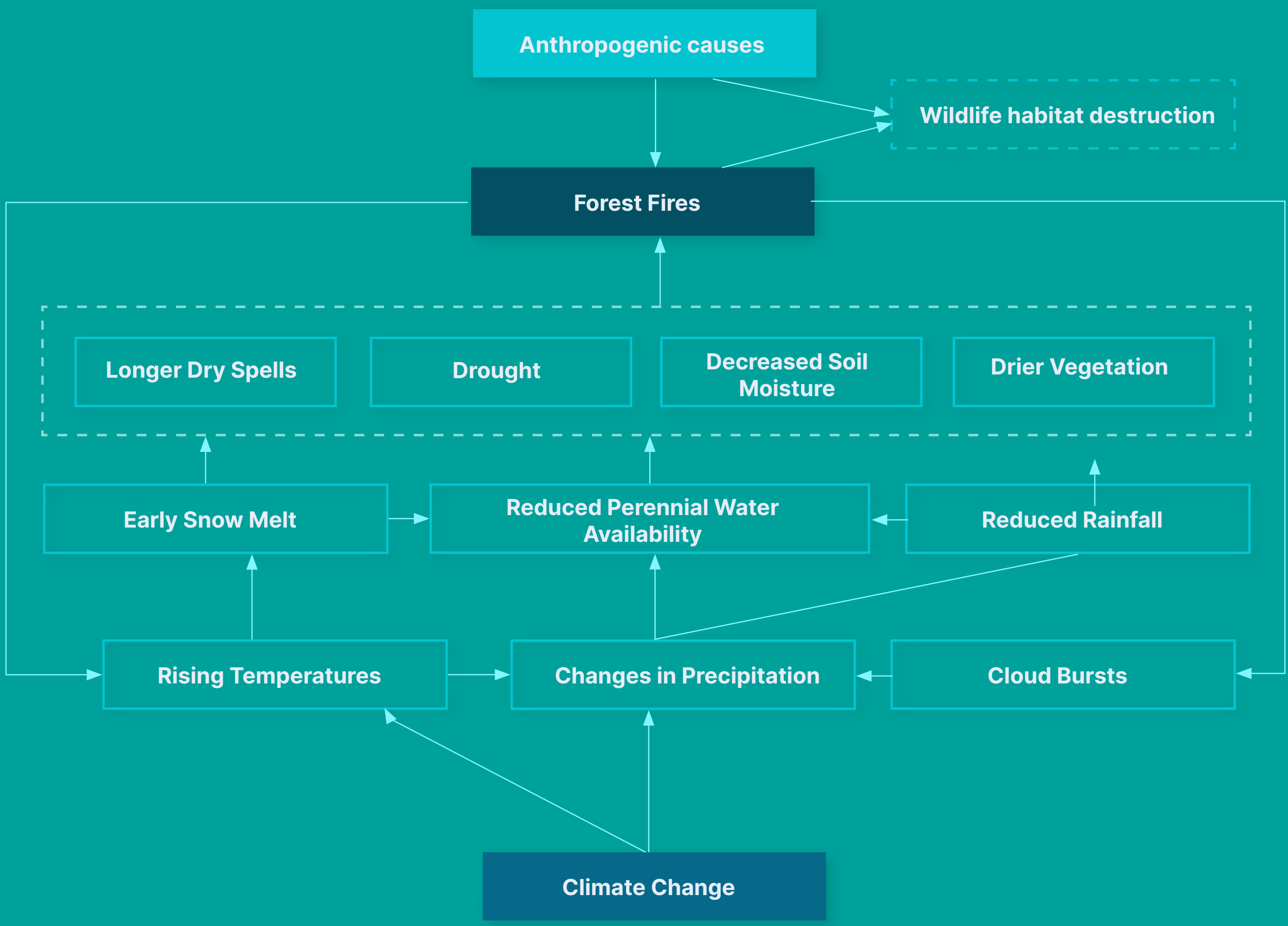
14 https://www.niti.gov.in/sustainable-development-indian-himalayan-region

15 https://www.sciencedirect.com/science/article/pii/S2666719322000322#bib0058

16 https://www.sciencedirect.com/science/article/pii/S2666719322000322#bib0017

Box 5

Impact Map of Climate Change on forest management*



* Source: Authors' analysis based on primary and secondary research

Climate change impacts pose a serious threat to the Indian Himalayan Region as it can lead to altering of the structure, function, and composition of the Himalayan forests and are expected to influence the region's biodiversity. When we compare the region with other hilly regions in India, the Himalayas face a relatively high-temperature rise. The Intergovernmental Panel on Climate Change (IPCC) has recognized the Himalayan ecosystem as fragile and highly vulnerable to changing climate (IPCC 2007).

Due to rapid warming of the Himalayan region, various effects such as species range shift, phenological shifts in plant's life cycle, forest growth patterns, and changes in ecosystem boundaries can be seen in the region. Climate change can further affect the biodiversity of the region in the form of species adapting to new environmental conditions or adjusting their distribution to follow suitable habitat conditions or face extinction if they cannot move or adapt. The changes in flora and fauna of the region can also be attributed to anthropogenic factors besides climate change impacts. The multiple drivers well-known in the region are (i) encroachment of habitats, (ii) land-use/land-cover (LULC) change, (iii) fragmentation of land (iv) forest fires (v) deforestation (vi) introduction of invasive plant species, (vii) expansion of agricultural land into forest lands.

