Template/Pro forma for Submission

NMHS-Himalayan Institutional Project Grant

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

NMHS Reference No.:	NMHS/2018-19/SG65/65

Date of Submission:	0	8	0	6	2	0	2	3
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

PROJECT TITLE (IN CAPITAL)

GEOSPATIAL MAPPING OF RET AND OTHER IMPORTANT NWFP SPECIES AND CAPACITY BUILDING FOR THEIR COMMUNITY BASED CONSERVATION IN THE TRIBAL AREAS OF UTTARAKHAND

Project Duration: from **01.02.2019** to **31.10.2022**

***Submitted to*:**
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GENERAL INSTRUCTIONS:

1. The Final Technical Report (FTR) has to commence from the date of start of the Project (as per the Sanction Order issued at the start of the project) till its completion. Each detail has to comply with the NMHS Sanction Order.
2. The FTR should be neatly typed (in Arial with font size 11 with 1.5 spacing between the lines) with all details as per the enclosed format for direct reproduction by photo-offset process. Colored Photographs (4-5 good action photographs), tables and graphs should be accommodated within the report or should be annexed with captions. Sketches and diagrammatic illustrations may also be given giving step-by-step details about the methodology followed in technology development/modulation, transfer and training. Any correction or rewriting should be avoided. Please give information under each head in serial order.
3. Training/ Capacity Building Manuals (with details contents of training programme technical details and techniques involved) or any such display material related to project activities along with slides, charts, photographs should be brought at the venue of the Annual Monitoring & Evaluation (M&E) Workshop and sent at the NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora 263643, Uttarakhand. In all Knowledge Products, the Grant/ Fund support of the NMHS should be duly acknowledged.
4. The FTR Format is in sync with many other essential requirements and norms desired by the Govt. of India time to time, so each section of the NMHS-FTR needs to duly filled by the proponent and verified by the Head of the Lead Implementing Organization/ Institution/ University.
5. Five (5) bound hard copies of the Project Final Technical Report (FTR) and a soft copy should be submitted to the **Nodal Officer, NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora, Uttarakhand**.

The FTR is to be submitted into following two parts:

Part A –Project Summary Report

Part B–Project Detailed Report

Following Financial and other necessary documents/certificates need to be submitted along with Final Technical Report (FTR):

Annexure I	**Consolidated and Audited Utilization Certificate (UC) & Statement of Expenditure (SE)**, including interest earned for the last Fiscal year including the duly filled GFR-19A (with year-wise break-up)
Annexure II	**Consolidated Interest Earned Certificate**
Annexure III	**Consolidated Assets Certificate** showing the cost of the equipment in Foreign and Indian currency, Date of Purchase, etc. (with break-up as per the NMHS Sanction Order and year wise).
Annexure IV	**List of all the equipment, assets and peripherals** purchased through the NMHS grant with current status of use including location of deployment.
Annexure V	Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department
Annexure VI	**Details, Declaration and Refund of any Unspent Balance transferred through Real-Time Gross System (RTGS) in favor of NMHS GIA General**

DSL: Date of Sanction Letter

2	**9**	**0**	**1**	**2**	**0**	**1**	**9**
d	d	m	m	y	y	y	y

DPC: Date of Project Completion

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

Part A: Project Summary Report

1. Project Description

i.	Project Reference No.	NMHS/2018-19/SG65/65							
ii.	Type of Project	Small Grant	✓	Medium Grant		Large Grant			
iii.	Project Title	Geospatial mapping of RET and other important NWFP species and capacity building for their community based conservation in the tribal areas of Uttarakhand							
iv.	State under which Project is Sanctioned	Uttarakhand							
v.	Project Sites (IHR States covered) (Maps to be attached)	Uttarakhand							
vi.	Scale of Project Operation	Local	✓	Regional		Pan-Himalayan			
vii.	Total Budget/ Outlay of the Project	₹ 32,00,000/-							
viii.	Lead Agency								
	Principal Investigator (PI)	Dr. Manoj Kumar							
	Co-Principal Investigator (Co-PI)	Dr. Hukum Singh, Forest Research Institute, Dehradun Dr. P. K. Verma, Forest Research Institute, Dehradun Dr. P. S. Rawat, Forest Research Institute, Dehradun Dr. A. K. Tripathi, Forest Research Institute, Dehradun								
ix.	Project Implementing Partners	Forest Research Institute, Dehradun							
	Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail	Dr. Manoj Kumar, Scientist- C, IT & GIS Discipline Ph. No:8077413164 E-mail :manojfri@gmail.com							

2. Project Outcomes

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

The Indian Himalayas are the repository of rich biodiversity with many endemic species and provide a multitude of ecosystem services. With due pace of increasing human interferences and unsustainable harvesting, biodiversity of the region is threatened and require conservation planning. Tribal communities of the region have considerable dependence on the forest produce that also have contribution in healthcare and pharmaceutical industries. Many of these forest produce are derived from plants that are on the verge of extinction due to over extraction from wild, whereas climate change imposes an additional threat. Therefore, it is necessary to identify such plants that need to be prioritized for conservation. Different species have different use-value with dissimilar threats, thus needs systematic evaluation to prioritise species conservation. At the same time, different species have different habitat preference. Therefore, it essential to map suitable habitat for these species for current as well as future climate scenarios to prioritize conservation areas and to prepare a conservation plan. The project was conceptualized with the objectives of (i) identification of priority NWFP/RET species and mapping of their suitable habitat for conservation to formulate actions involving local community, (ii) capacity building of tribal community for additional income generation and biodiversity conservation, (iii) modelling the potential sites of cultivation and conservation for the identified priority species, (iv) assessing projected impacts of climate change on habitat suitability of identified priority species and their resilience planning, and (v) development of web based Biodiversity Information System (BIS) for the study region. A customized questionnaire was developed separately to collect information at the local community level and to have expert opinion. Available published literature for the study region were also referred for the prioritization of species. A total of 89 plant species were reported by experts and locals that have medicinal values falling under NWFP category. Multiple-use of plants for different purposes make them more threatened while the threat level is also guided by the part of the plant that is extracted. All such factors were considered to rank species of conservation priority using (i) Nativity/endemism (N), (ii) IUCN Threat level (T), (iii) multiple Usages of species (U), and (iv) Parts extracted or used (P). Range of values for each factor was allocated scores after deducing logical inference through published literature, local community opinion and expert level consultations. Listing and ranking of fifty priority species were done while economical values of these top listed species were used to suggest species that can be adopted by the local community for cultivation to improve financial status. It is observed that Aconitum heterophyllumis top ranked species followed by *Dactylorhiza hatagirea*, *Paris polyphyllum, Angelica glauca, Gentiana kurroo, Podophyllum hexandrum,* etc. Six plant species viz. *Aconitum heterophyllum, Gentiana kurroo, Taxus wallichiana, Podophyllum hexandrum, Swertia chirayita* and *Asparagus racemosus*, for which sufficient geo-coordinates were available, were considered for species distribution modelling. All the data was processed using R statistical software. To map current and projected habitat suitability, generalized logistic models, random forest, Maxent, and neural network-based modelling approaches were used. The variation in accuracy when using various approaches has been summarized. Vulnerability assessment for the future climate change

scenarios revealed an increase in the climate suitable area under future climate scenarios. The most influential variable guiding the suitability was an increase in temperature, which might be one of the reasons for having increased suitable habitat in the colder region, which is expected to warm to achieve suitable habitat temperature. Loss of suitable habitat was projected at lower elevations, whereas suitability increased at higher elevations. Chakrata region has enough potential to emerge as an in-situ conservation and cultivation site for low and mid altitude NWFP plant species. The present study would serve as pilot study that could be replicated for larger extent for prioritising species of conservation in other habitats.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (in bullets points)
1	Identification of priority species of conservation in tribal blocks dominated by Jaunsari community.	• Listing of NWFP/RET plant species comprising more than 50 plant species of the region. • Questionnaire that can be used for prioritizing species of conservation was made at two levels. One for the experts and another one for the community and local farmers. • List of top priority plant species in Kalsi, Chakrata and Tiuni based on endemism, parts used, threat level, use value, altitude, ease of cultivation and market value prepared. • A final list of prioritized species.
2	Develop model for mapping the potential sites of cultivation and conservation for the identified priority species.	• Geo-coordinates of top priority plant species collected based on field survey. • Raster files of topographic parameters, forest type, forest cover and climatic parameters prepared. • Multiple spatial layers developed that can be used in modelling the habitat suitability of species. • Spatial model built for mapping habitat suitability.
3	Capacity building of tribal community for additional income generation and biodiversity conservation.	This objective could not be achieved because of insufficient time. While implementing the project it was realized that capacity building would require a dedicated project with considerable time. This will be achieved through a separate project where learnings of the present project will be utilized.

4	Projected impacts of climate change on habitat suitability of identified priority species and its resilience planning.	• Final habitat suitability map under present scenarios was developed. • Final habitat suitability map under future climate change scenarios was developed.
5	Development of web based Biodiversity Information System (BIS) for the study region.	• Initial framework of Biodiversity Information System developed.

2.3. Outputs in terms of Quantifiable Deliverables*

S.No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, & Reason thereof:
1	Prioritizing the High value species on the basis of Extensive consultation with local farmers, grower of the species, traders, medicinal boards	Number of species prioritized (Nos.)	10	--
	Develop the Habitat Maps of selected species (>10 Species)	Habitat Map developed (Nos.)	10	--
2	Tailored training at field level for the capacity building of tribal communities (> 50 HH)	No. of trainings organized (Nos.)	Nil	Capacity building objective is planned to be achieved through a separate follow up project.
3	Compilation of available information for the web based content, development of content management system appropriate for the BIS	No. of Reports/Research articles/Policy documents/Manual prepared and published (Nos.)	3 papers communicated	

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

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

S.No.	Particulars	Number/Brief Details	Remarks/ Attachment
1.	New Methodology developed		
2.	New Models/ Process/ Strategy developed		
3.	New Species identified		
4.	New Database established		

S.No.	Particulars	Number/Brief Details	Remarks/ Attachment
5.	New Patent, if any		
	I. Filed (Indian/ International)		
	II. Granted (Indian/ International)		
	III. Technology Transfer(if any)		
6.	Others (if any)		

3. Technological Intervention

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

4. New Data Generated over the Baseline Data

S. No.	New Data Details	Status of Existing Baseline	Additionality and Utilisation New data
1.	Information on rare, endangered and threatened species that require urgent conservation planning for its protection was collected.	Fragmented information available in unorganised way.	Can be used in conservation planning and its implementation.

5. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S. No.	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	**ST**	**Woman**	**Total**
1.	Workshops						
2.	On Field Trainings						
3.	Skill Development						
4.	Academic Supports						
	Others (if any)						

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

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held	Beneficiaries
1.	Sustainable Development Goal (SDG)	Goal 10: reduce inequalities Goal 13: Climate action Goal 15: Life on Land		• Project supports marginalised and disadvantaged group of tribal community in Chakrata region of Uttarakhand for their inclusive growth and income enhancement (Goal 10). • Project identifies suitable habitat of priority species under projected climate for their planting and conservation (Goal 13). • Project helps conservation of forest by suggesting alternative land outside forest for cultivation of species being extracted.
2.	Climate Change/INDC targets			
3.	International Commitments			
4.	Bilateral engagements			
5.	National Policies			
6.	Others collaborations			

7. Project Stakeholders/ Beneficiaries and Impacts

S. No.	Stakeholders	Support Activities	Impacts
1.	Gram Panchayats		
2.	Govt Departments (Agriculture/ Forest)		
3.	Villagers		
4.	SC Community		
5.	ST Community		
6.	Women Group		
	Others (if any)		

8. Financial Summary (Cumulative)

S. No.	Financial Position/Budget Head	Funds Received	Expenditure/ Utilized	% of Total cost
I.	Salaries/Manpower cost			
II.	Travel			
III.	Expendables &Consumables			
IV.	Contingencies			
V.	Activities & Other Project cost			
VI.	Institutional Charges			
VII.	Equipments			
	Total			
	Interest earned			
	Grand Total			

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

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

S. No.	Name ofEquipments	Cost (INR)	Utilisation of the Equipment after project
1.	UPS	17,346/-	
2.	Workstation*	3,19,905/-	
3.			
4.			
5.			

Details provided separately **(*ref* **Annexure III &IV).**

10. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States Covered	1	Uttarakhand
2.	Project Site/ Field Stations Developed		
3.	New Methods/ Modeling Developed	2	• Method for prioritizing species • Method for mapping suitable habitat
4.	No. of Trainings arranged		
5.	No of beneficiaries attended trainings		
6.	Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA):	1	I JRF
7.	SC stakeholders benefited		
8.	ST stakeholders benefited		
9.	Women Empowered		
10.	No of Workshops Arranged along with level of participation		

11.	On field Demonstration Models initiated		
12.	Livelihood Options promoted		
13.	Technical/ Training Manuals prepared		
14.	Processing Units established		
15.	No of Species Collected		
16.	New Species identified		
17.	New Database generated (Types):	**1**	• Biodiversity Information System developed
	Others (if any)		

11. Knowledge Products and Publications:

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

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

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

Particulars	Recommendations
Utility of the Project Findings	Conservation of rare, endangered and threatened categories of forest species.
Replicability of Project	Methods of the project can be used for other habitats.
Exit Strategy	Capacity building of local community for the cultivation of priority species having high market value will be done through a follow up project. The information and knowledge gained while implementing the present project will be utilized in the follow up project.

(**PROJECT PROPONENT/ ORDINATOR**)

(Signed and Stamped)

(**HEAD OF THE INSTITUTION**)

(Signed and Stamped)

Place: ……..
Date:…../……/……

PART B: PROJECT DETAILED REPORT

3 EXECUTIVE SUMMARY

Biodiversity is the basis of the existence and survival of life on Earth. Biodiversity supports in functioning of the ecosystems by providing essential products and services in the form of medicine, fresh water, food and oxygen etc. Himalayan Ecosystem, identified as one of the important ecosystem providing essential ecosystem services requires conservation and protection of its biodiversity. Out of total NTFP utilization in India, medicinal plants make 80%, plants of edible use make 40%, others material and cultural requirements make 7.5%, fibre utilisation makes 6%, fodder makes 5% and others make less than 5%. Out of 17,000 flowering plants and about 31,000 species of non-flowering species, 10,000 species are used by the people in one form or the other. Socio-economic and ecological characteristics of western Himalayas have led to development in utilization of NTFP. 17 percent of the landless people depend on it for daily paid labour and 39 percent are involved in NTFP collection as an occupation (Shiva, 1996). Conservation and protection of the important Medicinal and Aromatic Plants (MAPs); Rare, Endangered and Threatened (RET) plants and Non-wood Forest Products (NWFPs) is extremely important in this region, however, information on available potential habitat for their in situ conservation or its cultivation in agriculture lands is often less known for most of the species. The project intends for biodiversity conservation in selected tribal blocks of Uttarakhand for in situ conservation, dissemination of information related to biodiversity conservation and cultivation of species assisted by training on propagation technique mainly for Jaunsari tribal community in the Chakrata, Kalsi and Tiuni tribal tehsils of district Dehradun.

The occurrence of particular species in a confined space is guided by various factors like topographic variations of slope, aspect, elevation, varying climatic conditions, landscape matrices, soil properties, and land disturbances. However, information on each of these variables for the species needs to be

comprehended and analysed for the demarcation of potential sites of conservation or cultivation, which has not been done for many of the important species. The project intends to first identify potential species that are important and are threatened or on the verge of extinction, which demand immediate scientific intervention for their conservation. The study has developed a model for the identification and conservation of potential habitat for identified species. Capacity building of the communities for the cultivation and propagation of the identified selected species near to the mapped potential habitats has been done through a tailored training programme. Cultivation of these species in their identified suitable agriculture lands mapped through this project is expected to reduce the pressure of extraction from their wild habitats that are protected areas. It aims to provide detailed information on the diversity, distribution, use pattern, and conservation status of selected NTFPs/RET species with market potential, as well as to propose a possible method for long-term management and role in the livelihood improvement of dependent communities. Six plant species, viz., *Aconitum heterophyllum, Gentiana kurroo, Taxus wallichiana, Podophyllum hexandrum, Swertia chirayita,* and *Asparagus racemosus*, for which sufficient geo-coordinates were available, were considered for species distribution modelling. All the data was processed using R software. To map current and projected habitat suitability, generalised logistic models, random forest, Maxent, and neural network-based modelling approaches were used. The variation in accuracy when using various approaches has been summarised. Vulnerability assessment for the future climate change scenarios revealed an increase in the climate suitable area under future climate scenarios.

2. INTRODUCTION

3.5 Background of the Project (max. 500 words):

Himalayan ecosystems are recognised as one of the richest depositories of biodiversity, providing critical ecosystem services to many people. At the same time, various factors, both natural as well as anthropogenic, threaten its biodiversity. Ever increasing population pressure has increased the demand for the extraction of important species that have medicinal and other commercial values. Limited available space, on the other hand, has aggravated the problem manifold. The knowledge of potential habitat is documented for many species, but the chances of successful cultivation in other similar resembling spaces have not been mapped and are not known exactly for many of these species. In spite of various protection measures to conserve these species in the protected areas, they are often targeted and are illegally extracted because of their high commercial value. If these species are encouraged to be grown in other cultivable lands other than the protected areas, the pressure on their natural habitat will certainly be curtailed. This requires information on mapping of the available suitable space and dissemination of information to the cultivars. The project aimed to map the cultivable lands in the selected tribal blocks of Uttarakhand, which is one of the states of the Indian Western Himalayan (IWH) region.

The degree of establishment of species is the outcome of several factors, including climate, geology, topography, vegetation, landscape structure, ecosystem properties, and the physiological traits providing opportunity for the establishment of a particular species. Despite the fact that landscape ecology (the study of the effect of spatial pattern on ecological processes; Turner 1989) emerged as a scientific discipline more than two decades ago, little research has addressed the effect of landscape structure on species occurrence (Deckers et al. 2005). Topographic variations of slope, aspect, elevation, environmental condition, landscape metrics, soil properties, and land disturbances guide the preference level of occurrence of a species. Places with a variety of landforms and larger climatic variations provide an opportunity for the establishment of different kinds of species. Himalayan ecosystems provide favourable climatic conditions for the establishment and growth of many important species in their many parts. However, the realised niche or natural distribution of species is restricted to certain areas, which might be largely influenced by landscape factors which require investigation to map suitable habitat. The present research is aimed at developing a model for mapping potential habitats governed by various factors such as landscape structure (defined by various landscape metrics) and topographic features (elevation; distance from canal, river, road, settlement) supporting the establishment of a species together with development of an online information repository to disseminate important information on plant biodiversity.

2.2 Overview of the Major Issues to be Addressed (max. 1000 words)

Population growth, deforestation, and climate change are increasingly putting pressure on the realised niche of species. Landscapes change constantly because of natural and anthropogenic drivers. These drivers underlie fragmentation and habitat loss, which are the greatest threats to biodiversity and ecosystem services. Coupled with social, economic, and political stresses, this puts constant pressure on the shrinkage of available space and makes the species more vulnerable to extinction. Once these factors are clearly known and models are developed, this can help in identifying the potential habitat for conservation and cultivation that would help in management of biodiversity.

Due to growing competition among collectors, it is common practise to conduct early in-situ harvesting, often when the plants are at an immature reproductive stage. This causes not only the insufficient collection of raw material but also leads to habitat destruction to create a situation where the natural regeneration of the plants is adversely affected (Badola and Aitken, 2003). Hence, inappropriate harvest practises are major concerns that need to be tackled using proper continual training. The total numbers of plant species with medicinal usage are observed more at the higher altitudes than the lower ones (Malik et al., 2015). In India, most of the traded medicinal plants are collected from the wild, and most often in a destructive and unsustainable manner (Dhar et al. 2000).