- The above impact map shows the direct and indirect interlinkages between climate change and the subsequent effects on forests.
- Both anthropogenic factors and other factors such as pollution, drier vegetation, droughts etc., lead to forest fires, leading to increase emissions and decreased carbon sequestration.[17]
- Forest fires causing rise in temperatures, coupled with change in precipitation patterns, can potentially cause cloud bursts , leading to early snow melt, reduced availability of perennial water, and reduced rainfall.[18]
- Forest fires have a direct impact on increased instances of human-wildlife conflict[19], harming the natural wildlife populations of the area.

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 forest management in the Himalayan states climate resilient and help the 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 warming

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17 https://www.researchgate.net/publication/349279031_Forest_Fire_in_Uttarakhand_Causes_Consequences_and_Remedial_Measures

18 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1731190

19 https://www.researchgate.net/publication/354022498_Human-wildlife_conflict_in_Uttarakhand_Impact_opportunities_and_ground_level_perspectives_with_mitigating_strategies

are highly vulnerable on a continuum to the impacts of climate change.[20] 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."[21]

- 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'.[22] This sensitivity and lack of adaptive capacity of the primarily stems from the following factors:

- High dependence of a large proportion of the population (60%) on forests for their livelihoods.

- Forests play a vital role in regulating the water cycle, preventing soil erosion, and mitigating the effects of climate change.

- Forests in the Indian Himalayas provide a wide range of essential goods and services to local communities, including food, fuel, fodder, timber, and medicinal plants.

- Increase in frequency and intensity of disturbances such as forest fires, landslides, and floods due to climate change. These disturbances can cause significant damage to forests

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20 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)

21 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)

22 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 3

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 land.** • Infrastructural constraints for implementing heavy machines and tools to scale up fire prevention • Prevention of forest guards and rangers to directly access forest fires • Implications for scale of reforestation and afforestation activities in the region	Develop specialized fire prevention and monitoring technologies tailored to hilly terrain and remote access challenges.	Deployment of fire detection drones equipped with thermal imaging sensors for early forest fire detection. Integration of remote sensing and GIS technologies to map fire-prone areas and assess risks. Implementation of mobile-based applications for forest guards and rangers to report and monitor forest fires remotely. Use of satellite communication systems for real-time data transmission from remote forest areas. Incorporation of AI-driven predictive models for assessing fire risk in hilly terrain and planning reforestation and afforestation activities accordingly.
2	**Limited Connectivity** • Puts constraints on real-time data transmission and communication in remote forest areas. • Hinders the quick response of forest guards and rangers to incidents. • Limits the availability of internet-based tools and technologies for forest management.	Create rugged technology ecosystems which can be used even in low connectivity regions	Inclusion of compact and mobile fire prevention equipment in the technology stack. This equipment should limit the use of internet dependence Integration of lightweight drones guided by satellites with thermal imaging capabilities for fire detection. Installation of advanced sensors for fire detection in harsh terrains. Creation of apps to enable forest guards to communicate emergencies and seek help in difficult areas. Integration of GIS and satellite information into unified fire control systems.

Source: Authors' analysis based on field work in Champawat, Uttarakhand in July and August 2023, stakeholder interactions with the state government, district administration, and institutions like G.B.Pant National Institute of Himalayan Environment (NIHE), Forest Research Institute (FRI) etc. with subsequent technology scouting.

Strategic Context

SECTION 3

Pain Points: Surfaced Through Fieldwork

Inability to timely detect forest fires

Forest fires are aggravators of climate change. They not only cause the release of huge amounts of carbon dioxide into the atmosphere, but also prevent future sequestration of the greenhouse gas (GHG) due to the destruction of green cover, not to mention the damage done to the ecosystem services and biodiversity.

Scientific studies like the Global Forest Resource Assessment (GFRA) 2020 have reported that forests are under increasingly difficult fire-weather conditions, with climate change causing extended fire seasons as well as the larger magnitude of fires.[1]

Humans are responsible for 75% of all global wildfires,[2] and this percentage is even higher for India. As per the Forest Survey of India, India also has approx. 11%[3] of its forest cover in the extremely to very highly fire prone zone. This is a serious cause for concern in terms of increased carbon dioxide emissions and loss of carbon sink and therefore a necessary case for intervention.

In Uttarakhand, forest fire events increased from 922 in 2002 to 41,600 in 2019[4], impacting forest structure and function. The monitoring of forest fires in Uttarakhand has indicated that chir pine forests are most susceptible to forest fires, followed by dry deciduous scrub forest. About 4 lakh ton[5] pine needles are dropped annually in the Pine forests, which add to the inflammability of the forest floor due to rise in ambient temperature during summer. Some of the major reasons for such forest fires are anthropogenic factors (land use dynamics, particularly near roads and human settlements) and shift in traditional land management practices.

Paucity of fire-fighting methods and tools that can be deployed readily throughout the hilly and mountainous terrain of the region

Historically, the Forest Department in Uttarakhand has used methods such as creating fire lines and control burning to prevent and control forest fires. These methods have been used since the British period.