The Uttarakhand government is making a continuous effort to promote conservation and cultivation of MAPs. These measures include herbal gardens, nurseries for supply of quality material, cultivation of threatened species, conservation and development of areas naturally rich in MAPs. Even though the state forest department has banned the collection of 30 medicinal plants (Garbyal et al. 2005), there is a persistent illegal trade in high-value MAP. Since collection of NWFPs is freely accessible without paying any royalty to the state government, it partly encourages over exploitation of some species (Balemie and Kebebew, 2006). The number of farmers engaged in the cultivation of aromatic plants in Uttarakhand has dramatically increased from 301 in 2003-04 to 2714 in 2006-2007 and the area under aromatic plants has increased tenfold. Despite the existence of successful examples and the ongoing conservation effort through cultivation, the locals prefer wild harvest. Lack of market demand, lack of continual training, and improper prioritisation cause insufficient and often unpredictable output in terms of economic profit, which demotivates NWFP cultivators to continue.

Prioritization based on endemism, threat status, mode of harvest and use value of plant species as demonstrated by Kala et al., 2004 and further improved by Tali et al., 2019 is good for prioritising rare and endangered plants for conservation, but the method does not consider market demand and feasibility of cultivation of a particular species, such as whether it will be profitable to the producers and traders. Conservation and protection of the important Medicinal and Aromatic Plants (MAPs); rare, endangered and threatened (RET) plants; and non-wood forest products (NWFPs) is vitally important. However, information on the availability of potential space for their cultivation or *in situ* conservation is not widely known for many species.

The project intends to facilitate cultivation of selected priority species together with their *in situ* conservation for species which have been widely extracted from the tribal areas. There is a lack of information regarding the available lands that could be a potential space for the cultivation of selected priority species. The project involved mapping of suitable cultivation areas, in situ conservation areas, and dissemination of information related to biodiversity conservation in the Chakrata, Kalsi, and Tiuni tribal sub-districts (tehsils) of Dehradun, Uttarakhand. This was a pilot study to test the viability of a similar initiative on a larger scale.

2.3 Baseline Data and Project Scope (max. 1000 words)

Different species have different use-values with dissimilar threats, thus needing systematic evaluation to prioritise species conservation. At the same time, different species have different habitat preferences. Therefore, it is essential to map suitable habitats for these species for current as well as future climate scenarios to prioritise conservation areas and prepare a conservation plan. Changing climatic conditions in the future may alter the natural habitat and distribution of NTFP/RET species, resulting in the loss of the concerned species in an ecosystem. To predict future habitat suitability and

distribution in the natural ecosystem, species distribution modelling can be done to map the potential habitats of species. Present work demonstrates the use of species distribution modelling to map suitable habitats under present and future climate change scenarios. We also demonstrate how to prioritise species for its conservation planning. The work was implemented in the Chakrata, Kalsi, and Tiuni tribal tehsils of Dehradun district.

In rural areas like Kalsi, Chakrata, and Tiuni tehsil, much important information lies with the local people, and hence retrieving information from them is important. The locals have the most up-to-date knowledge of the flora in their immediate vicinity. Therefore, semi-structured questionnaire-based surveys were conducted in 36 villages in the study area, 9 in Kalsi, 13 in Chakrata, and 14 in Tiuni tehsil. Information on NWFP species of the region and their uses was compiled by interviewing locals using a questionnaire specifically designed for it. The interest of locals in capacity building and cultivation programmes was also noted. At the same time, the opinion of experts working in similar domains was also noted through a different set of a questionnaire specifically designed to collect information from experts. We visited different institutes, NGOs, research organizations, and individuals to collect information on expert opinion. The collected information about common names, botanical names, taxonomic classification, habitat, uses, parts used, sowing time, harvest period, etc. was compiled. The working plan of Chakrata forest, Forest Flora of Chakrata, research papers, and other published literature were referred to collect desired information. Information from the IUCN database, Integrated Taxonomic Information System database, National Centre for Biotechnology Information database, and other databases were also referred.

After extensive literature review, more than 400 plant species were identified to occur in the state of Uttarakhand, which is also the richest Western Himalayan Region state in terms of natural availability of MAPs and NWFP plant species. Out of these identified 400 plant species, 76 plants were found in IUCN Red List data, which included 8 RET, 65 Least Concerned, and 3 Data Deficient plants.

The Conservation Assessment and Management Planning (CAMP) list of Uttarakhand (http://www.smpbuk.org/) contains 60 conservation priority plant species in the state. Plants such as *A. heterophyllum, Allium stracheyi, Angelica glauca, D. hatagirea, Emblica officinalis, Picrorhiza kurrooa, P. hexandrum, Rheum emodi, Swertia chirayita, Terminalia chebula*, and *Valeriana jatamansi* are among the Globally Significant Medicinal Plants (Negi et al., 2018). *A. heterophyllum* (Atis) has an annual trade of about 100-200 metric tonnes in India. It is used in many ayurvedic formulations like Balachatur bhadrikachurna, Chandraprabhavati, Khadiraditaila, etc. (Kumar & Singhal, 2019). According to the National Medicinal Plants Board, *Bauhinia variegata* has a current market demand of about 100–200 metric tonnes annually. Talispatra *(Taxus baccata*) and Devadaru (*Cedrus deodara*) are also important ayurvedic medicinal plants, and their annual market demand is 100–200 and 1000–2000 metric tons, respectively.

The project scope also included to develop Biodiversity Information System that would contain vital information related to the biodiversity of the region.

2.4 Project Objectives and Target Deliverables (as per the NMHS Sanction Order)

- Identification of priority species of conservation in tribal blocks dominated by Jaunsari community in Kalsi, Chakrata and Tiuni tehsils of Dehradun.
- Develop model for mapping the potential sites of cultivation and conservation for the identified priority species.
- Capacity building of tribal community for additional income generation and biodiversity conservation.
- Projected impacts of climate change on habitat suitability of identified priority species and its resilience planning.
- Development of web based biodiversity information system (BIS) for the study region.

3 METHODOLOGIES, STARTEGY AND APPROACH

3.1 Methodologies used for the study (max. 1000 words)

3.1.1 Study area:

The project site consists of Kalsi, Chakrata, and Tiuni tehsils of Dehradun district. It lies between 31° 2’ 15’’ and 30° 30’ 28" N and 77° 42’ 7" and 78° 5’ 1" E (Fig 1). The region is bordered by Himachal Pradesh on the west; Uttarkashi on the north-east; and Tehri Garhwal on the east. The region is popularly known as Jaunsar-Bawar because of the Jaunsar and Bawar tribesmen living in the area. Chakrata tehsil has higher altitude areas as compared to Kalsi and Tiuni and hence receives heavy snowfall. Rikhnar Range, Babar Range, Molta Range, Kanasar Range, Devdhar Range, and River Valley Range are the few ranges in the study area. View of some of the selected area is shown in Figs. 2-5.

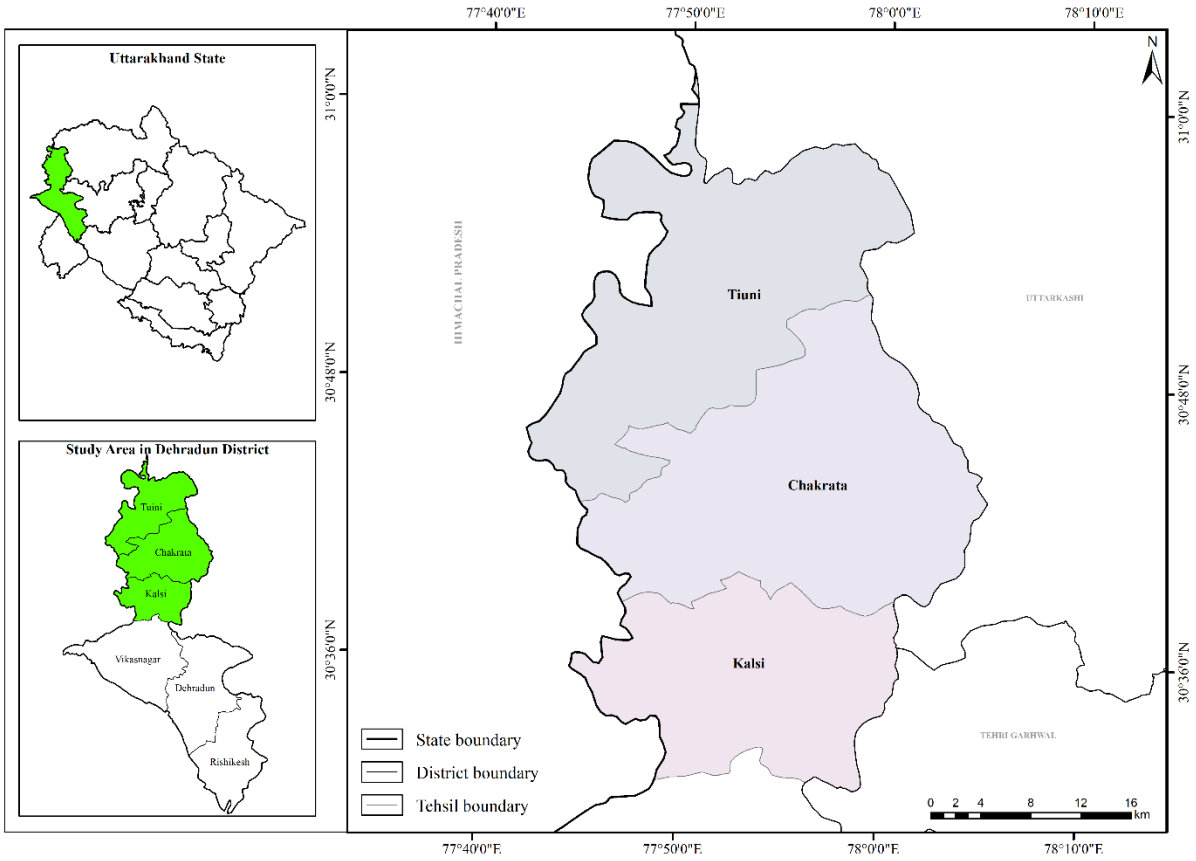


Fig. 1: Map showing location of study area in the Himalayan state of Uttarakhand, India

Project site:

Fig.1: View of Bhudher area (at left). **Fig.2:** View of Rikhnar Range from Chakrata (at right)


Fig. 4: Mountainous landscape of Kalsi tehsil (at left). **Fig.3:** Distant village in Kalsi tehsil (at right)

3.2 Preparatory Actions and Agencies Involved (max. 1000 words)

3.3 Details of Scientific data collected and Equipments Used (max 500 words)

For the prioritization of species, information was gathered from a variety of sources, including literature review, interaction with the people of the Uttarakhand Biodiversity Board, non-governmental organizations etc. The project area includes the tehsils of Kalsi, Chakrata, and Tiuni in the Dehradun district of Uttarakhand. Researchers and experts who have previously or are currently conducting studies on the NWFP/RET and priority species of the Indian Himalayan Region were also contacted. They were approached for questionnaire-based survey that was used for stakeholder consultation to priorities the species for conservation. Two different questionnaires were prepared separately for each level that included experts and local farmers. Climatic and non-climatic variable processing using open source software i.e. R. Species distribution modelling for selected plant species was implemented in open-source software i.e. R. The common and scientific names of some of the priority species for conservation in the region is shown in Table 1.

Table 1: Priority plant species for conservation found in the Kalsi, Chakrata and Tiuni tehsils of Uttarakhand, India

Common Name	Scientific Name	Common Name	Scientific Name
Khair/Kher	*Acacia catechu*	Shrikkoli	*Lilium polyphyllum*
Atis	*Aconitum heterophyllum*	Kamil	*Mallotusphilippensis*
Bach	*Acorus calamus*	Katiyal	*Morina longifolia*
Pangar	*Aesculus indica*	Kimu	*Morus serrata*
Pudina Ghaans	*Ageratum conyzoides*	Tambaku	*Nicotiana tabacum*
Neelkanthi	*Ajuga parviflora*	Tulsi	*Ocimumtenuiflorum*
Jambu	*Allium stracheyi*	Satva/Satuva	*Paris polyphylla*
Choru	*Angelica glauca*	Avla/Amla	*Phyllanthus emblica*
Chamur	*Artemisia roxburghiana*	Ban Kakdi	*Podophyllum hexandrum*
Sharanvi	*Asparagus racemosus*	SalabMisri	*Polygonatumverticillatum*

Common Name	Scientific Name
Neem	*Azadirachta indica*
Kachnar/Kachnal	*Bauhinia variegata*
Chitra	*Berberis aristata*
Kasmal	*Berberis asiatica*
Semal	*Bombax ceiba*
Ank	*Calotropis procera*
Bhang	*Cannabis sativa*
Kalijiri	*Carum carvi*
Amaltas	*Cassia fistula*
Sadabahar	*Catharanthus roseus*
Deodar	*Cedrus deodar*
Malkangni	*Celastruspaniculatus*
Khadik	*Celtis australis*
Padam/Paja	*Cerasus cerasoides*
TejPatta	*Cinnamomum tamala*
Dalchini	*Cinnamomum verum*
Nimbu	*Citrus medica*
Kakdi	*Cucumis sativus*
Haldi	*Curcuma longa*
Kachoor	*Curcuma raktakanta*
Akash Bel	*Cuscutareflexa*
Nagarmotha	*Cyperus scariosus*
Hatajari	*Dactylorhizahatagirea*
Nirbhishi	*Delphinium denudatum*
Chalan	*Desmodiumgangeticum*
Kairo	*Desmodiummultiflorum*
Banchulu	*Devendraea angustifolia*
Tirmal	*Ficus auriculata*
Fedu	*Ficus palmata*
Gular	*Ficus racemosa*
Karu	*Gentiana Kurroo*
Kala Bach	*Gloriosa superba*
Bhimal	*Grewia optiva/oppositifolia*
Vriddhi	*Habenariaedgeworthii*
Jatropha	*Jatropha curcas*

Common Name	Scientific Name
Bhekoi	*Prinsepia utilis*
Chullu/Van Chullu	*Prunus armeniaca*
Padam	*Prunus Puddum*
Nashpati	*Pyrus comminus*
Moru	*Quercus dilatata*
Banj	*Quercus leucotrichophora*
Kharsu	*Quercus semecarpifolia*
Kakoli	*Rascoea purpurea*
Archa	*Rheum webbianum*
Burans	*Rhododendron arboreum*
Kujoi	*Rosa brunonii*
Karanvi/Karanoi	*Roylea cinerea*
Almoda	*Rumex hastatus*
Ritha	*Sapindusmukorossi*
Tilairi	*Sarcococcasaligna*
Kuth	*Saussureacostus*
Bhutkeshi	*Selinumvaginatum*
Kathurchara	*Skimmialaureola*
Katiya/Kateri/Kantakari	*Solanum virginianum*
Chiraita	*Swertia chirayita*
Thuner	*Taxus wallichiana*
Baheda	*Terminalia bellirica*
Harad	*Terminalia chebula*
Pili Jadi	*Thalictrum foliolosum*
Dande ki Javan	*Thymus linearis*
Giloy	*Tinospora cordifolia*
Ajwain	*Trachyspermumammi*
Bichughas	*Urtica dioica*
Jatamansi/Mushkbala	*Valerianajatamansi*
Vanafsa	*Viola pilosa*
Songi/Nirgundi	*Vitex negundo*
Timur	*Zanthoxylum armatum*
Adrak	*Zingiber officinale*
Jangli Ber	*Ziziphus mauritiana*

3.4 Methodology adopted for the prioritization of species for the conservation and propagation and important findings

An extensive literature review was undertaken to list various NTFP plant species in the study area. In rural areas like Kalsi, Chakrata and Tiuni tehsil, important information lies with the local people, and hence retrieving information from them is important. The locals have the most up-to-date knowledge of the flora in their immediate vicinity. Therefore, semi-structured questionnaire-based surveys were conducted in 36 villages in the study area i.e., 9 in Kalsi, 13 in Chakrata and 14 in Tiuni tehsil. Information on NWFP species of the region and their uses was compiled by interviewing locals using a questionnaire specifically designed for it. The interest of locals in capacity building and cultivation

programmes was also noted. At the same time, the opinions of experts working in similar domains were also noted through a different set of questionnaires specifically designed to collect information from experts. We visited different institutes, NGOs, research organizations, and individuals to collect information on expert opinion. A schematic flow diagram of the overall adopted methodology is depicted in Figure 6. A list of species on the basis of information provided by the local community and the experts is presented in Table 2. The overall score for prioritisation of species was done on the basis of individual scores given for endemism, threat level, use value, and part harvested.

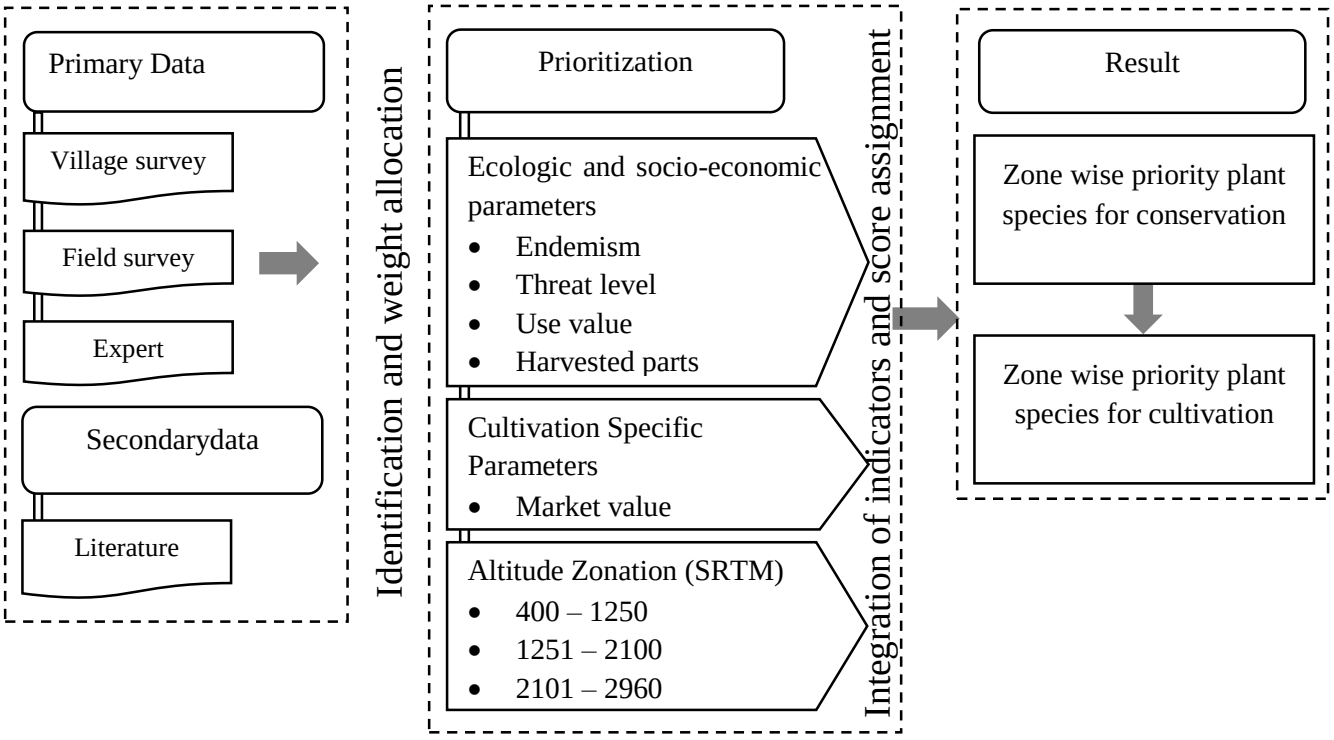


Fig.6: Schematic representation of methodology adopted for the prioritization of species

3.5 Primary Data Collected (max 500 words)

During a 2-year field survey and data collection across the selected sites, the occurrence sites of selected NTFPs/RET plant species in the study region were collected. The extensive questionnaire based surveys was done in the villages of Kalsi, Chakrata, and Tiuni Tehsils to collect information from the local community. Field based surveys in the identified regions of species occurrence as per the feedback received from the people of forest department and local communities were done to collect geo-coordinates of occurrence location using hand held GPS. The top priority plant species in Kalsi, Chakrata, and Tiuni were listed based on endemism, parts used, threat level, use value, altitude, ease of cultivation, and market value after stakeholder consultation and sampling in the study region. Experts from the Biodiversity Board and Medicinal Plants Board, Botany and NTFP experts, Ayurveda practitioners, and other experts in the field were also consulted. The systematic literature review was done before doing fieldwork. Reconnaissance surveys could identify natural habitats and related

environmental characteristics which was used in species distribution modelling to map viable habitats for current and future climate change scenarios.

3.6 Details of Field Survey arranged (max 500 words)

The occurrence locations of selected NTFPs/RET plant species in the study region were collected during a 2-year field survey. First field visit (Sept - Oct, 2019) - A visit to Chakrata & Deoban nursery was made, and contact was established with the nursery caretaker. Before the end of the season, *Aconitum heterophyllum, Gentiana kurroo, and Habenaria intermedia* were discovered in the wild. 2nd field visit (January - February, 2020) and 3rd field visit (March - April, 2020) was done specifically for the surveys in 36 villages of Kalsi, Chakrata, and Tiuni Tehsils to collect feedback of communities using a standard questionnaire developed for the project. The field survey was carried out with the assistance of the Deoban nursery caretaker. Multiple surveys were done to collect information on occurrence locations of rare NTFP plant species endemic to Chakrata's high altitude region. Field photos and geo-coordinates of top priority plant species were collected from the field. Overall villagers gave positive response and showed interest in capacity building and NTFP plant species cultivation idea.

3.7 Rapid rural appraisal and survey done in selected villages of the study area

A semi structured questionnaire was developed to receive feedback from the different stakeholders that included State Medicinal Plants Board, State Biodiversity Board, Centre for Aromatic Plants, individual experts and academician working in the domain of Botany, Medicinal value products, NWFP, and the local communities. The questionnaires used during surveys for expert opinion and to collect information from communities are shown below.

Questionnaire for expert opinion

Objectives of the study: Identification of priority RET/NWFP species for conservation

The study aims to prepare a list of RET/NWFP species having commercial importance that need to be conserved urgently and to explore viable options of conservation and cultivation of the species outside the forests, specifically in the Kalsi, Chakrata and Tyuni tehsils of Dehradun district, Uttarakhand.

Objectives of the questionnaire

- Identification of priority species for conservation
- Identification of priority species that could be cultivated
- Approaches for the capacity building of local communities for conservation of priority species
- Development of Biodiversity Information System

Important criteria to be met while selecting species

- Should be either RET or should have NWFP values
- Should have extraction source predominantly from wild/forests
- Should have natural occurrence in the study region

- Should be cultivable outside forest (legal forest land) area

Respondents and target groups of resource persons

- Local farmers
- Researchers, practitioners and scientists of the domain
- Conservationists
- Traders and vendors
- Consumers
- Policy makers
- Jaunsari tribes

Focused discussion on

- Important RET/NWFP species that need to be conserved
- Various threats to identified species
- Extent of extraction of identified species
- Commercial importance of the species
- Suitable habitats of the identified species
- Viable options for the conservation
- Conflict of interest, if any
- Other important points

Process to be adopted for the survey

- Number of iterative surveys to be conducted depending upon the outcome of the initial surveys
- Survey to be accomplished with short discussion on issues of conservation of RET/NWFP plants
- Discussion may have more open end questions which would be included in second round of the survey
- Second survey will be more specific and will be designed on the basis of outcome of first survey
- Anonymous feedback of responses will be given to participants at the end of each survey
- The process will be adopted to reach consensus on major immerging issues

Questionnaire for expert opinion

1. Name: ……...…….
2. Address: …….
3. Email ID: ……...
4. Phone no: ……...
5. Occupation: ...……
6. Specific area of expertise related to conservation/cultivation, tick (√) appropriate option/s

(i) Research and Education (ii) Trading

(iii) Technology development and implementation (iv) Cultivation/user (v) Policy making

7. Year of experience in related domain mentioned at sr. no. 3 above: ……years
8. Name and contact details of organizations/resource persons working in the conservation/cultivation/trading of RET & NWFP species

i) ……..

……..

ii) ……..

……..

iii) ……..

……..

iv) ……..

……..

v) ……..……

……..

vi) ……..……

…….....

9. List of important RET species of conservation

SN.	Local/common name	Botanical name	Used for	Parts used
i)				
ii)				
iii)				
iv)				
v)				
vi)				
vii)				
viii)				
ix)				
x)				

10. List of important NWFP species of conservation

SN.	Local/common name	Botanical name	Used for	Parts used
i)				
ii)				
iii)				
iv)				

v)				
vi)				
vii)				
viii)				
ix)				
x)				

11. Most important RET (top five) species according to you listed at sr. no. 9 above

SN.	Local/common/botanical name	Area of occurrence/natural habitat
i)		
ii)		
iii)		
iv)		
v)		

12. Most important NWFP (top five) species according to you listed at sr. no. 10 above

SN.	Local/common/botanical name	Area of occurrence/natural habitat
i)		
ii)		
iii)		
iv)		
v)		

13. According to you, which conservation approaches can be adopted effectively and why?

……

……

……

……

……

14. What do you think about cultivation as conservation method for the RET & NWFP species of the study area?

……

……

……

……

……

15. According to you, what efforts/support will motivate the people to cultivate RET & NWFP species in the region?

……

……

……

……

……

16. Are you willing to be associated in due course and wish to be contacted by us in due course? (Yes/No)……..

17. Do you have any suggestions or additional inputs?

……

……

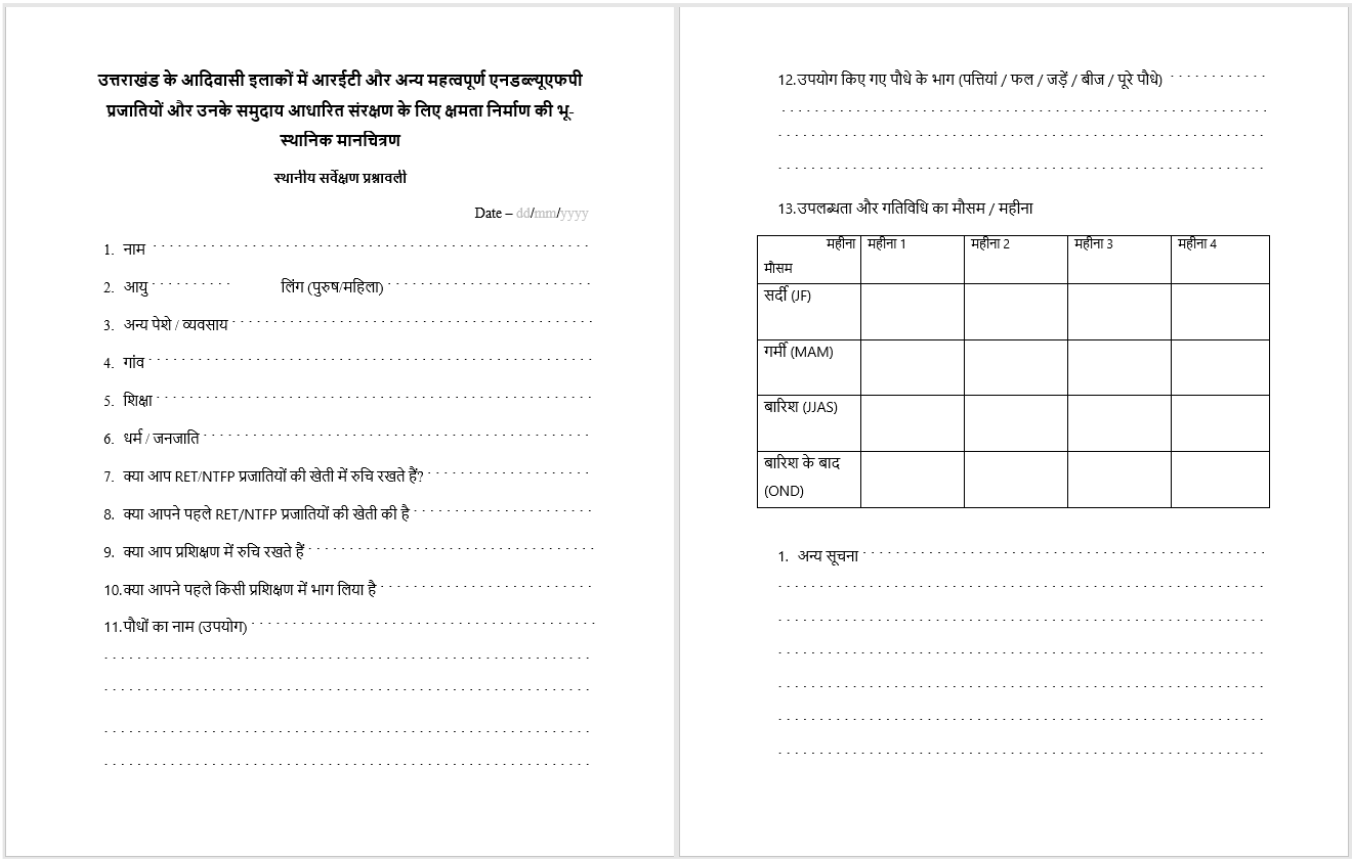
……

……

……

(Signature)

A separate questionnaire was prepared for discussion with locals regarding plant species used by them, readiness to cultivate NWFP plant species, their interests, and environmental awareness as shown below.



उत्तराखंड के आदिवासी इलाकों में आरईटी और अन्य महत्वपूर्ण एनडब्ल्यूएफपी प्रजातियों और उनके समुदाय आधारित संरक्षण के लिए क्षमता निर्माण की भू-स्थानिक मानचित्रण

स्थानीय सर्वेक्षण प्रश्नावली

Date – dd/mm/yyyy

1. नाम .....
2. आयु ..... लिंग (पुरुष/महिला) .....
3. अन्य पेशे / व्यवसाय .....
4. गांव .....
5. शिक्षा .....
6. धर्म / जनजाति .....
7. क्या आप RET/NTFP प्रजातियों की खेती में रुचि रखते हैं? .....
8. क्या आपने पहले RET/NTFP प्रजातियों की खेती की है .....
9. क्या आप प्रशिक्षण में रुचि रखते हैं .....
10. क्या आपने पहले किसी प्रशिक्षण में भाग लिया है .....
11. पौधों का नाम (उपयोग) .....

12. उपयोग किए गए पौधे के भाग (पत्तियां / फल / जड़ें / बीज / पूरे पौधे) .....

13. उपलब्धता और गतिविधि का मौसम / महीना

महीना / मौसम	महीना 1	महीना 2	महीना 3	महीना 4
सर्दी (JF)				
गर्मी (MAM)				
बारिश (JJAS)				
बारिश के बाद (OND)				

1. अन्य सूचना .....

Fig.7: Questionnaire developed for interviewing local community

Extensive village surveys were conducted for compiling information on NWFP/RET plant species of Chakrata region. Locals from 36 different villages were interviewed and it was found that total 89 plant species of NWFP and MAP value are known by locals to exist in the region. Surveys and discussion with the locals were held in the villages through rapid rural appraisal (Fig. 8). During these visits it was found that general consensus exists among the locals regarding decline in the overall density of selected plant species. The local farmers showed keen interest in cultivation of NWFP plant species for livelihood benefit and conservation purpose.

A

B

Fig. 8: Interaction with the local communities: (A) ChhajadHartad village, (B) Kandar village and (C) Silaura village

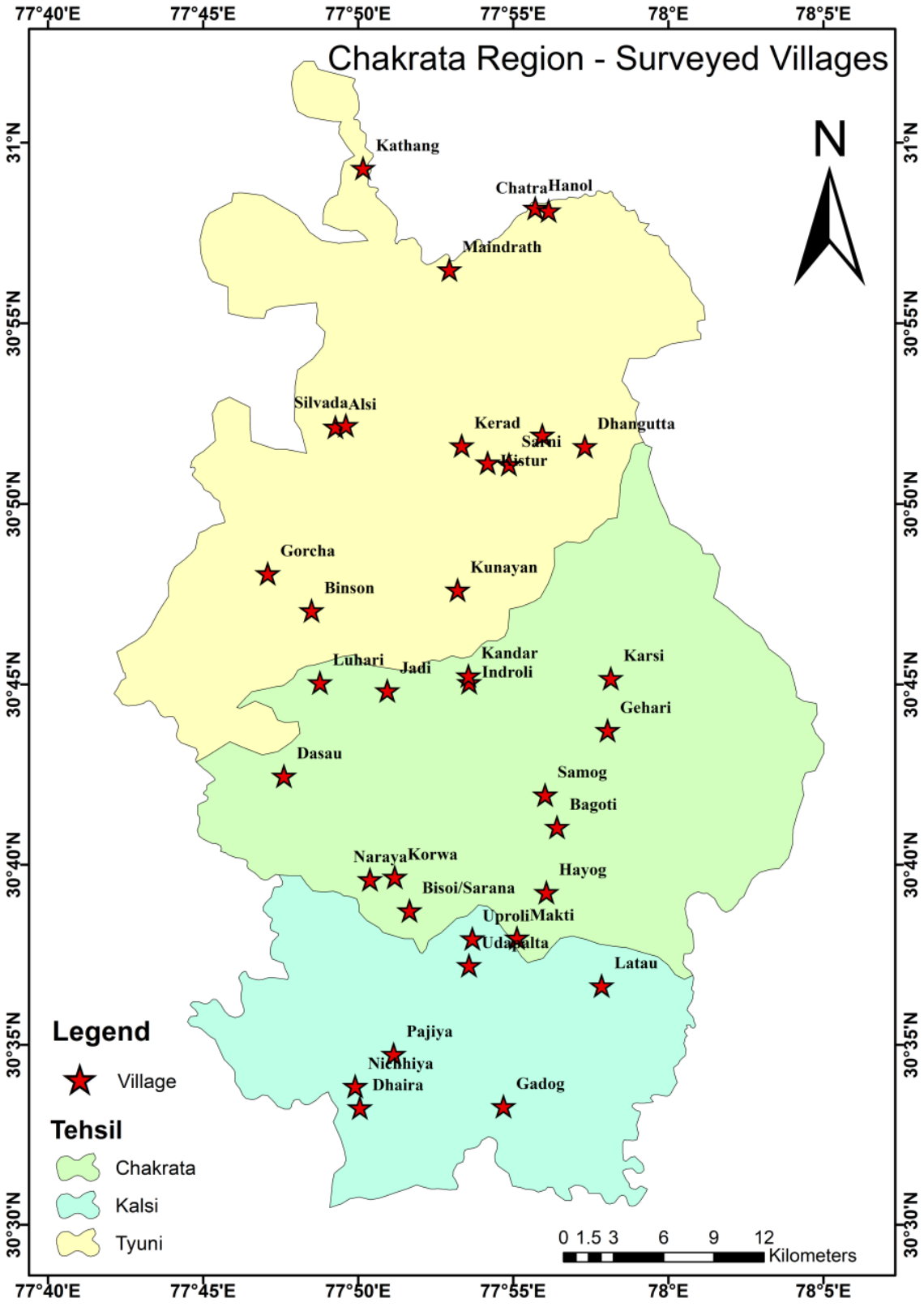


Fig.9: Map showing locations of surveyed villages in Dehradun district of Uttarakhand.

3.8 Strategic Planning for each Activities (max. 1000 words)

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

Activities	1st Year		2nd Year		3rd Year	
	1st - 6th month	7th - 12th month	1st - 6th month	7th - 12th month	1st - 6th month	7th - 12th month
Establishment of MoU/contract between the funding agency and collaborating Institutes						
Review of literature						
Consultation with stakeholders						
Procuring essential satellite images and other statistics						
Field survey for collecting desired information/field based workshop						
Processing of satellite images						
Compilation of all information in a usable format for developing model						
Development and testing of model						
Development of web based Biodiversity Information System (BIS)						
Compilation of reports and statistics						
Dissemination of information						

4 KEY FINDINGS AND RESULTS

4.5 Major Research Findings (max. 1000 words)

4.1.1 Prioritization of species for the conservation and propagation and important findings

Endemism is one of the important parameters for the prioritisation of species for conservation. Evidence suggests that plant species with more restricted distribution ranges are more likely to suffer (Brook et al., 2008). Threat status is a central indicator of the relative risk of species extinction. The species facing a higher threat should be given higher conservation priority (Tali et al., 2019). Whereas the use value can also be considered as one of the criteria for conservation priority. Use value was noted as the number of uses of a species. The species with the highest number of uses will have more demand and hence more extraction will take place (Kala et al., 2004). The threat is also determined by the part of plant species that is extracted or used. The method of harvest affects the survival of a plant species and results in population decline (Kala et al., 2004). Plant species whose roots are

extracted are more prone to extinction and hence require priority conservation. Therefore, the scoring for prioritisation would also depend upon the parts being used and extracted from the field of natural occurrence of a species. Different scores assigned for prioritization for the selected parameters of use value, endemism, threat levels and parts used in indicated in Table 3 and 4.