In the past, a total of 9,000 kilometers of fire lines have been created in the forests of Uttarakhand. These fire lines are typically 30, 50, or 100 feet wide. They need to be cleared every year to reduce fuel loading and the inflammability of the forest floor.[6]

An important measure to prevent and control forest fires is to mobilize tools, equipment, and resources to fire-prone areas in a timely manner. This will allow firefighters to respond to fires quickly and effectively.

Time consuming manual process of ground truthing and polygon fencing through GPS devices across inaccessible terrain in Uttarakhand

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1 https://www.fao.org/forest-resources-assessment/2020/en/

2 https://wwf.panda.org/discover/our_focus/forests_practice/forest_publications_news_and_reports/fires_forests/#:~:text=And%20in%20summer%202022%2C%20carbon,around%2075%25%20of%20all%20wildfires.

3 https://fsi.nic.in/focus-areas?pgID=focus-areas

4 https://fireecology.springeropen.com/articles/10.1186/s42408-023-00177-4

5 https://www.researchgate.net/publication/349279031_Forest_Fire_in_Uttarakhand_Causes_Consequences_and_Remedial_Measures

6 https://www.researchgate.net/publication/349279031_Forest_Fire_in_Uttarakhand_Causes_Consequences_and_Remedial_Measures

Ground truthing is the process of verifying the accuracy of data collected by remote sensing or other means. In the context of Uttarakhand with a total geographical area of 53,483 sq.km, out of which 46,035[7] sq.km is hilly, this can be a challenging task due to the state's rugged terrain and remote locations. Inaccessibility of many areas in Uttarakhand, due to several high-altitude mountain ranges, as well as dense forests and deep valleys, is the main challenge for ground truthing.

The time and cost of manual ground truthing can also be prohibitive. Ground truthing teams typically need to spend several days at each location, collecting data and verifying its accuracy. This can be a costly and time-consuming process, especially in remote areas.

As a result of these challenges, manual ground truthing in Uttarakhand is often limited to a small number of high-priority areas. This means that much of the state's land use and other data is still based on outdated or inaccurate information.

7 https://sbb.uk.gov.in/pages/display/93-about-uttarakhand#:~:text=Total%20geographical%20area%20of%20the,forests%20with%20very%20rich%20biodiversity.

Table 4

Pain point mapping for Climate Adaptive Forest Management in the Indian Himalayan Region

S.No	Pain Point	Operational Scenarios	Use Case	Functional Requirements
1	Inability to timely detect forest fires	**Nature of forest fires** • High number of forest fires in a short span of time in Champawat district during the peak season between February- May **Geography** • Considering the mountainous terrain, which is at times inaccessible, timely detection becomes key as geography poses constraints for rapid access **Technology Baseline** • Timing is a critical factor in the context of forest fires. At present, the Forest department receives both pre and post fire alerts only from the Forest Survey of India (FSI) - indicating that an existing service exists which is available to use by the relevant stakeholders in Uttarakhand • Considering that alerts are received from an external agency there is a possibility of delay – it has been observed that as time lapses the area ravaged by forest fires exponentially increases • At present, the Forest Department avails the services of local community members as fire watchers	Decentralised forest fire prediction and early detection systems	Unmanned Aerial Vehicles [UAVs] mounted with Thermal and Infrared Cameras & Smoke and Gas Detectors for precise detection of [potential] forest fires and real time monitoring. Infrared cameras will detect heat signatures and be used to identify the exact location of a fire. [even in low visibility.] Smoke detectors will detect the presence of smoke, which is usually an early indicator of fire. Gas detectors be used to detect the presence of flammable gases, which can be used to identify the location of a potential fire. Parameters to consider for UAV: Payload capacity, Weight, Max flying height, Frame rate [30Hz], Operating Temp [-2°C to 50°C], IP65 Rating to protect from Dust, Water and extreme weather. Parameters for Infrared Camera: Pixel count, communication data rate, resolution, and refresh rate Parameters for Smoke & Gas detectors: Ability to detect hazardous gases such as detect chlorine, carbon monoxide, nitrogen dioxide and other combustible gases.

S.No	Pain Point	Operational Scenarios	Use Case	Functional Requirements
2	Paucity of fire-fighting methods and tools that can be deployed readily through out the hilly and mountainous terrain of the region	**Geography** • Mountainous terrain with elevation ranging from 200-2200 metres above sea level with certain areas characterised by dense and very dense forests • The undulated topography coupled with dense forest covers limits the accessibility of the conventional firefighting mechanisms (for example, absence of motorable roads for the fire brigade trucks to enter and operate) • Presence of Chir pine in the region exacerbates the problem as Chir pine needles have resin which is highly flammable • At times density of forests and extreme heat generated during a fire incident limits the ability of human beings to actively engage in dousing activities **Logistics** • Transportation of large payloads of water to douse fire is a challenge. Additionally, it is also important to note that these regions are characterised by water shortages (Limited water infrastructure in the hilly terrains) • Limited connectivity **Technology Baseline** • Currently, the management of forest fires involves the forest service, fire departments, and local communities, with women notably entering the forests	• Remotely operated monitoring and fire-fighting tools • Fire fighting body suits and fire beaters	Three parameters that can help in easy operation to combat forest fires. Navigation: Reliable navigation systems that can help UAVs navigate to the location of a fire and provide accurate information about the fire's location and spread. [Gyroscope, Accelerometers, and GPS] Communication: UAVs need to have robust communication systems that can transmit real-time information about the fire to authorities on the ground, allowing them to develop an effective response plan. [Operating range [5km] depending on the drone, and range for obstacle perception are crucial parameters for Communication system for UAVs] Autonomy: UAVs need to be able to operate autonomously, without the need for constant human intervention. This will allow them to quickly and efficiently locate and monitor fires, providing valuable information to authorities on the ground. [Using robust image processing, pre-programmed flight paths, and auto pilot can reduce the level of human intervention needed].