Table 2: Plant species recognized through expert consultation and village surveys

Common name	Scientific name	Common name	Scientific name
Khair/Kher	*Acacia catechu*	Shrikkoli	*Lilium polyphyllum*
Atis	*Aconitum heterophyllum*	Jeevak	Malaxismuscifera
Bach	*Acorus calamus*	Kamil	*Mallotusphilippensis*
Pangar	*Aesculus indica*	Katiyal	*Morina longifolia*
Pudina Ghaans	*Ageratum conyzoides*	Kimu	*Morus serrata*
Neelkanthi	*Ajuga parviflora*	Tambaku	*Nicotiana tabacum*
Jambu	*Allium stracheyi*	Tulsi	*Ocimumtenuiflorum*
Choru	*Angelica glauca*	Satuva	*Paris polyphylla*
Chamur	*Artemisia roxburghiana*	Amla	*Phyllanthus emblica*
Sharanvi	*Asparagus racemosus*	Ban Kakdi	*Podophyllum hexandrum*
Neem	*Azadirachta indica*	SalabMisri	*Polygonatumveticullatum*
Kachnar	*Bauhinia variegata*	Bhekoi	*Prinsepia utilis*
Chitra	*Berberis aristata*	Chullu/Van Chullu	*Prunus armeniaca*
Kasmal	*Berberis asiatica*	Padam	*Prunus Puddum*
Semal	*Bombax ceiba*	Nashpati	*Pyrus comminus*
Ank	*Calotropis procera*	Moru	*Quercus dilatata*
Bhang	*Cannabis sativa*	Banj	*Quercus leucotrichophora*
Kalijiri	*Carum carvi*	Kharsu	*Quercus semecarpifolia*
Amaltas	*Cassia fistula*	Kakoli	*Rascoea purpurea*
Sadabahar	*Catharanthus roseus*	Archa	*Rheum webbianum*
Deodar	*Cedrus deodar*	Burans	*Rhododendron arboreum*
Malkangni	*Celastruspaniculatus*	Kujoi	*Rosa brunonii*
Khadik	*Celtis australis*	Karanvi	*Roylea cinerea*
Padam/Paja	*Cerasus cerasoides*	Almoda	*Rumex hastatus*
TejPatta	*Cinnamomum tamala*	Ritha	*Sapindusmukorossi*
Dalchini	*Cinnamomum verum*	Tilairi	*Sarcococcasaligna*
Nimbu	*Citrus medica*	Kuth	*Saussureacostus*
Kakdi	*Cucumis sativus*	Bhutkeshi	*Selinumvaginatum*
Haldi	*Curcuma longa*	Kathurchara	*Skimmialaureola*
Kachoor	*Curcuma raktakanta*	Katiya/Kantakari	*Solanum virginianum*
Akash Bel	*Cuscutareflexa*	Chiraita	*Swertia chirayita*
Nagarmotha	*Cyperus scariosus*	Thuner	*Taxus wallichiana*
Hatajari	*Dactylorhizahatagirea*	Baheda	*Terminalia bellirica*

Nirbhishi	*Delphinium denudatum*	Harad	*Terminalia chebula*
Chalan	*Desmodiumgangeticum*	Pili Jadi	*Thalictrum foliolosum*
Kairo	*Desmodiummultiflorum*	Dande ki Javan	*Thymus linearis*
Banchulu	*Devendraea angustifolia*	Giloy	*Tinospora cordifolia*
Tirmal	*Ficus auriculata*	Ajwain	*Trachyspermumammi*
Fedu	*Ficus palmata*	Bichughas	*Urtica dioica*
Gular	*Ficus racemosa*	Jatamansi	*Valerianajatamansi*
Karu	*Gentiana Kurroo*	Vanafsa	*Viola pilosa*
Kala Bach	*Gloriosa superba*	Songi/Nirgundi	*Vitex negundo*
Bhimal	*Grewia optiva*	Timur	*Zanthoxylum armatum*
Vriddhi	*Habenaria intermedia*	Adrak	*Zingiber officinale*
Jatropha	*Jatropha curcas*	Jangli Ber	*Ziziphus mauritiana*

Table 3: Ecologic and socio-economic parameters and assigned scores

Parameter	Category	Score	Parameter	Category	Score
Use value	More than 20	5	**Threat level**	Critically Endangered (CR)	4
	16-20	4		Endangered (EN)	3
	11-15	3		Vulnerable (VU)	2
	6-10	2		Near Threatened (NT)	1
	1-5	1		Not Evaluated (NE)	0
Endemism	Western Himalayas (WH)	3	**Part used**	Whole plant (wp)	5
	Himalayas (H)	2		Underground portion (rt, rz, bb)	4
	Native (NT)	1		Seed or fruit (sd, fr)	3
	Cultivated (CU)	0		Aerial portion or bark (ap, brk)	2
	Exotic (EX)	-1		Leaf, twig, resin or gum (lf, tg, rs, g)	1

(WH: Western Himalayas, H: Himalayas, NT: Native, CU: Cultivated, CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NE: Not Evaluated, ap: ariel part, lf: leaf, st: stem, tg: twig, bk: bark, fl: flower, fr: fruit, sd: seed, hwd: heartwood, rt: root, bu: bulb, tb: tuber, rz: rhizome, kr: kernel, mr: mericarp, wp: whole plant. Use value indicates number of different ailments in which a species is used.

Table 4: Prioritized NTFP plant species as per ecologic and socio-economic parameters.

SN	Scientific Name	Native (N)	Threat (T)	Use Value (U)	Parts Used (P)	Score				Total score
						N	T	U	P	
1	*Aconitum heterophyllum*	WH	CR	30	rt,wp	3	4	5	5	17
2	*Dactylorhizahatagirea*	H	CR	26	lf, fl, rt, wp	2	4	5	5	16
3	*Paris polyphylla*	WH	EN	30	rt, wp	3	3	5	5	16
4	*Angelica glauca*	WH	EN	12	rt, wp	3	3	3	5	14

5	*Gentiana Kurroo*	WH	CR	12	rt	3	4	3	4	14
6	*Podophyllum hexandrum*	H	EN	24	sd, lf, fr, rt	2	3	5	4	14
7	*Saussureacostus*	CU	CR	32	rt	0	4	5	4	13
8	*Lilium polyphyllum*	WH	CR	7	bu	3	4	2	4	13
9	*Valerianajatamansi*	H	VU	29	rz	2	2	5	4	13
10	*Swertia chirayita*	WH	NE	20	fr, lf, st, wp	3	0	4	5	12
11	*Habenaria intermedia*	WH	EN	10	bb, tb, st	3	3	2	4	12
12	*Asparagus racemosus*	NT	NE	27	st, sd, rt, wp	1	0	5	5	11
13	*Acorus calamus*	NT	NE	29	lf, rz, wp	1	0	5	5	11
14	*Delphinium denudatum*	WH	NE	13	sd, fl, rt, wp	3	0	3	5	11
15	*Thymus linearis*	WH	NE	15	wp, lf ,sd	3	0	3	5	11
16	*Urtica dioica*	NT	NE	33	st, lf, sd, ap, rt, wp	1	0	5	5	11
17	*Rheum webbianum*	WH	VU	7	lf, rt	3	2	2	4	11
18	*Vitex negundo*	NT	NE	17	fl, tw, rt, wp	1	0	4	5	10
19	*Allium stracheyi*	WH	VU	5	lf, st, fl, rt	3	2	1	4	10
20	*Taxus wallichiana*	NT	EN	13	st, br, fr, lf	1	3	3	3	10
21	*Zanthoxylum armatum*	NT	VU	18	lf, fl, bk, fr, sd ,st	1	2	4	3	10
22	*Polygonatumverticil latum*	NT	VU	11	lf, st, rz	1	2	3	4	10
23	*Gloriosa superba*	NT	VU	11	fl, sd, rt	1	2	3	4	10
24	*Azadirachta indica*	NT	NE	22	fl, fr,sd	1	0	5	3	9
25	*Berberis aristata*	H	NE	12	fr, br, rt	2	0	3	4	9
26	*Carum carvi*	NT	NE	26	sd, mr	1	0	5	3	9
27	*Cedrus deodar*	WH	NE	14	st, oil, bk, hwd, lf, wd	3	0	3	3	9
28	*Phyllanthus emblica*	NT	NE	21	bk, fr, sd	1	0	5	3	9
29	*Selinumvaginatum*	WH	NE	3	wp	3	0	1	5	9
30	*Thalictrum foliolosum*	H	NE	6	rt, wp	2	0	2	5	9
31	Malaxismuscifera	H	NT	1	bu	2	1	4	2	9
32	*Morina longifolia*	H	NE	6	rt, sd, wp	2	0	2	5	9
33	*Aesculus indica*	NT	NE	21	fr, sd, lf, kr, fl	0	0	5	3	8
34	*Ajuga parviflora*	WH	NE	15	ap	3	0	3	2	8
35	*Ocimumtenuiflorum*	NT	NE	8	lf, sd, wp	1	0	2	5	8
36	*Prinsepia utilis*	H	NE	4	ft, lf, sd, rt, wp	2	0	1	5	8
37	*Rhododendron arboreum*	NT	NE	8	br, lf, fl, wp	1	0	2	5	8
38	*Viola serpens*	NT	NE	14	fl, lf, rz	1	0	3	4	8
39	*Bombax ceiba*	NT	NE	8	bk, fr, rt	1	0	2	4	7
40	*Calotropis procera*	CU	NE	11	lf, rt, fl	0	0	3	4	7
41	*Morus serrata*	NT	NE	17	fr	0	0	4	3	7

42	*Tinospora cordifolia*	NT	NE	6	lf, rt, st	1	0	2	4	7
43	*Cinnamomum tamala*	H	NE	2	lf	2	3	1	1	7
44	*Cuscutareflexa*	NT	NE	12	st, wp, sd	1	0	3	3	7
45	*Bauhinia variegata*	NT	NE	12	bk, fl, tw	1	0	3	2	6
46	*Berberis asiatica*	NT	NE	2	rt	1	0	1	4	6
47	*Cassia fistula*	NT	NE	8	fr, lf, rt, bk, sd, wp	0	0	2	4	6
48	*Curcuma longa*	NT	NE	2	rz	1	0	1	4	6
49	*Ficus palmata*	NT	NE	8	fr, lt, lf	1	0	2	3	6
50	*Ficus racemosa*	NT	NE	9	bk, fr, lt, tw	1	0	2	3	6
51	*Sarcococcasaligna*	NT	NE	4	rt	1	0	1	4	6
52	*Skimmialaureola*	WH	NE	8	lf	3	0	2	1	6
53	*Solanum virginianum*	NT	NE	12	lf, fl	0	0	3	3	6
54	*Terminalia bellirica*	NT	NE	8	br, fr	1	0	2	3	6
55	*Trachyspermumammi*	NT	NE	6	sd, fr	1	0	2	3	6
56	*Zingiber officinale*	CU	NE	6	rz	0	0	2	4	6
57	*Acacia catechu*	NT	NE	6	bk,st	1	0	2	2	5
58	*Cannabis sativa*	NT	NE	20	lf, st	0	0	4	1	5
59	*Celastruspaniculatus*	NT	NE	3	sd	1	0	1	3	5
60	*Celtis australis*	NT	NE	3	fr, sd	1	0	1	3	5
61	*Cinnamomum verum*	NT	NE	10	bk	1	0	2	2	5
62	*Mallotusphilippensis*	NT	NE	3	fr, sd	1	0	1	3	5
63	*Prunus armeniaca*	CU	NE	6	sd	0	0	2	3	5
64	*Rosa brunonii*	CU	NE	2	fl, rt	0	0	1	4	5
65	*Sapindusmukorossi*	NT	NE	2	fr	1	0	1	3	5
66	*Terminalia chebula*	NT	NE	4	fr, sd	1	0	1	3	5
67	*Catharanthus roseus*	NT	NE	2	lf, fl	0	0	1	3	4
68	*Cucumis sativus*	CU	NE	5	sd, fr	0	0	1	3	4
69	*Pyrus comminus*	CU	NE	4	fr	0	0	1	3	4
70	*Artemisia roxburghiana*	NT	NE	3	lf	1	0	1	1	3
71	*Quercus leucotrichophora*	NT	NE	2	bk		0	1	2	3
72	*Ziziphus mauritiana*	NT	NE	1	lf	1	0	1	1	3
73	*Ageratum conyzoides*	NT	NE	1	lf	0	0	1	1	2
74	*Citrus medica*	CU	NE	1	lf	0	0	1	1	2
75	*Nicotiana tabacum*	CU	NE	2	lf	0	0	1	1	2

Project site has considerable altitudinal variation ranging between 400 to 2960m and since, altitude is dominant factor in determination of distribution range in Himalaya (Samant et al., 2007). Plant species were further grouped as per their respective altitudinal gradient for suggesting altitudinal preference of conservation sites.

Table 5: Elevation zone based grouping of plant species

Elevation Range (m)	Species
400-1250	*Asparagus racemosus, Acorus calamus, Ajuga parviflora, Vitex negundo, ,Berberisaristata, Carum carvi, Phyllanthus emblica, Gloriosasuperba*
1251-2100	*Paris polyphylla, Gentiana kurroo, Lilium polyphyllum, Valerianajatamansi, Swertia chirayita, Habenaria intermedia, Delphinium denudatum, Thymus linearis, Zanthoxylum armatum, Carum carvi, Cedrus deodar, Selinumvaginatum, Thalictrum foliolosum*
2101-2960	*Aconitum heterophyllum, Dactylorhizahatagirea, Paris polyphylla, Angelica glauca, Gentiana kurroo, Podophyllum hexandrum, Saussureacostus, Lilium polyphyllm, Valerianajatamansi, Swertia chirayita, Habenariaedgeworthii, Delphinium denudatum, Thymus linearis, Rheum webbianum, Allium stracheyi, Taxus wallichiana, Zanthoxylum armatum, Polygonatumverticillatum, Carum carvi, Selinumvaginatum, Thalictrum foliolosum,* Morina longifolia

4.1.2. Ease of cultivation and market value

As per discussion with the experts, market value and ease of cultivation play a crucial role in the success of conservation by cultivation. If the plant does not have market value and if it is not easy to cultivate, it is not going to yield any long-term benefit. However, it is problematic to establish objective data for these two parameters. The market value is based on the commodity in consideration, which could be a leaf, root, stem, bark, fruit, or flower, etc. The price of NWFP varies greatly, and unexpected variations in rates can be observed from one market to another. The reported market value of *Aconitum heterophyllum, which* is the highest among all the plant species, ranges from 6500–9250 Rs/kg root.

Table 6: Market value of NWFP plant species as per official data and literature

SN	Scientific name	Market value (₹/kg)
1	*Aconitum heterophyllum*	6500-9250
2	*Dactylorhizahatagirea*	1100-1150
3	*Paris polyphylla*	1950-3750
4	*Gentiana Kurroo*	150-200
5	*Podophyllum hexandrum*	200-290
6	*Saussureacostus*	230-450
7	*Lilium polyphyllum*	500-700
7	*Valerianajatamansi*	340-460
8	*Swertia chirayita*	400-480
9	*Asparagus racemosus*	350-765

10	*Acorus calamus*	65-95
11	*Delphinium denudatum*	80
12	*Thymus linearis*	60
13	*Allium stracheyi*	120-150
14	*Taxus wallichiana*	40-50
15	*Zanthoxylum armatum*	25-100
16	*Polygonatumverticillatum*	120
17	*Berberis aristata*	25-45
18	*Carum carvi*	200
19	*Thalictrum foliolosum*	240-400

Following the scores obtained for each species and the market value of the harvested products from each species together with the ease of cultivation as suggested by experts and the overall preference suggested by the local communities a list of top priority species was compiled and is presented in Table7.

Table: 7 List of top priority plant species for cultivation

SN	Common Name	Scientific Name		SN	Common Name	Scientific Name
1	Atis	*Aconitum heterophyllum*		15	Archa	*Rheum webbianum*
2	Satuva	*Paris polyphylla*		16	Songi/Nirgundi	*Vitex negundo*
3	Shrikakoli	*Lilium polyphyllum*		17	Jeevak	Malaxismuscifera
4	Chiraita	*Swertia chirayita*		18	Katiyal	*Morina longifolia*
5	Sharanvi	*Asparagus racemosus*		19	Nirbhishi	*Delphinium denudatum*
6	Jatamansi	*Valerianajatamansi*		20	Bach	*Acorus calamus*
7	Pili Jadi/Pili Jarhi	*Thalictrum foliolosum*		21	Neelkanthi	*Ajuga parviflora*
8	Ban Kakdi	*Podophyllum hexandrum*		22	Bhutkeshi	*Selinumvaginatum*
9	Kalijiri	*Carum carvi*		23	Kala Bach	*Gloriosa superba*
10	Karu	*Gentiana Kurroo*		24	Dande ki Javan	*Thymus linearis*
11	Jambu	*Allium stracheyi*		25	Tulsi	*Ocimumtenuiflorum*
12	SalabMisri	*Polygonatumverticillatum*		26	Vanafsa	*Viola serpens*
13	Vriddhi	*Habenaria intermedia*		27	Ank/Aank	*Calotropis procera*
14	Thuner	*Taxus wallichiana*				

4.1.3 On field identification and geo-coordinate collection of RET species

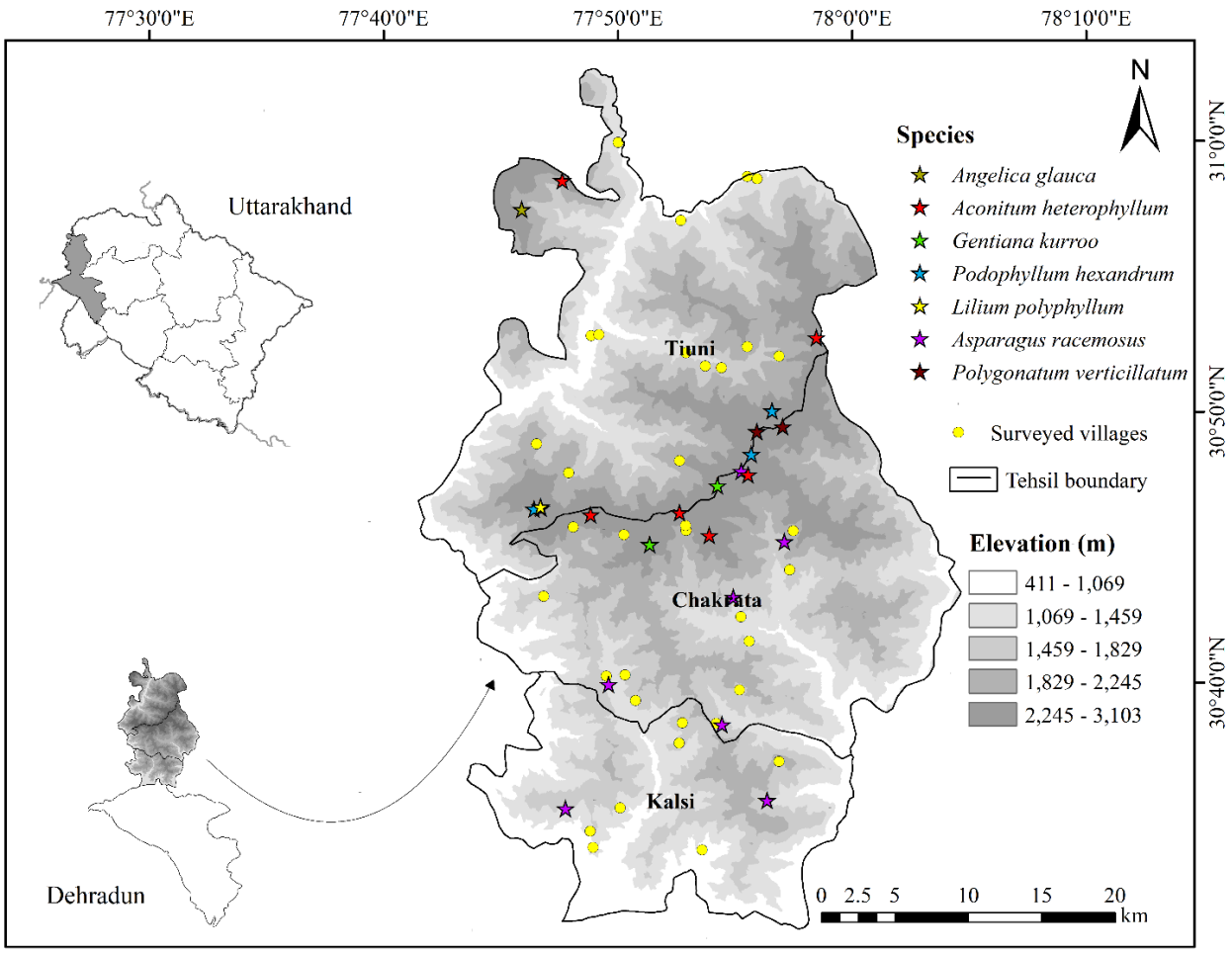


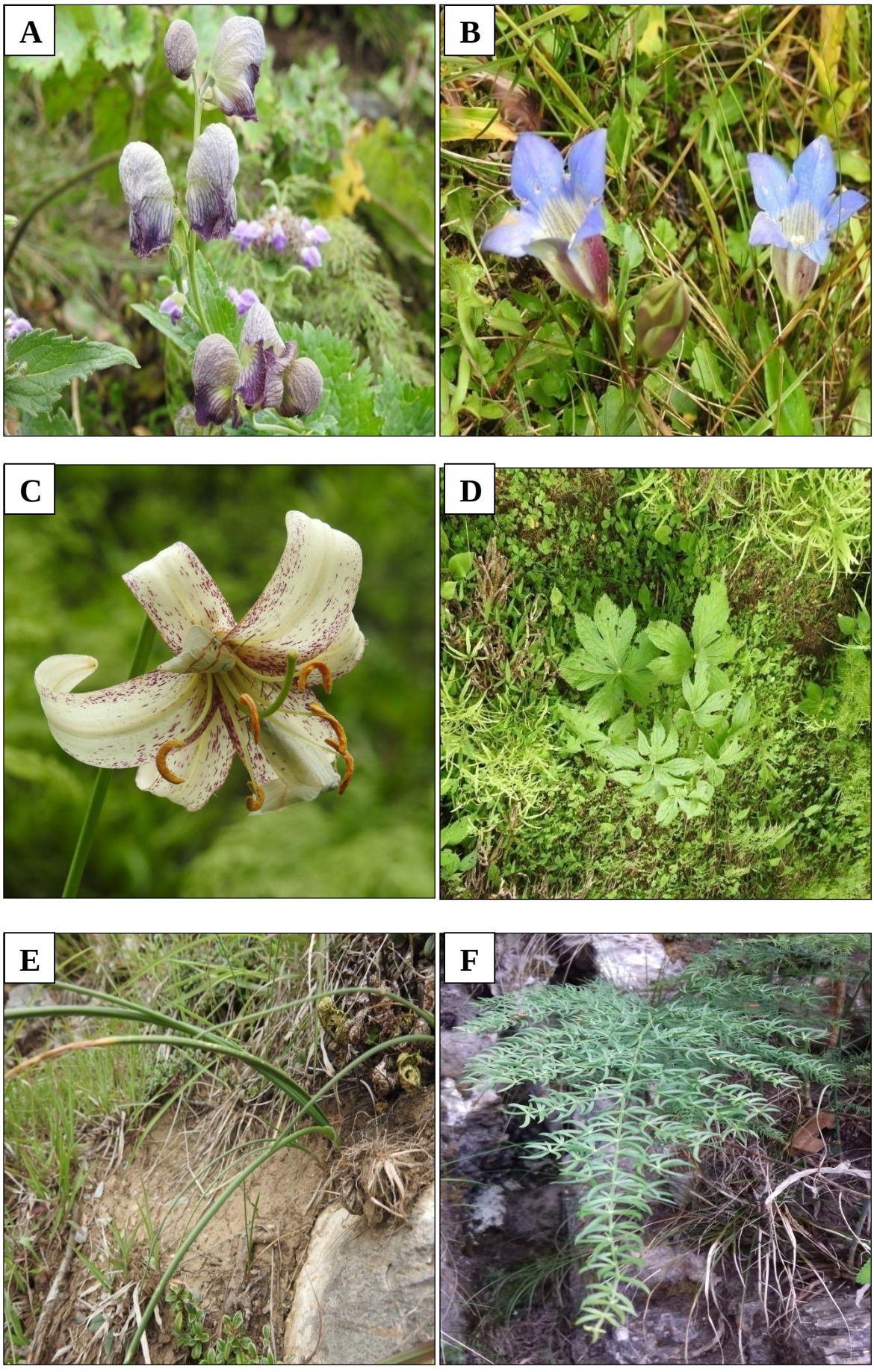
Fig. 11: Surveyed villages and RET plant species located during field survey results

Following plant species were identified during field survey and their geo-coordinates are being collected. Efforts are being made to locate other rare plant species as well.

Among below listed plant species *Aconitum heterophyllum* commonly known as Atis, is categorized as Endangered by IUCN. The root of the species is utilized in Ayurveda and Chinese medicine and it is also one of the top cultivated medicinal plant species. Atis is fairly easy to cultivate and promises high economic returns from 4000 to 9000 ₹/kg root. It is listed by Herbal Research and Development Institute as priority species for cultivation and is also subsidized by the government. *Gentiana kurroo* and *Lilium polyphyllum* are categorized as critically endangered and endangered respectively. *Podophyllum hexandrum*, *Allium stracheyi, Asparagus racemosus, Swertia chirayita* and *Carum carvi*are other plant species prioritized by HRDI and subsidized by the government for cultivation.

Table 8: Top 20 prioritized plant species for conservation and cultivation

SN	Scientific Name	Native (N)	Threat (T)	Use Value (U)	Parts Used (P)	N	T	U	P	Total
1	*Aconitum heterophyllum*	WH	CR	30	wp, rt	3	4	5	5	17
2	*Dactylo rhizahatagirea*	H	CR	26	lf, fl, rt, wp	2	4	5	5	16
3	*Paris polyphylla*	WH	EN	30	rt, wp	3	3	5	5	16
4	*Angelica glauca*	WH	EN	12	rt, wp	3	3	3	5	14
5	*Gentiana Kurroo*	WH	CR	12	rt	3	4	3	4	14
6	*Podophyllum hexandrum*	H	EN	24	sd, lf, fr, rt	2	3	5	4	14
7	*Saussurea costus*	CU	CR	32	rt	0	4	5	4	13
8	*Lilium polyphyllum*	WH	CR	7	bu	3	4	2	4	13
9	*Valeriana jatamansi*	H	VU	29	rz	2	2	5	4	13
10	*Swertia chirayita*	WH	NE	20	fr, lf, st, wp	3	0	4	5	12
11	*Habenaria edgeworthii*	WH	NE	10	bu, tb, st	3	2	2	4	11
12	*Asparagus racemosus*	NT	NE	27	st, sd, rt, wp	1	0	5	5	11
13	*Acorus calamus*	NT	NE	29	lf, rz, wp	1	0	5	5	11
14	*Delphinium denudatum*	WH	NE	13	sd, fl, rt, wp	3	0	3	5	11
15	*Thymus linearis*	WH	NE	15	wp, lf ,sd	3	0	3	5	11
16	*Rheum webbianum*	WH	VU	7	lf, rt	3	2	2	4	11
17	*Vitex negundo*	NT	NE	17	fl, tw, rt, wp	1	0	4	5	10
18	*Allium stracheyi*	WH	VU	5	lf, st, fl, rt	3	2	1	4	10
19	*Taxus baccata*	NT	EN	13	st, br, fr, lf	1	3	3	3	10
20	*Zanthoxylum armatum*	NT	VU	18	lf, fl, bk, fr, sd ,st	1	2	4	3	10


A
B
C
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E
F

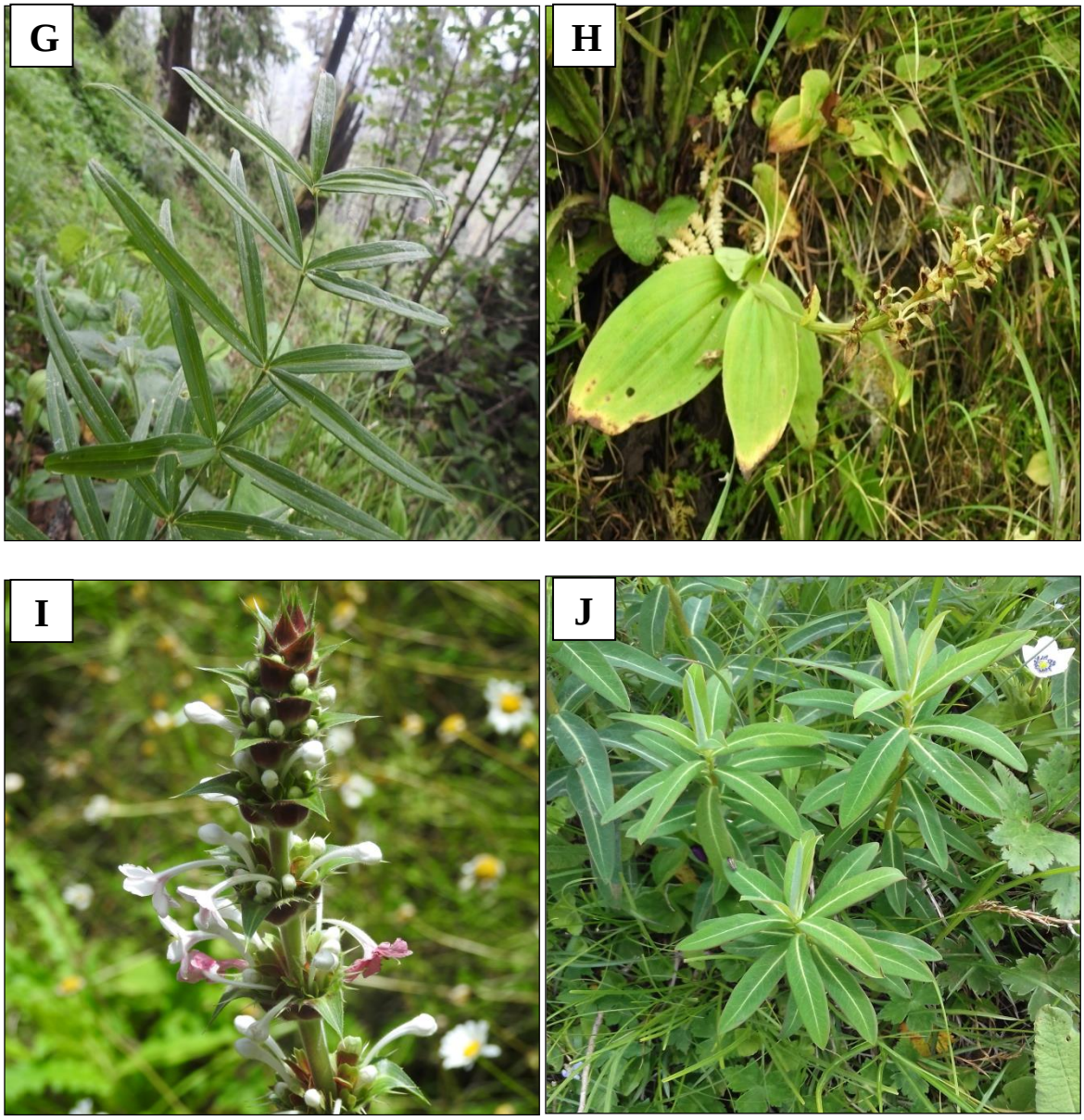

Fig. 12: Plant species located in the field appropriate for the conservation prioritization: (A)*A. heterophyllum*, (B) *G. kurroo*, (C) *L. polyphyllum*, (D) *P. hexandrum*, (E) *A. stracheyi*, (F) *A. racemosus*, (G) *P. verticillatum*, (H) *H. edgeworthii*, (I) *M. longifolia*, (J) *S. chirayita*

Majority high value NWFP and RET plant species were found in the high elevation range of Chakrata and Tiuni Tehsil. The plant species located are as given in the below figure.

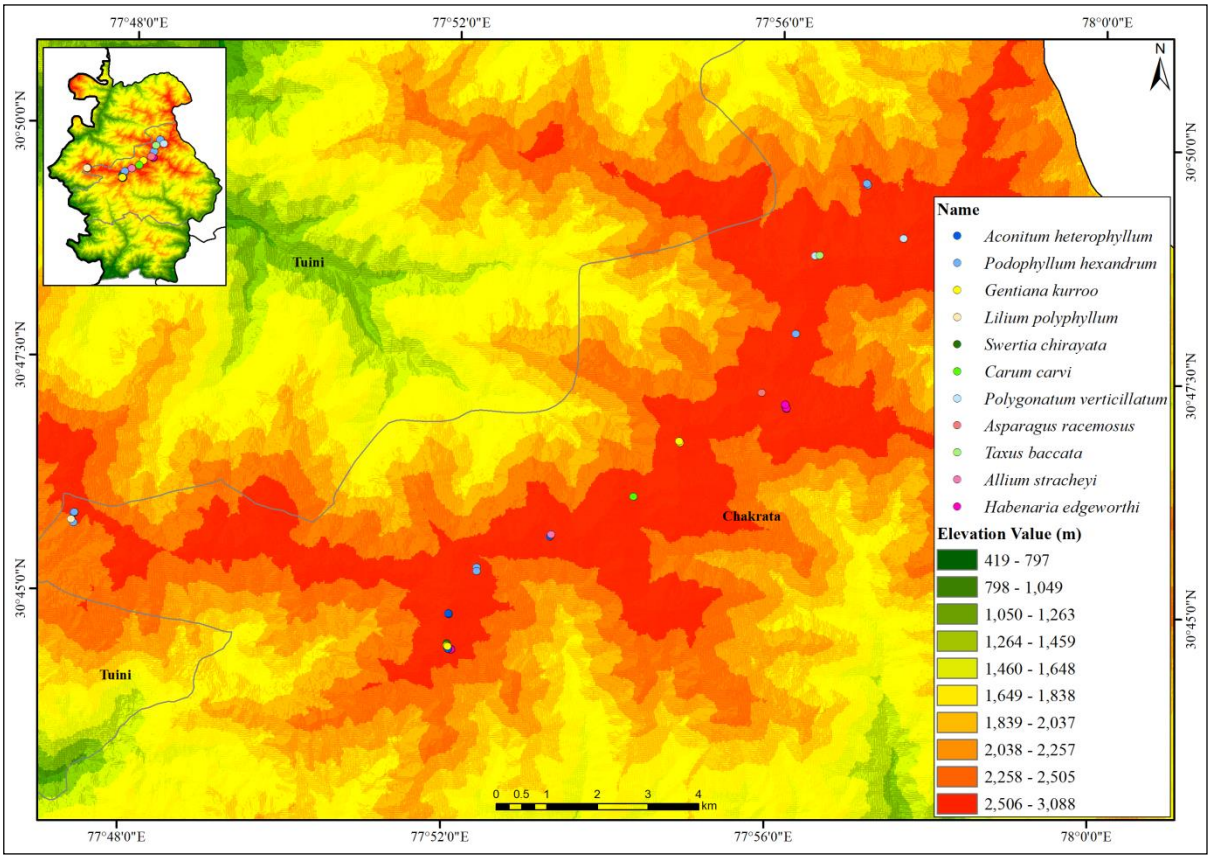

Fig. 13: Map showing elevation ranges of occurrence of selected plant species in Chakrata and Tiuni tehsil of Dehradun, Uttarakhand.

4.1.3 Topographic and environmental variables of habitat suitability

- The elevation of an area is a critical habitat parameter for a plant species.
- Topographic slope steepness will have a direct impact on water runoff and soil erosion. Steep slopes will have less vegetation due to less soil. Soil is normally not stable at slopes greater than 35%. Hence, it is an important plant habitat parameter.
- Topographic aspect induces soil moisture and exposure to sunlight, wind, and rain, which hence contributes significantly to the habitat of plant species. Sunny slopes retain less moisture due to higher evaporation and stronger solar radiation, whereas shady sites have higher soil moisture retention.
- Curvature is the second derivative of a surface, or the slope.
- Forest cover is shown in three density classes, viz., very dense forest (VDF) with more than 70% canopy density, moderately dense forests (MDF) with canopy density between 40% and 70%, and open forests (OF) with canopy density between 10% and 40%.
- Forest type is decided by the major type of vegetation, micro-climatic parameters of the area like moist or dry, and latitudinal position like tropical, subtropical, temperature, etc.