S.No	Pain Point	Operational Scenarios	Use Case	Functional Requirements
2	Manual ground truthing across inaccessible terrain which is time consuming in an already overstretched department	**Geography** • Mountainous terrain with elevation ranging from 200-2200 metres above sea level with certain areas characterised by dense and very dense forests pose challenges Certain forest areas might be practically inaccessible for manual interventions **Departmental Challenges** • A Forest Department characterised by high workload (the DFO has a staff of less than 300 for a district which has a forest area of 132,337 hectares) **Technology Baseline** • Ground truthing conducted manually by the forest staff	• Remote ground truthing • On site soil testing facilities	Agility and flexibility to manoeuvre in the hilly terrain Camera features to automate the ground truthing process this includes identification of landscape features and collection of soil samples Intelligent terrain mapping systems that integrate data collected (images/ videos) Localised soil testing facilities Intelligent soil monitoring which also provide extension to the Forest Department on various alternatives of plant species that can be utilised for afforestation or reforestation

S.No	Pain Point	Operational Scenarios	Use Case	Functional Requirements
3	Time consuming manual process of polygon fencing through GPS devices in inaccessible terrains	**Geography** • Mountainous terrain with elevation ranging from 200-2000 metres above sea level with certain areas characterised by dense and very dense forests pose challenges for the polygon fencing process conducted manually by the forest staff • Certain forest areas might be practically inaccessible for manual interventions hence the accuracy is compromised **Departmental Challenges** • A Forest Department characterised by high workload (the DFO has a staff of less than 300 for a district which has a forest area of 132,337 hectares) **Technology Baseline** • At present polygon fencing is done using Google Earth and capturing of coordinates manually	• Remotely controlled polygon fencing process • Unmanned vehicles/ drones with installed camera features to automate the polygon fencing process	• Agility and flexibility to manoeuvre in the hilly terrain • Installed camera features • Intelligent system with a high range (geographical area covered) • Indigenous alternative to Google Earth (exploring NAVIC and other options)

User Persona Mapping

User persona mapping refers to the process of collating and segmenting information about potential decision makers and technology adopters. 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 Tables 7-9) 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.

Table 5

User Persona Mapping for Efficient Forest 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 | Forest Rangers
Role and Key Priorities	• **Role:** • Facilitate deployment of innovative technological solutions across the state to help effectively protect and manage forests and forests resources • Designing procurement and technology funding mechanisms. • Key Priorities: Uttarakhand@25, Adarsh Champawat, science, and technology led development of Uttarakhand; effective protection and restoration of forests to ensure biodiversity conservation, minimize disruption of forest resources due to forest fires, ensure livelihoods of forest dependent.	• **Role:** • Incorporating mechanisms to deal with the impacts of climate change on forest cover and resources via district development plans • Operationalise procurement; sanction funds; Capacity building of local • Key Priorities: Adarsh Champawat; minimize disruption of forests due to forest fires, promote and implement forest conservation practices	• **Role:** • Delivery & adoption of the technology for climate adaptive forest management both for community and individual/ household purposes • Funding and procurement; Awareness about modern technologies; Change Agents; Capacity building of local communities. • Key Priorities: Preservation of forest cover, access to forest resources, and safety of local communities during forest fires

Attitudes and Interests	• The administration understands the importance of leveraging emerging technologies for climate adaptive forest management in hilly terrain. • The administration focuses on ensuring protection and preservation of forests 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 ensure protection of forests from potential forest fires through early and timely detection systems. • The district administration is also keen on deploying simple cost-effective solutions, for example light-weight metal plough (alternative for wooden plough), that can reduce the requirement of cutting trees.	• Representatives showed enthusiasm for adopting the lightweight and user-friendly metallic plough – VL Syahi Hal. This innovative tool is gaining traction in the Almora and nearby districts, with over 10,000 farmers already incorporating it into their farming practices.
Behaviour and Decision Triggers	• Uttarakhand is a forest rich state with 65% of forest cover and provides essential resources and livelihoods to many small and marginalised farmers. Therefore, the administration is keen to adopt decentralised forest protections systems. • 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 is keen on adopting cost effective solutions such as the metallic plough • District Forest officials expressed concerns regarding the costing of unmanned ground vehicles (UGV) that enable forest surveillance in inaccessible areas and thermal imaging sensor cameras for early forest fire detection. • The officials did mention that the unmanned ground vehicle (UGV) could be piloted in hilly terrains given the costs involved.	• Community members expressed interest in adopting cost-effective and easily deployable solutions
Functional Requirements from Technology	• Simple, and cost-effective technologies that can be utilized by citizens to manage forest fires and ensure preservation of forest resources	• Cost effective tools and systems that can be easily integrated for forest fire prediction and management	• Cost effective tools and systems that can be easily integrated for forest fire prediction and management