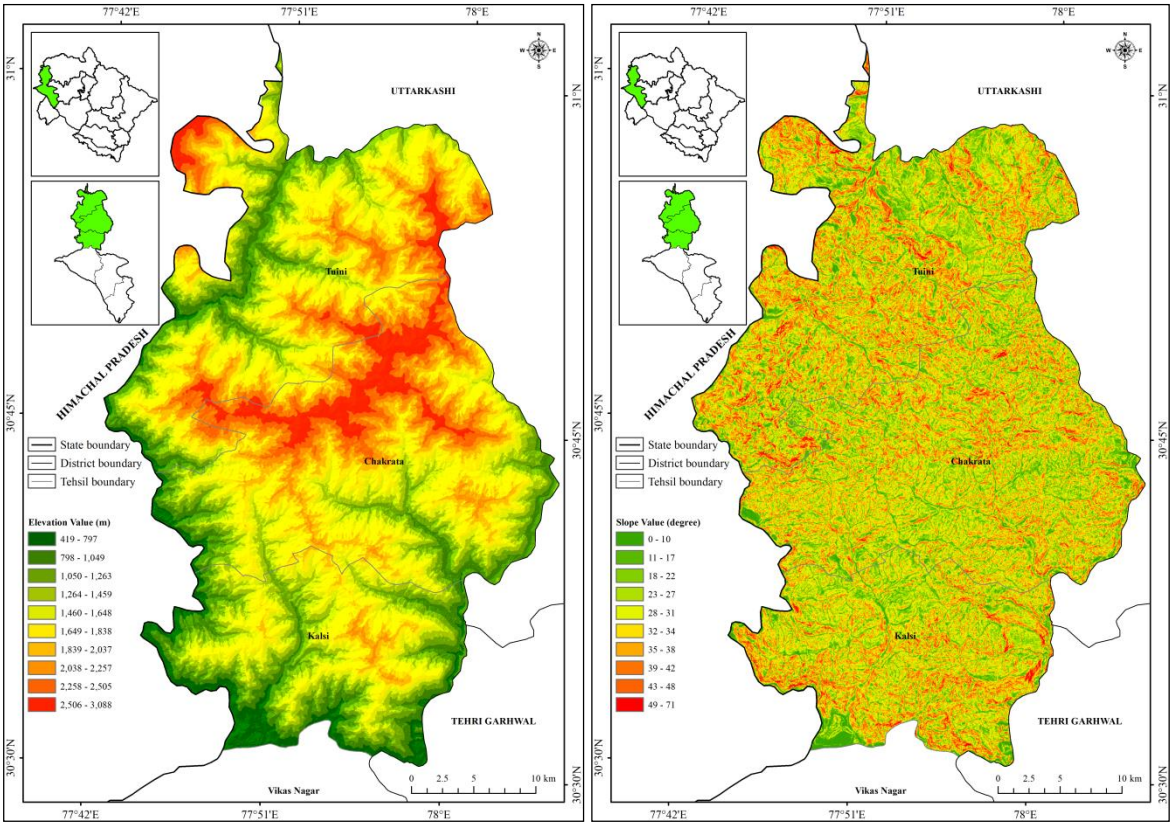

Figure 14: Elevation (left) and slope (right) map of the study area

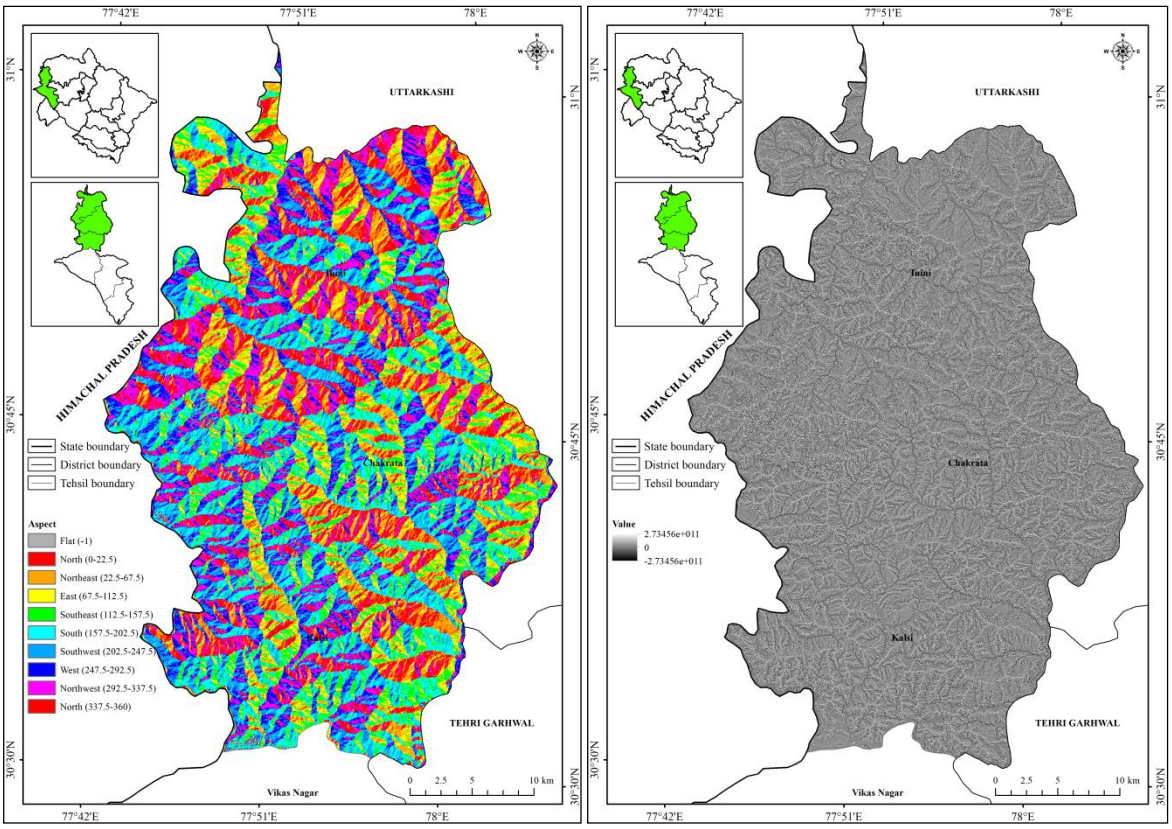

Fig. 15: Map showing aspect (left) and curvature (right) of the study area

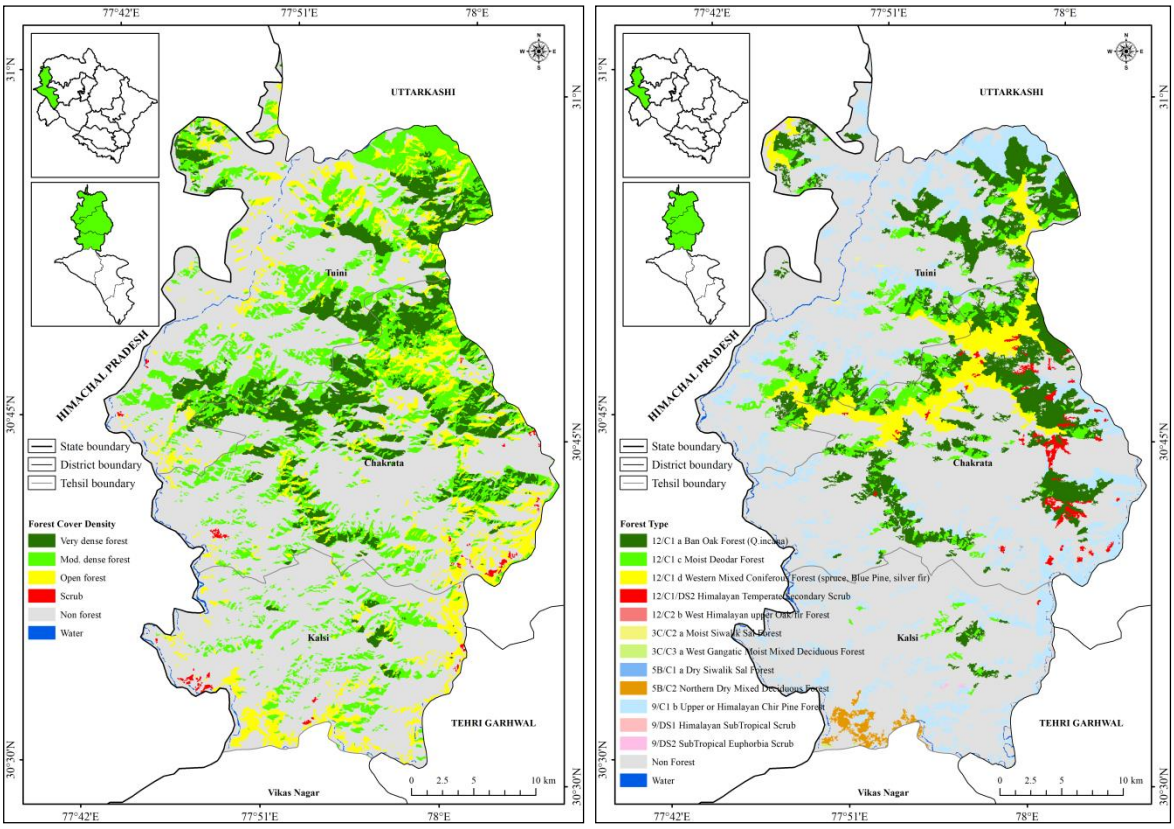

Fig. 16: Forest cover density (left) and forest type (right) map of study area

4.1.4 Habitat suitability modelling

Table 9: Studies available on Species Distribution Modelling (SDM)

SN	Authors	Objectives	Method	Outcomes
1.	Qin et al., 2020	Modelling current and future distribution of dietary plant of Gobi Bear, based on RCP2.6 using Maxent	Worldclim variables for current and future period and altitude, RCP2.6 for simulating habitat distribution	Model performance and contributions of environment variables Predicted habitat suitability
2.	Zhang et al., 2016	To predict suitable habitat regions using new approach and to explore environmental factors affecting active ingredients of *Scutellariabaicalensis*.	Fuzzy logics processing followed by Maxent modelling and then comprehensive evaluation	Key environmental factors and potential suitable cultivation regions
3.	Radosavljevic et al., 2014	To detect overfitting and tune program settings for most suitable model	K-fold cross validation for evaluation : randomly partitioned, geographically structured and masked geographically structured	Insights on tuning model for suitable results as per species
4.	Marmion et al., 2009	To test accuracy of different methods for threatened plant species	Species distribution modeling was carried out for 8 modeling techniques and combined using five methods	Census method does not always improve accuracy of the single-method. It is necessary to understand key issues of each model for generating results.
5.	Feeley et al., 2011	To test accuracy of SDM with different sample size	Modeling using randomly sampled data of different size	Large sample size gave most accurate species distribution
6.	Drake et al.,2006	To model ecological niches using support vector machine	Model preparation and model testing	Support Vector Machine was found to generate better results
7.	Hong et al., 2019	To assess impact of climate change and LULC on the invasion risk	Future invasion risk assessment using RCP-SSP based Maxent model	Inclusion of land use change to climate

		of *Thrips palmi* in the future		change generates meaningful results

Selection of appropriate environmental layers is essential for Species Distribution Modelling (SDM). It is not possible to use interpolations from direct measurements like rain gauges or automatic weather stations (AWS), therefore pre-existing, pre-processed or remotely sensed secondary data are essential input layers to the SDM. Other parameters, such as topography, contribute more at a local scale, according to Woodward (1990) (Luoto et al., 2007). Topographic parameters such as slope, aspect, and elevation can also be used as fine-scale local climatic conditions (Gogol-Prokurat, 2011). Essential variables like moisture, gradients, solar radiation, air temperature, and rockiness all correspond with topography (Meentemeyer et al., 2001). Topographic variables such as slope or aspect or direct variables such as potential solar radiation are broadly used in SDM and evolutionary ecology (Kozak et al., 2008; Leempoel et al., 2015). Remotely sensed land surface temperature (LST) improves SDM projects significantly (Deblauwe et al., 2016).

Following studies show application of SDM for suitable habitat mapping of rare and endangered plant species.

Environment Layers

Table 10: SDM studies reviewed for environment layers and method selection

SN	Authors	Species	Environment layers	Method/Model	Outcome
1.	Marcer et al.,2013	Rare plant species, *Asplenium majoricum, Carduncellusdianius, Diplotaxisibicensis* and *Euphorbia squamigera*	Worldclim variables, distance from coast and soil pH prepared from European Soil Database and Harmonized World Soil Database	Maximum entropy (Maxent) modelling was utilized. Residual spatial autocorrelation was measured using Monte-carlo simulation of Moran's I autocorrelation coefficient from spdep package in R. Model evaluation and selection method from Pearson et al., 2007 was followed. dismo R package was utilized	SDM was found to be valid tool for conservation management of rare species in well-surveyed areas

2.	Sharma et al., 2018	Medicinal plant species, *Perilla frutescens*	14 worldclim variables along with aspect, slope, elevation and vegetation layers	Maxent model was utilized. Autocorrelation check of environment layers was performed using R.	The study indicates habitat distribution modelling for medicinal plant species can be carried using small number of occurrence points
3.	Kunwar et al., 2020	Rare medicinal plant species, *Dactylorhizahatagirea* and *Paris polyphylla*	19 worldclim variables and SRTM DEM derived slope	Maxent model was utilized with bootstrap validation, model performance calculation using AUC, in addition to True Skill Statistic, sensitivity and specificity.	Habitat modelling using Maxent was found to be reasonable and correct based on AUC and TSS evaluation
4.	Gogol-Prokurat, 2011	Rare plant species, *Calystegiastebbinsii, Ceanothus roderickii, Packeralayneae*and*Wyethia reticulata*	Climate and topography, substrate (soil type and geologic substrate), fire history and vegetation (TC brightness, TC greenness and wetness) layers	Maxent based SDM, model discrimination success using Maxent AUC, modified Hosmer-Lemeshow deciles of risk test for model goodness of fit	Species with narrow habitat requirements were successfully modelled for predicting habitat suitability at local scale

Studies mentioned above have used a combination of worldclim and topographic variables along with land use, land change, vegetation, fire history, soil pH, etc. The predictions are based on current conditions and do not predict habitat suitability for future conditions (Gogol-Prokurat, 2011). Species Distribution Modelling has also been employed for discerning the distribution of invasive species in current and future scenarios so that a proper mitigation strategy can be adopted (Yan et al., 2020). If a species is not observed at a particular location, it will be recorded as an absence point, but the actual reason for absence could be lack of dispersal or dormant seed. Other accuracy assessment methods

include bootstrapping, True Skill Statistics, sensitivity and specificity (Allouche et al., 2008, Lobo et al., 2010). The 24 environment layers as given in the below table were considered for SDM.

Table 11: Environment layers processed for species distribution modelling

SN	Layer	Description
1	Bioclim1	Annual Mean Temperature
2	Bioclim2	Mean Diurnal Range (Mean of monthly (max - min temp))
3	Bioclim3	Isothermality (Bio2/Bio7) ×100
4	Bioclim4	Temperature Seasonality (standard deviation × 100)
5	Bioclim5	Max temperature of warmest month
6	Bioclim6	Min temperature of coldest month
7	Bioclim7	Temperature annual range (Bio5 - Bio6)
8	Bioclim8	Mean temperature of wettest quarter
9	Bioclim9	Mean temperature of driest quarter
10	Bioclim10	Mean temperature of warmest quarter
11	Bioclim11	Mean temperature of coldest quarter
12	Bioclim12	Annual precipitation
13	Bioclim13	Precipitation of wettest month
14	Bioclim14	Precipitation of driest month
15	Bioclim15	Precipitation of seasonality (Coefficient of variation)
16	Bioclim16	Precipitation of wettest quarter
17	Bioclim17	Precipitation of driest quarter
18	Bioclim18	Precipitation of warmest quarter
19	Bioclim19	Precipitation of coldest quarter
20	FC	Forest Cover
21	FT	Forest Type
22	ELE	Elevation (Cartosat)
23	SLP	Slope (Derived from ELE)
24	ASP	Aspect (Derived from ELE)

Multi-collinearity test was performed on 24 variables using ENMTools package in R. Variables which had correlation coefficient greater than or equal to 0.8 were excluded. 8 variables viz. bioclim1, bioclim3, bioclim4, bioclim18, FC, FT, SLP and ASP were used in the SDM.

Table 12: Presence points collected from field by field survey during year 2019-2020 for top ten priority species

SN	Species	Number of presence points collected from field
1.	*Aconitum heterophyllum*	31
2.	*Paris polyphylla*	12

3.	*Gentiana kurroo*	26
4.	*Podophyllum hexandrum*	24
5.	*Valeriana jatamansi*	15
6.	*Swertia chirayita*	28
7.	*Habenaria edgeworthii*	11
8.	*Asparagus racemosus*	25
9.	*Acorus calamus*	26
10.	*Taxus wallichiana*	16

Suitable habitat mapping using Species Distribution Modelling (SDM) was done for RET plant species, viz., *Aconitum heterophyllum*, *Gentiana kurroo*, *Podophyllum hexandrum*, *Swertia chirayita*, *Asparagus racemosus,* and *Taxus wallichiana,* based on the number of presence points recorded from the field survey. These species were selected for modelling based on preliminary observations collected from the field, while for other species, sufficient numbers of presence locations are not available. Hence, the modelling work could not be done for a few priority species. Many species, like *Lilium polyphyllum,* due to their rarity and limited geographic area, impose challenges for coordinated collection. The different models used for the habitat suitability mapping tested were Maxent, Logistic Model, Random Forest, and Neural Network.

4.1.5 Habitat suitability modelling results of *Aconitum heterophyllum* (Atis)

A total of 31 presence points were recorded from the field survey for *A. heterophyllum*. For the Maxent model, which is a presence-only model, a train and test sample of 22 and 9 points, respectively, were used to validate the model. The remaining 3 models, logistic regression, random forest, and neural network, used 62 presence-absence points.

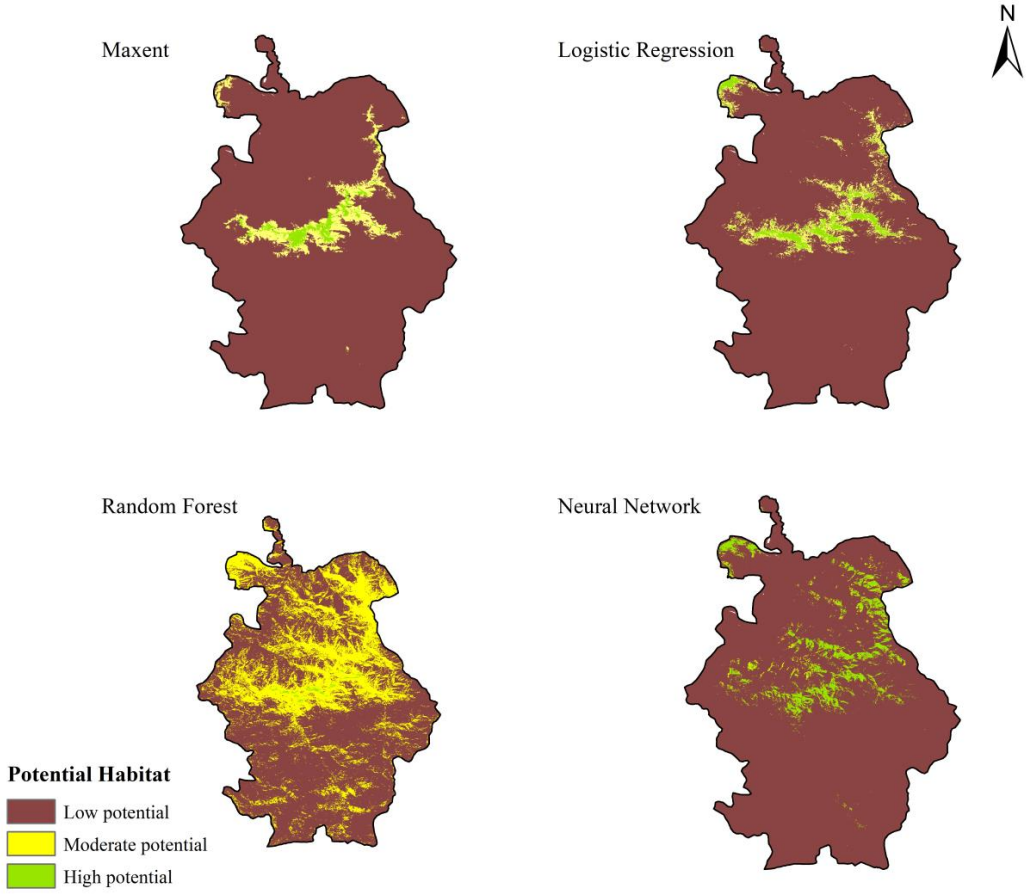

Fig. 17: Current habitat suitability modelling results of *Aconitum heterophyllum*

Different results with variations in accuracy were obtained for selected RET plant species. *A. heterophyllum* showed higher habitat suitability at high elevation sites, whereas *Asparagus racemosus* showed higher habitat suitability at low elevation sites (Figure 19).

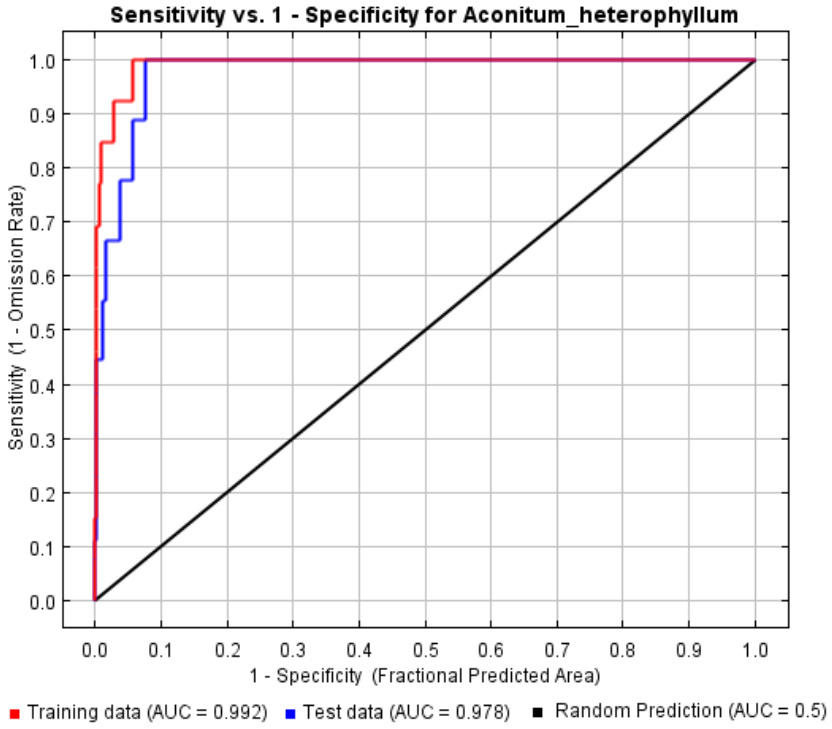

Fig.18: Maxent based area under curve (AUC) graph of *Aconitum heterophyllum*

Analysis of the variables revealed the contribution of forest type to be 43.6%, followed by the contribution of temperature seasonality (bioclim4) to be 42.2% and topographic aspect to be 8.4%.