Need Feature Mapping

The pain-points and operational scenarios for climate-adaptive forest 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

Technology Stack

SECTION 4

The need for technological intervention is of utmost importance for successful implementation of climate adaptive forest 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 forests (Forest Fires)[1] in the Indian Himalayan Region

	Prediction	Early Detection
AI/MV	AI algorithms on top of satellite imagery to map the forest areas & identify regions which can be classified as hotspots for human activities	Cameras with a MV layer to detect smoke plume and send alerts along with GPS coordinates
Advance Sensing	1. Satellite based Synthetic Aperture Radar (SAR) imaging techniques to detect atmospheric changes (temperature, humidity, rainfall, wind, smoke, & solar radiation) and predict fire vulnerable hotspots within the forest area for continuous monitoring 2. Radio acoustic sounding as a way to infer the meteorological flow or temperature profiles in forest areas	Sensors with the capability to detect temperature, humidity, rainfall, wind, smoke, & solar radiation to be deployed in hotspots for real time detection of any anomaly
UAV		Thermal sensors mounted on drones for continuous monitoring of area within a geofenced boundary
Advanced Materials		
Digital Platforms	Customized digital platforms to leverage UAV,GIS, GPS, Remote Sensing, IoT and Big Data, which facilitates key information to the authorities for efficient management	

1 Forest Survey of India (FSI) presently employs satellite imagery for predicting forest fire-prone areas and disseminates early warnings through text messages to a local network. Our proposed technological interventions aim to complement FSI's nationwide approach by advocating a decentralized system at the state or district level. This approach focuses on enhancing forest management through advanced tools, including geophysical mapping, unmanned systems, scraping systems, alternate materials, and value addition services. These interventions align with FSI's existing efforts, aiming to bolster local capacities and tailor solutions to specific regional needs, contributing to a more robust and nuanced forest fire management strategy.

Box 7

Technology Stack for climate adaptive forests (Forest Fires) in the Indian Himalayan Region

	Alert and Relay →	Mitigation
AI/MV		AI to process data from various sources to map the most vulnerable areas under a forest fire & guide the mitigation measures accordingly
Advance Sensing		Remote sensors & in-situ sensors to detect wind speed, direction of spread & temperature variations for a better mitigation approach
UAV		Drones with high payload capacity to 1. Geo fence a area based on the spread of fire 2. Deliver water to douse fires
Advanced Materials		1. Technical apparel with heat resistance to withstand high temperatures 2. Fire beaters made with materials with high heat resistance
Digital Platforms	Real time alerts over a mobile optimised dashboard for the forest rangers and locals	
Hardware	Portable wireless communication systems with voice & media transfer capability and is GPRS	1. Lightweight back mounted tanks with sprinkler system 2. Handheld lightweight fire beater

Box 7

Technology Stack for climate adaptive forests (Reforestation) in the Indian Himalayan Region

	Ground Truthing	Analyse	Sowing	Monitoring
Sensors	AI to process multiple data streams to devise a GIS based repository for a specified location	Machine learning based optical analyser to test soil parameters	MV enabled cameras to monitor to flora & fauna	Cameras with a MV layer to detect smoke plume and send alerts along with GPS coordinates
Advance Sensing	Satellite based hyperspectral & multispectral imagery to measure various parameters within a specified area	Various sensors to measure & map soil, water & atmospheric parameters		Satellite based and in-situ sensors to monitor the various parameters to ensure a steady growth of flora
UAV	Camera based sensors mounted on drones for measurement of crown density	MV enabled cameras on drones for terrain mapping	GPS enabled drone systems with different payload capabilities to 1. geo-fence a particular area 2. deposit seeds, and 3. Deliver other inputs	Nano-drones to continuously conduct surveillance in a geo-fenced area
Digital Materials	Customized digital platforms to leverage UAV, GIS, GPS, Remote Sensing, IoT and Big Data, which facilitates key information to the authorities for efficient management			

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 field showcase at Champawat. This showcase was an inclusive event, drawing participation from a diverse group. We had innovators, research labs, and line departments from the district administration. Additionally, the event was graced by the presence of over 300 community members from the region, including students, farmers, Self-Help Groups (SHGs), and local academia.

Prioritisation Matrix[1]

The “Technology Matrix for Forest Management” presents a comprehensive framework that illuminates the transformative potential of diverse technologies in the context of climate-adaptive forest management practices. Within this framework, we investigate four distinct technological domains. Each domain provides unique capabilities and applications that can be leveraged to address challenges in various aspects of forest management, such as fire prevention, reforestation, and

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 6

User Persona Mapping for Efficient Forest Management

Feature	Description	Capability			
		AI/MV	IoT/CPS	Mechanised Equipment	Misc.
Geophysical Mapping and Monitoring Systems	The application of advanced technologies to identify forest fire hotspots, assess reforestation sites, and monitor progress. This approach integrates geospatial data and monitoring tools to ensure precise mapping and efficient management of forested areas.	A long-range camera with machine vision to identify vulnerable forest fire hotspots by capturing high-resolution images and utilizing advanced algorithms. It detects subtle temperature changes and smoke patterns, pinpointing potential fire risks. A suitable model should have specifications such as a focal length of 50mm or above, infrared imaging capability, and real-time processing capacity.		-. UAVs to identify reforestation sites by capturing aerial data, assessing terrain, soil quality, and biodiversity. High-resolution imaging identifies suitable areas. 2. UAVs to track plant growth, health, and survival rates using multispectral sensors. 3. They also offer real-time data transmission for analysis. A suitable 4. UAV with flight time of 60+ minutes, 4K RGB camera, and multispectral sensors to ensure detailed mapping and ongoing progress assessment in reforestation efforts.	-
Unmanned sowing and input delivery systems	Unmanned sowing and input delivery systems utilize autonomous aerial and ground vehicles to conduct precise seed distribution for reforestation. Automation of delivery of seeds, essential resources, and fire inhibitors, enhancing efficiency and accuracy in forest restoration and fire management efforts.	–	–	UAVs and UGVs for seed sowing and input delivery for reforestation through precision drops and automated dispersal systems. Equipped with specialized compartments, they ensure accurate seed bombing and input distribution. Suitable UAVs/UGVs feature payload capacity of 5+ kg, GPS-guided flight, and customizable release mechanisms, enabling efficient, large-scale reforestation efforts.	

Feature	Description	Capability			
		AI/MV	IoT/CPS	Mechanised Equipment	Misc.
Scraping systems	Scraping systems employ advanced tools and robots to create strategic fire lines within forests, mitigating the spread of wildfires. This method ensures rapid and precise clearing of vegetation, acting as a vital barrier to protect natural habitats and facilitate efficient firefighting efforts, enhancing overall forest fire management.	–	–	1. UGVs to create forest fire lines by deploying specialized tools and robotic systems to clear vegetation swiftly and strategically.	-
Alternate Materials	Alternate materials involve utilizing non-traditional substances such as metals to craft products, reducing the reliance on wood resources. This sustainable approach mitigates deforestation by promoting the use of eco-friendly alternatives, safeguarding natural habitats, and fostering responsible resource management in various applications and industries.	–	–	–	Using metal ploughs to eliminate the need for cutting trees to make wooden ploughs, significantly reducing forest dependency.
Smart Soil Testing	To provide the soil testing services at the farmers' doorstep by determining all the soil parameters such as pH, moisture, nitrogen, potassium, phosphorus contents	Machine learning based optical analyser, which is connected to cloud, battery operated and is GPS enabled. The optical analyser had the following features:			

Feature	Description	Capability			
		AI/MV	IoT/CPS	Mechanised Equipment	Misc.
Value Addition Services	Value addition services involve transforming forest waste and produce into useful products, reducing environmental impact. This initiative enhances forest management by repurposing materials, minimizing fire hazards like pine needles, and generating value from resources that would otherwise go unused.	–	–	1. Using pelletiser for compressing pine needles and making pellets than can be used for cooking.	-

Adoption Levers

A central objective of the FTS was to facilitate the adoption of innovative technologies by government decision-makers and the local community. To achieve this goal, the event focused on aligning each showcased technology with Everett Rogers' Adoption Levers.[1] This strategic approach ensured that the exhibited solutions not only demonstrated technological excellence but also addressed the unique needs and adoption dynamics of the local context. By addressing key attributes such as compatibility, simplicity, trialability, observability, and relative advantage, the FTS aimed to pave the way for the adoption of these technologies by government decision-makers.

Everett Rogers in his seminal work Diffusion of Innovations 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:

- **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.

- **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.

- **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.

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

- **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 11-13) 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

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

Table 7

Adoption levers for Forest Fires

	Adoption Lever	Technology / Op Scenario Summary	How did Showcase achieve this?
1	Relative Advantage	• Implementation of advanced fire prevention tools and technologies that surpass traditional methods.	• The demonstration showcased the use of Unmanned Ground Vehicles (UGVs) for creating fire lines and remotely operated forest monitoring • The showcase also successfully demonstrated the use of pelletizers for processing pine needles, enhancing current fire management practices
2	Complexity	• Ensuring that new fire prevention technologies align with existing forest management practices and strategies.	• The Showcase demonstrated how new technologies can augment existing forest management practices, making them compatible and easily adaptable. • However, in the case of UGVs, administration found some gaps to align the existing practices with the technology solution being demonstrated
3	Compatibility	• Simplification of fire prevention processes and tools for easy understanding and utilization.	• Community members quickly grasped the simplicity of the new tools and processes especially of the pelletizer • Reduced complexity increased the participation of local communities. • Administration found the simplified tools and processes facilitated easier training for forest guards and rangers.

	Adoption Lever	Technology / Op Scenario Summary	How did Showcase achieve this?
4	Trialability	• Allowing forest guards and rangers to experiment with the new fire prevention tools on a limited basis.	• Local forest guards and community members had hands-on experience with the new tools. • Trialability increased confidence in using the tools effectively. • The administration showed interest to deploy these technologies on a trial basis
5	Observability	• Demonstrating the visible impact of new tools on fire prevention and control.	• Community engagement demonstrated the practical benefits of fire management technologies. • Authorities and forest managers acknowledged the advancements in fire prevention techniques. • Tangible benefits in fire management were evident from the use of these technologies.