Table 13: Model discrimination values for different models of potential habitat study

SN	Model	AUC
1	Maxent	0.978
2	Logistic Regression	0.778
3	Random Forest	0.978
4	Neural Network	0.278

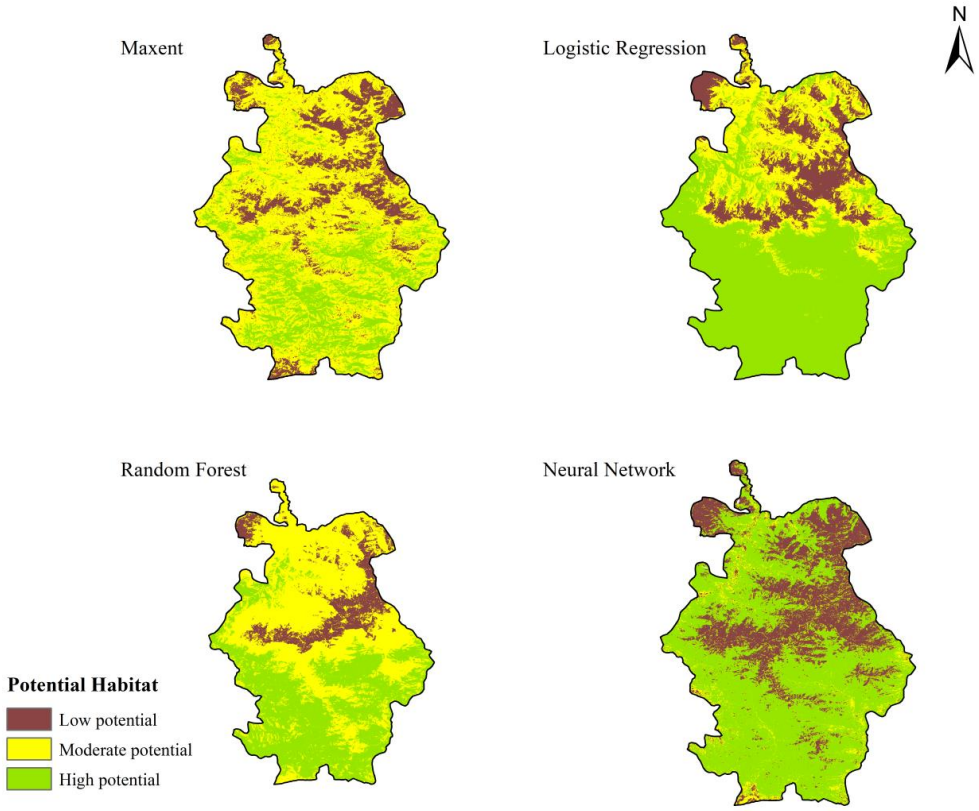

Fig. 19: Current habitat suitability modelling results of *Asparagus racemosus*

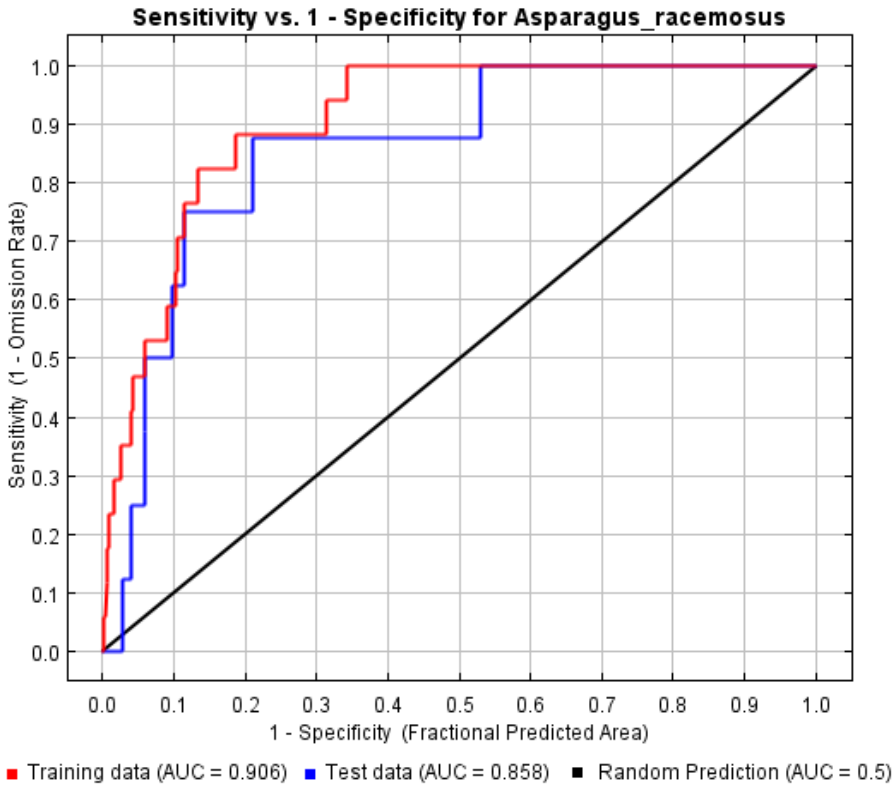

Fig.20: Maxent based area under curve (AUC) graph of *Asparagus racemosus*

Analysis of variables revealed the contribution of forest type to be 24.4%, followed by the contribution of forest cover to be 22.2%, mean annual temperature (bioclim 1) to be 14.5%, topographic slope 12.1%, and isothermality (bioclim 3) to be 11.7%.

Table 14: Model discrimination values for different models of potential habitat study

SN	Model	AUC
1	Maxent	0.858
2	Logistic Regression	0.893
3	Random Forest	0.982
4	Neural Network	0.589

Other models used for species distribution modelling are Support Vector Machine (SVM), Generalized Boosted Regressions Model (GBRM), Multivariate Adaptive Regression Splines (MARS) and ensemble (Figure 25).

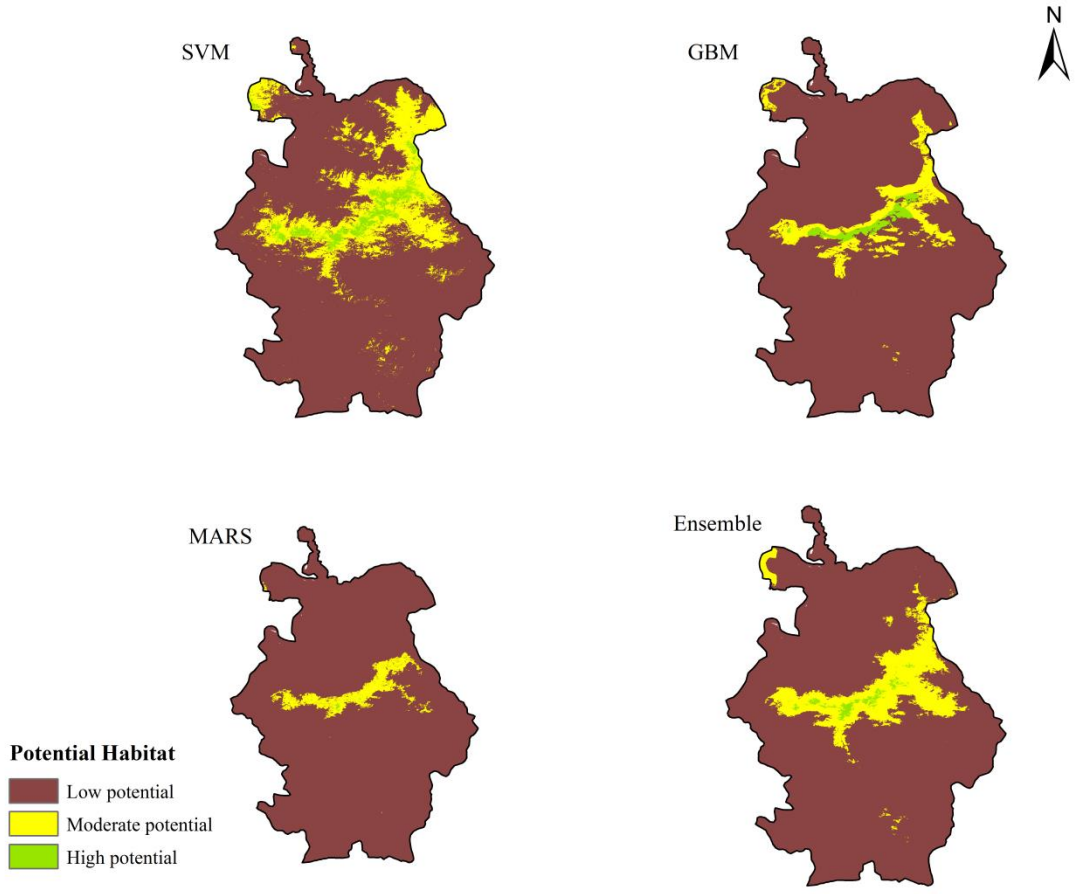

Fig. 21: Current habitat suitability modelling results of *Podophyllum hexandrum* with ensemble of support vector machine (SVM), generalized boosted regression (GBRM), and multivariate adaptive regression splines (MARS).

Table 15: Model accuracy assessment results

SN	Model	AUC	Kappa
1	SVM	0.860	0.71
2	GBRM	0.980	0.60
3	MARS	0.982	0.74
4	Ensemble	0.947	0.77

Use of SDM for conservation decisions requires a thorough assessment of model accuracy to prevent errors in prioritisation of habitat (Gogol-Prokurat, 2011). Although model discrimination (i.e., AUC) is accepted as a standard measure of model accuracy, the highest discrimination values were not necessarily the best for ranking habitat suitability on a continuous scale. For example, in the case of aconitum, the random forest model shows an AUC value of 0.978 (Table 13), but the overall prediction result is unrealistic. Therefore, using the AUC as the sole measure of model accuracy is not useful for identifying habitat for conservation planning (Gogol-Prokurat, 2011). Similarly, habitat suitability modelling for the other four species has been done. Fine tuning of models like neural networks is essential for obtaining accurate results. Considerable differences were observed under different modelling techniques. Therefore, appropriate model selection is important, along with ensemble techniques. Usually, in the ensemble method, the AUC score is used as a weightage.

Table 16: R packages for species distribution modeling and relevant analysis

SN	Tool	Description	Author
1.	*raster* package	Reading, writing, manipulating, analyzing and modelling of raster datasets	Hijmans et al., 2013
2.	*ENMTools* package	Construction of niche models and analyzing patterns of niche evolution	Warren et al., 2010
3.	*landscapemetrics* package	Calculating landscape metrics for categorical raster files	Hesselbarth et al.,2019
4.	*randomForest* package	Classification and regression based random forest algorithm	Leo Breiman
5.	*neuralnet* package	Training of neural networks	Fritsch et al., 2019
6.	*dismo* package	Provides various methods for implementing species distribution modeling	Hijmans et al., 2017
7.	*SSDM* package	Species distribution modeling using single or ensemble method	Schmitt et al., 2017

8.	*exactextractr*	To perform zonal statistics using polygon	Hijmans et al., 2017
9.	*SpatialEco*	Utilities to support spatial data manipulation, query, sampling and modelling. Also provides statistical exploratory tools.	Evans et al., 2015

Multiple free and open source tools like QGIS, Maxent and Fragstat can be used for species distribution modelling and analysis of suitable habitat along with packages in R statistical software.

4.1.6 Suitable habitat of *Aconitum heterophyllum* (Atis) under future climate change scenarios

The Intergovernmental Panel on Climate Change (IPCC) estimates the extinction of 20–30% of species before the end of the 21st century due to the rise in global temperatures (IPCC 2014). Observations indicate the warming rate of the Himalayas to be 3 times faster than the average global warming and has affected animals and plants of the region (E. Sharma et al., 2009; Shrestha et al., 2015). In other words, high-altitude areas are expected to experience a much more rapid rise in temperature of up to 4–5 °C by 2100 (Alfthan et al., 2018).

Under Coupled Model Inter-comparison Project 5 (CMIP5), the RCPs were the basis for climate model projections (Taylor, Stouffer, & Meehl, 2012) and were assessed in the IPCC AR5 (IPCC, 2013). The recent, CMIP6, has been formulated on the basis of scientific gaps learned from CMIP5 (Bai et al., 2021). The climate projections under CMIP6 will differ from CMIP5 due to updated versions of climate models, a new inception year for the future scenarios, i.e., 2015 for CMIP6 (O'Neill et al., 2016), as well as new emission trends and land use scenario (Riahi et al., 2017). The SSPs describe alternative evolutions of future society in the absence of climate change or climate policy. The projections are concerned with the social changes regarding changing climate, adaptation, mitigation, or impacts (O'Neill et al., 2016).

For mapping suitable habitat under future climate change scenarios, four integrated scenarios viz. SSP 126, SSP 245, SSP 370, and SSP 585 and 2 RCP scenarios viz. RCP 4.5 and RCP 8.5 were considered. SSP126 represents the low future radiative forcing pathways in the IAM literature. It predicts a warming of less than 2 ^{0}C by 2100. The SSP 245 scenario envisions a mid-pathway wherein trends continue their historical patterns without significant deviations. SSP 370 represents the medium-to-high-end range of future pathways. This scenario envisions substantial land use and land cover and also a high concentration of Near-Term Climate Forcers (NTCF), viz., SO_2, NH_3, and PM2.5. The SSP 585 scenario assumes relatively optimistic trends for human development, substantial investments in education and health, rapid economic growth, and well-functioning institutions (O'Neill et al., 2016). It is the only SSP scenario with high enough emissions to produce radiative forcing of 8.5 W/m^2. RCP4.5

is a stabilisation scenario at a stabilised radiative forcing of 4.5 W m^{-2} after 2100, whereas RCP 8.5 is a high emissions scenario at a radiative forcing of 8.5 W m^{-2} by 2100 (Bai et al., 2021).

Projection of future suitable habitat for *A. heterophyllum* was done for the Indian Western Himalayas (IWH) with geo-coordinates collected during the field visit and secondary data from other sources.

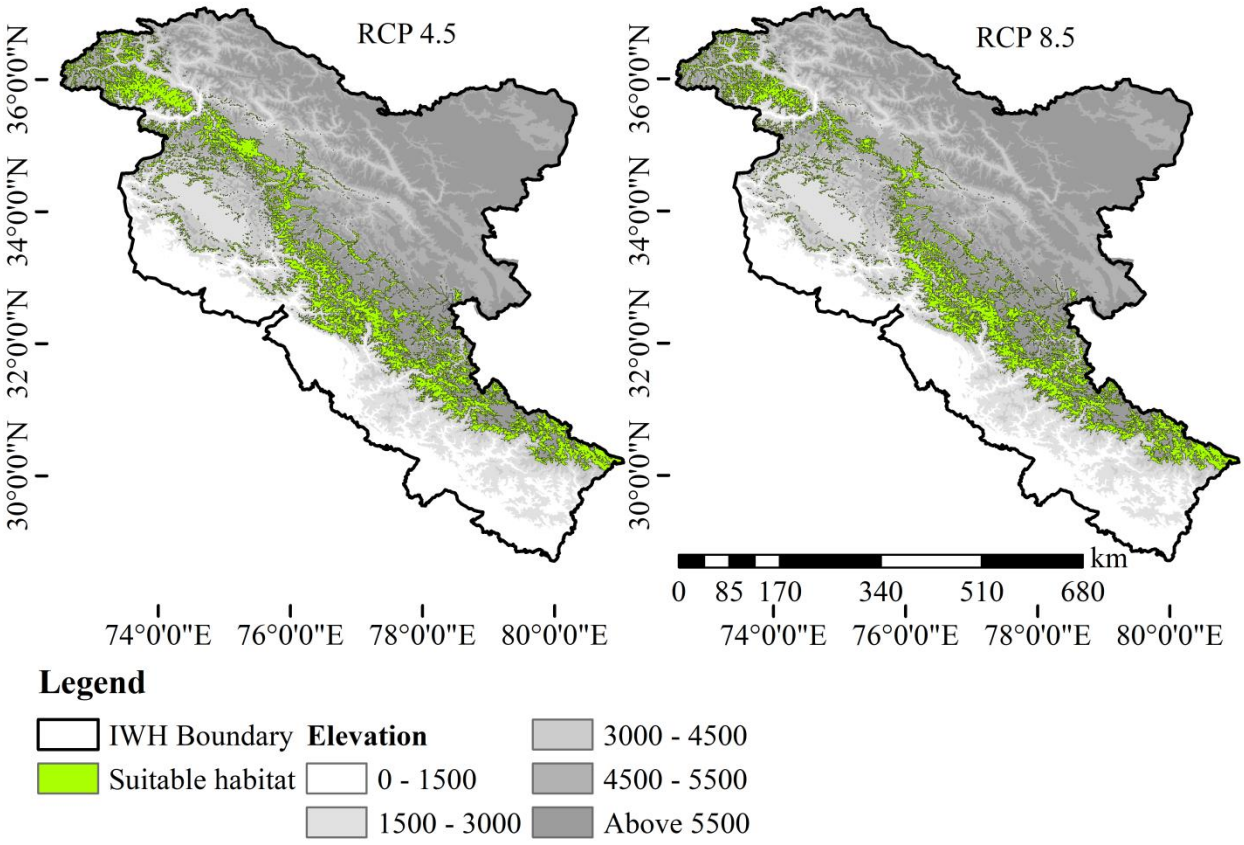

Fig. 22: Projected suitable habitat under representative concentration pathway RCP 4.5 and RCP 8.5

A total area of 32,168 km^2 was found to be suitable for *A. heterophyllum* (Atis) under current climatic conditions. RCP 4.5 and RCP 8.5 projected suitable habitat areas of 42,141 km^2 and 37,351 km^2, Projected respectively.

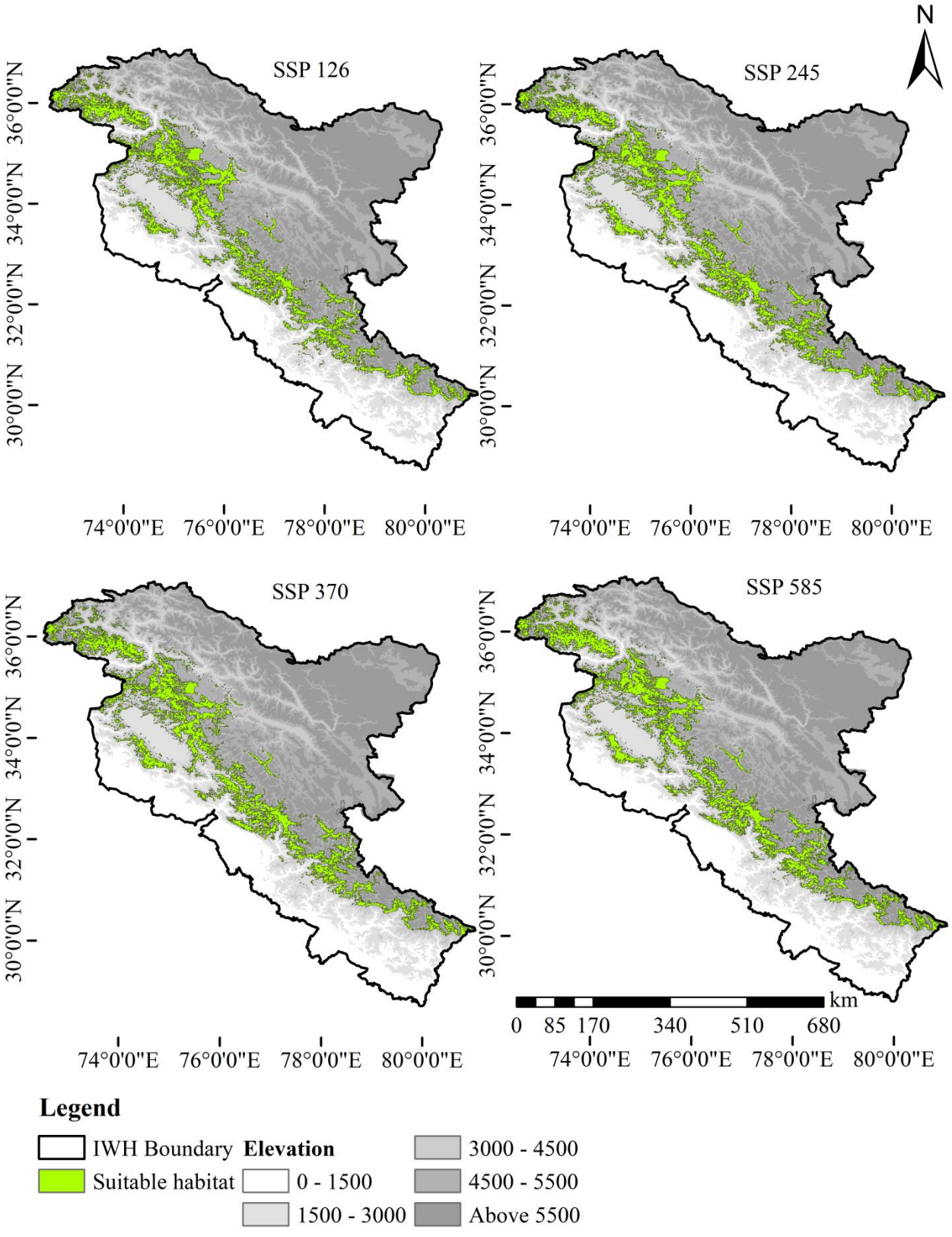

Fig. 23: Projected suitable habitat under shared socio-economic pathways

Similarly, under SSP 126, a total suitable habitat of 38,241 km^2 was projected. Similarly, SSP 245 and SSP 370 showed suitable habitat of 38,363 km^2 and 38,129 km^2 respectively. Whereas, SSP 585 showed the highest projected suitable area of 39,894 km^2.