Table 8

Adoption levers for afforestation and reforestation

	Adoption Lever	Technology / Op Scenario Summary	How did Showcase achieve this?
1	Relative Advantage	• Implementation of advanced afforestation and reforestation tools and technologies that surpass traditional methods	• • Community members observed to use advanced tools, and showed interest but noticed that some technologies are very advanced for them to handle. • Real-time making and burning of Bio-Char, created from pine needle and Lantana were showcased • Decision-makers witnessed the performance of tools like pelletizers, leading to their endorsement for wider use.
2	Complexity	• Ensuring that new afforestation and reforestation technologies align with existing forest management practices and strategies.	• Showcase integrated some new technologies seamlessly with existing community forest management practices. • Community members found the new tools compatible with their knowledge and practices. This includes using pine pellets for cooking and other heating requirements • Administration appreciated the ease of integrating new technologies with existing forest management strategies.
3	Compatibility	• Simplification of afforestation and reforestation processes and tools for easy understanding and utilization.	• 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**	• Allowing forest guards and communities to experiment with the new afforestation and reforestation tools on a limited basis.	• Local forest guards and community members had hands-on experience with the new tools. • Trialability increased confidence in using the tools effectively. • Forest guards and communities gained practical experience during the showcase.
5	**Observability**	• Demonstrating the visible impact of new tools on afforestation and reforestation outcomes.	• Community members gained first-hand experience with innovative technologies in action. • Live demonstrations provided tangible learning opportunities for those involved. • Stakeholders witnessed the application of new technologies in a real-world setting. • The event showcased the practical use of advanced tools in forest management.

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 10) 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 forest management practices.

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 10

Performance Matrix

Feature	Description	Capability			
		AI/MV	IoT/CPS	Mechanised Equipment	Misc.
Geophysical Mapping and Monitoring Systems	The application of advanced technologies to identify forest fire hotspots, assess reforestation sites, and monitor progress. This approach integrates geospatial data and monitoring tools to ensure precise mapping and efficient management of forested areas.	A long-range camera with machine vision to identify vulnerable forest fire hotspots by capturing high-resolution images and utilizing advanced algorithms. It detects subtle temperature changes and smoke patterns, pinpointing potential fire risks. A suitable model should have specifications such as a focal length of 50mm or above, infrared imaging capability, and real-time processing capacity.		-. UAVs to identify reforestation sites by capturing aerial data, assessing terrain, soil quality, and biodiversity. High-resolution imaging identifies suitable areas. 2. UAVs to track plant growth, health, and survival rates using multispectral sensors. 3. They also offer real-time data transmission for analysis. A suitable 4. UAV with flight time of 60+ minutes, 4K RGB camera, and multispectral sensors to ensure detailed mapping and ongoing progress assessment in reforestation efforts.	Storing all the datasets in one dashboard along with displaying the data as per user requirement
Unmanned sowing and input delivery systems	Unmanned sowing and input delivery systems utilize autonomous aerial and ground vehicles to conduct precise seed distribution for reforestation. Automation of delivery of seeds, essential resources, and fire inhibitors, enhancing efficiency and accuracy in forest restoration and fire management efforts.	–	–	1. UAVs and UGVs for seed sowing and input delivery for reforestation through precision drops and automated dispersal systems.	

Table 10

Performance Matrix

Feature	Description	Capability			
		AI/MV	**IoT/CPS**	**Mechanised Equipment**	**Misc.**
Scraping systems	Scraping systems employ advanced tools and robots to create strategic fire lines within forests, mitigating the spread of wildfires. This method ensures rapid and precise clearing of vegetation, acting as a vital barrier to protect natural habitats and facilitate efficient firefighting efforts, enhancing overall forest fire management.	–	–	1. UGVs to create forest fire lines by deploying specialized tools and robotic systems to clear vegetation swiftly and strategically.	Storing all the datasets in one dashboard along with displaying the data as per user requirement
Alternate Materials	Alternate materials involve utilizing non-traditional substances such as metals to craft products, reducing the reliance on wood resources. This sustainable approach mitigates deforestation by promoting the use of eco-friendly alternatives, safeguarding natural habitats, and fostering responsible resource management in various applications and industries.	–	–	–	Using metal ploughs to eliminate the need for cutting trees to make wooden ploughs, significantly reducing forest

Table 10

Performance Matrix

Feature	Description	Capability			
		AI/MV	IoT/CPS	Mechanised Equipment	Misc.
Smart Soil Testing	To provide the soil testing services at the farmers' doorstep by determining all the soil parameters such as pH, moisture, nitrogen, potassium, phosphorus contents	Machine learning based optical analyser, which is connected to cloud, battery operated and is GPS enabled. The optical analyser had the following features: 1. Weight = 300gms 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	Various sensors to test: 1. Structural properties (soil texture, type and bulk density); 2. Soil fertility (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Carbon Exchange Capacity, soil pH, soil acidity, percent organic matter (OM); 3. Soil salinity (Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR: used to evaluate the effect of sodium on soil structure))	-	-
Value Addition Services	Value addition services involve transforming forest waste and produce into useful products, reducing environmental impact. This initiative enhances forest management by repurposing materials, minimizing fire hazards like pine needles, and generating value from resources that would otherwise go unused.	–	–	1. Using pelletiser for compressing pine needles and making pellets than can be used for cooking. 2. Using forest waste that acts as an accelerant for forest fires and convert them into bio-char.	

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 forest management technologies and practices. These technologies and practices have the potential to establish robust forest 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 11).

Table 11

Assessment and Advisory Matrix

Operational Scenario	Emerging Technologies	Idealized Capability Requirement	Capabilities Indicated in Field Technology Showcase	Recommended Course of Action
• Forest Fire Detection and Management	AI & Machine Vision (MV) in Geophysical Mapping and Monitoring Systems; IoT/ CPS Mechanised Equipment	Advanced and reliable detection of forest fires; efficient management and response to minimize damage; high-precision mapping for reforestation planning	Use of AI & MV for real-time hotspot identification, advanced algorithms for fire risk assessment, IoT-based monitoring for continuous surveillance of forest areas. High-resolution imaging for detailed mapping.	Implement a network of AI & MV systems for continuous monitoring and early detection of forest fires. Establish a control center for real-time data analysis and response coordination. Phase-wise deployment in regions with the highest fire risk.
• Reforestation and Biodiversity Assessment	UAVs for Terrain Analysis and Biodiversity Monitoring	Accurate assessment of potential reforestation sites; effective monitoring of plant growth and biodiversity; data-driven decision-making for reforestation strategies	High-resolution imaging and multispectral sensors mounted on UAVs for detailed analysis of terrain, soil quality, and biodiversity. UAVs equipped for real-time data transmission and analysis for effective monitoring of reforestation efforts.	Deploy UAVs equipped with advanced sensors for comprehensive terrain and biodiversity analysis in potential reforestation areas. Regular monitoring missions to track plant growth and assess reforestation success. Develop a data repository for ongoing analysis and strategy refinement.
• Automated Reforestation and Resource Distribution	Unmanned Sowing and Input Delivery Systems	Efficient and scalable reforestation processes; precise and controlled distribution of seeds and essential resources; automation to enhance speed and reduce manual labor	Use of autonomous aerial and ground vehicles for high-precision seed distribution and resource delivery in reforestation projects. Systems equipped with specialized compartments for accurate seeding and resource allocation. UAVs/UGVs with significant payload capacity and GPS-guided flight paths for large-scale operations.	Introduce unmanned systems for automated and large-scale reforestation efforts. Develop protocols for precision drops and resource distribution in targeted reforestation zones. Train personnel in the operation and maintenance of these systems for optimal use.

Operational Scenario	Emerging Tech-nologies	Idealized Capability Requirement	Capabilities Indicated in Field Technology Showcase	Recommended Course of Action
• Wildfire Prevention and Containment	Scraping Systems for Strategic Fire Line Creation	Rapid deployment of fire lines to contain and prevent the spread of wildfires; enhancement of overall forest fire management capabilities; strategic and efficient use of resources for fire prevention	Deployment of UGVs equipped with specialized tools and robotic systems for rapid and strategic clearing of vegetation to create fire lines. Systems designed for autonomous navigation, adapting to varied terrains, and using fire-resistant materials. Capabilities for robust off-road use and extended operation times.	Implement advanced scraping systems with UGVs for strategic fire line creation in high-risk areas. Develop a program for regular maintenance and upgrading of these systems. Train forest management teams in the use of these tools for effective wildfire prevention and containment strategies.

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 forest management. These technologies and practices have the potential to strengthen forests 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 forest 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 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 may comprise of members from the forests and allied departments, research, and industry sectors, as well as members from the local government. In this committee, UCOST could act as the member convener.

This committee may be responsible for researching and developing innovative climate adaptive forest management 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 may 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 forests in the Indian Himalayan Region

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 Hon'ble 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 forests 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 forest management. Capacity building of local stakeholders should include training on scientific and technological advancements in climate adaptive forests, community-led research and analysis, and the development of tools and strategies for monitoring and evaluation of climate adaptive forest management 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 forest management 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 forest management 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 forests. 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 forest management practices.

This data should be analysed to identify areas where the deployment of technology could help. 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 forests 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 agriculture 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, communities in the region are increasingly vulnerable to forest fires, land degradation, etc.

Therefore, it is essential that the government take proactive measures to promote climate adaptive forests 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 forest 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)

Dr Piyush Joshi
Sr. Scientific Officer

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No. 23381/UCS&T/RSC (USSTC)/2023 Dehradun,
Dated 11[th] October, 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 18th – 19th October 2023.

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

The names of the shortlisted innovators are as follows:

1. Optimised Electrotech Pvt. Ltd.
2. DTown Robotics Private limited
3. Resham Sutra Pvt. Ltd.
4. Hydrogreens Agri Solutions Pvt. Ltd.
5. Schoppen Solutions Private Limited
6. GreenPod Labs Pvt. Ltd.
7. Rural Mandi Fintech Private Limited
8. Prayogik Technologies Private Limited
9. Gramodygh Vikas Sansthan

We look forward to their participation in the event. In case of any queries or concerns, please contact me at piyush@ucost.in.

(Dr. Piyush Joshi)

Sr. Scientific Officer, UCOST

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