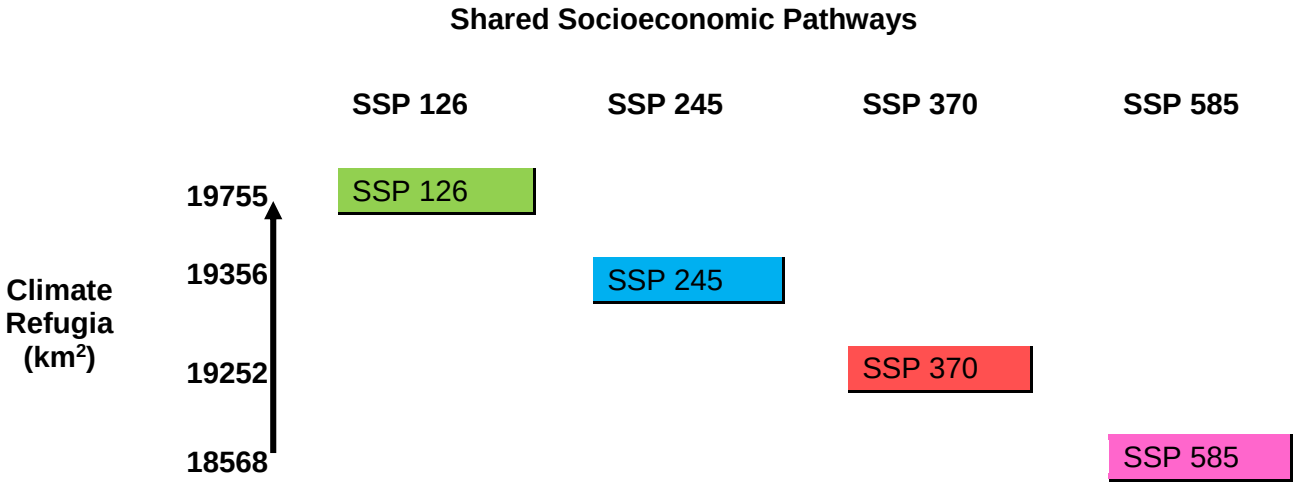

Fig.24:SSP – RCP scenario matrix

Even though the suitable habitat increased under future climate scenarios, a drop in climate refugia was observed under each successive SSP (Figure 23) and RCP scenario. Under RCP 4.5 climate refugia of 14912 km^2 was projected whereas, a further decrease to 12670 km^2 was projected under RCP 8.5.

Vulnerability assessment was done by defining following categories of habitat

1. **Unchanged habitat or Climate refugia:** the suitable habitat from current scenario which retains suitability in the future scenario projections.
2. **Vulnerable habitat:** the suitable habitat from current scenario which loses suitability in the future scenario projections.
3. **Increased suitability:** the unsuitable habitat from current scenario which gains suitability under future scenario projections.
4. **Unsuitable habitat:** the unsuitable habitat which remains unsuitable in future scenario projections.

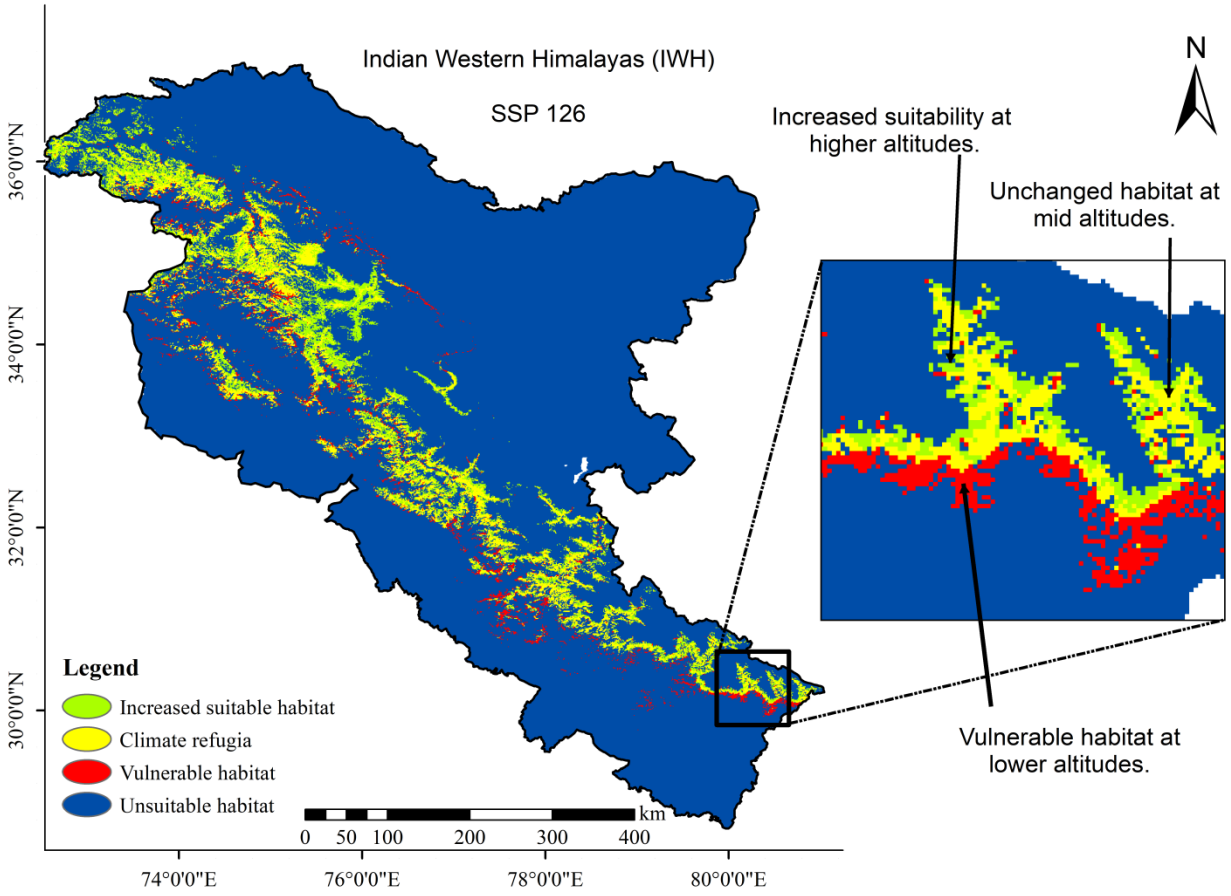

Fig. 25: Projected habitat change map under SSP 126 scenario

Future projections based on changing climate reveal altered extent and distribution by conversion of suitable habitat into unsuitable and vice versa. Habitat vulnerability assessment revealed a net increase in suitable habitat under all future scenarios. The loss of suitable habitat at lower elevations was found to have been compensated for by a greater increase in suitable habitat at higher elevations. Zonal statistics performed using the elevation layer revealed the 3000–3500m altitudinal range to be most suitable for *A. heterophyllum*.

Various landscape metrics have been developed and widely applied to landscape structure analysis to quantify the number, abundance, and configuration of different land cover classes (Gustafson, 1998, 2019; Uuemaa et al., 2013). Landscape metrics were calculated using the landscape metrics package in R. The core of the package includes functions to compute landscape metrics with raster data as input (Hesselbarth et al., 2019).

Table 17: Patch level landscape metrics for *A. heterophyllum* using queen's 8-directions

	No. of patches	Mean patch area (km^2)	Mean nearest neighbour distance (m)
Current	2136	11.78	2282.46
Representative Concentration Pathways			
RCP 4.5	1798	21.61	2368.57
RCP 8.5	1795	19.24	2337.97
Shared Socio-economic Pathways			
SSP 126	1308	26.87	2374.28
SSP 245	1265	27.90	2362.52
SSP 370	1310	26.76	2285.01
SSP 585	1273	28.84	2347.43

Landscape metrics analysis at the patch level shows a decrease in the number of patches under all the future scenarios. A greater decrease is observed under shared socio-economic pathways. The decrease in the number of patches is also accompanied by an increase in the average patch area. A slight increase in nearest neighbour distance is observed under future climate scenarios (Table 15).

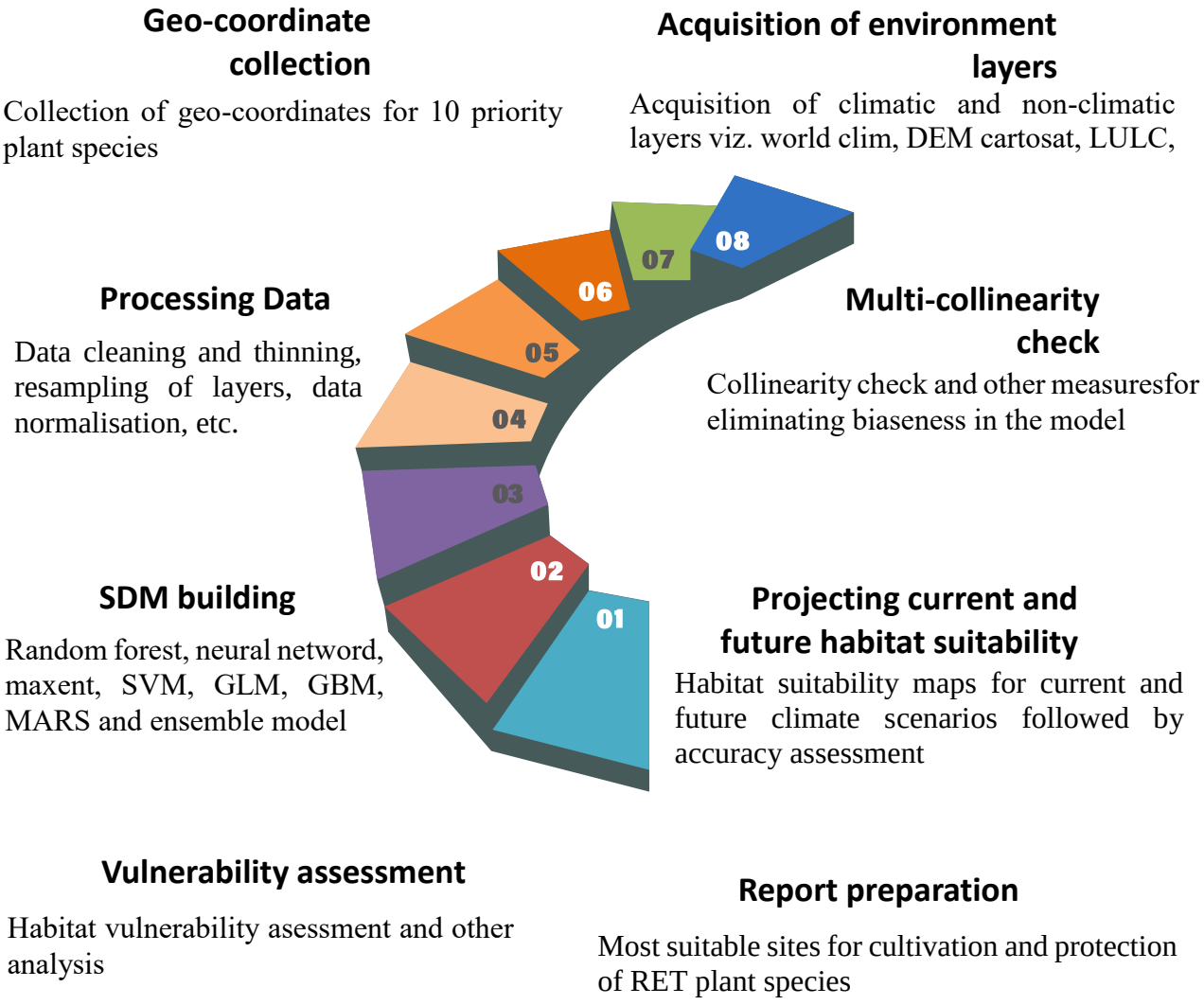

Fig.4 Steps involved in mapping suitable habitat for cultivation and conservation

4.1.7 Biodiversity Information System

A web-based Biodiversity Information System (BIS) is developed as the fifth and last objective of the project to provide critical information on important NWFP and RET species of the study region. However, the present version of BIS can be up-scaled for the entire Himalayan region. Gradually, we are adding different options, tools, and information to the BIS to make it appropriate for individual users, state agencies, and other stakeholders. The information is segregated into two broader categories, where the first category information would be accessible to everyone, while the second category information would be available to selected users only after a password-based login.

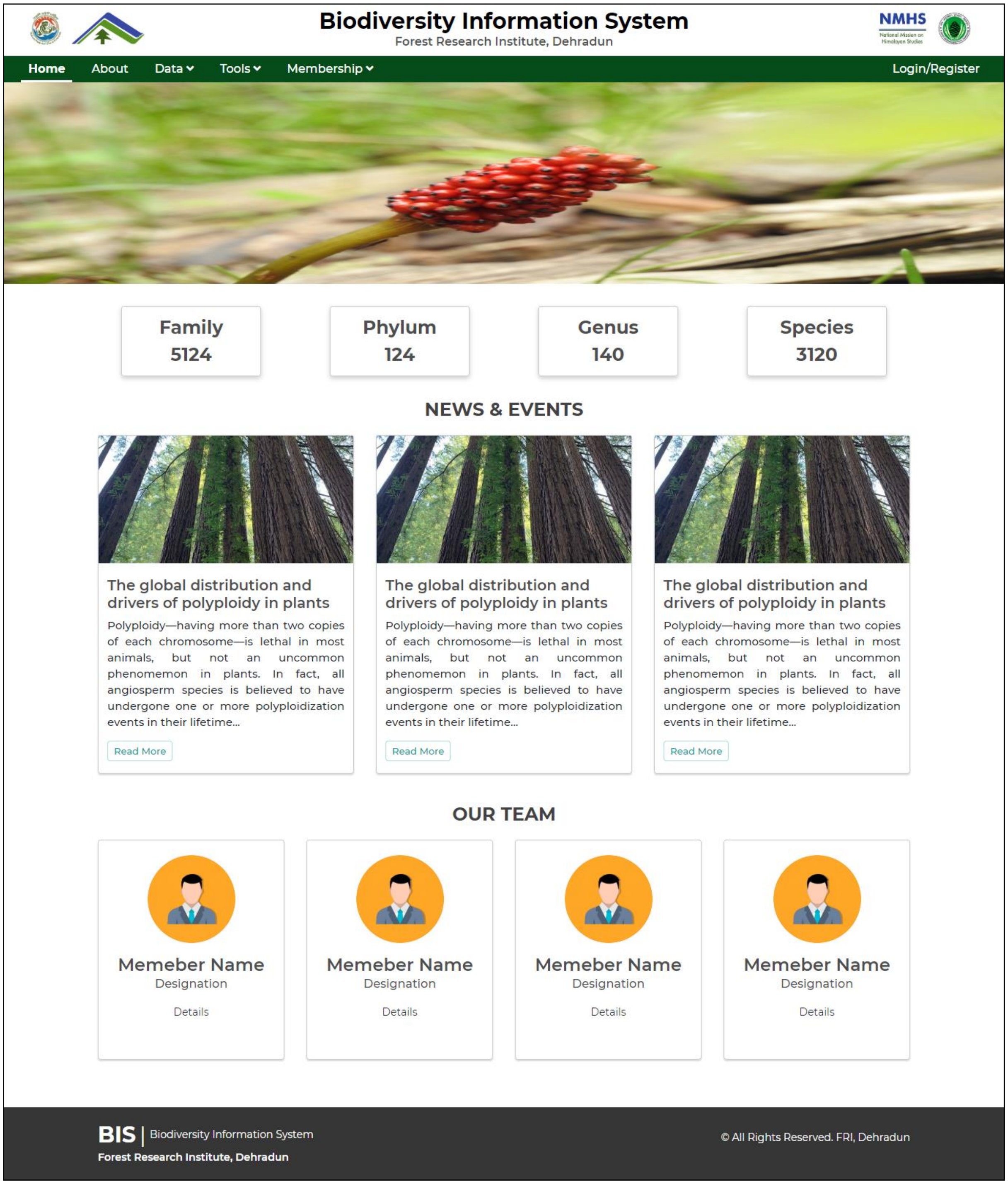

Fig. 27: A screenshot of Biodiversity Information System Home Page

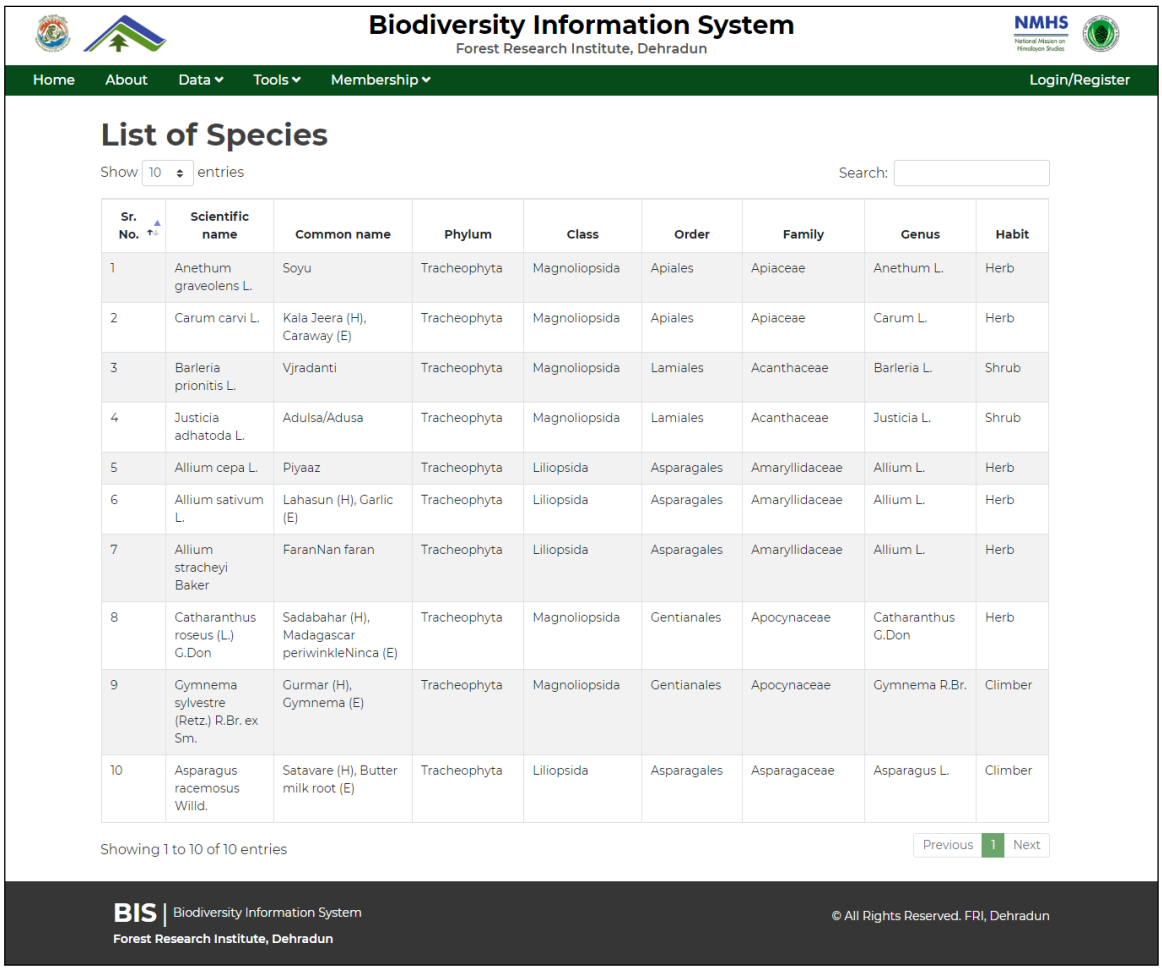

Fig. 28: Listing of species in the Biodiversity Information System

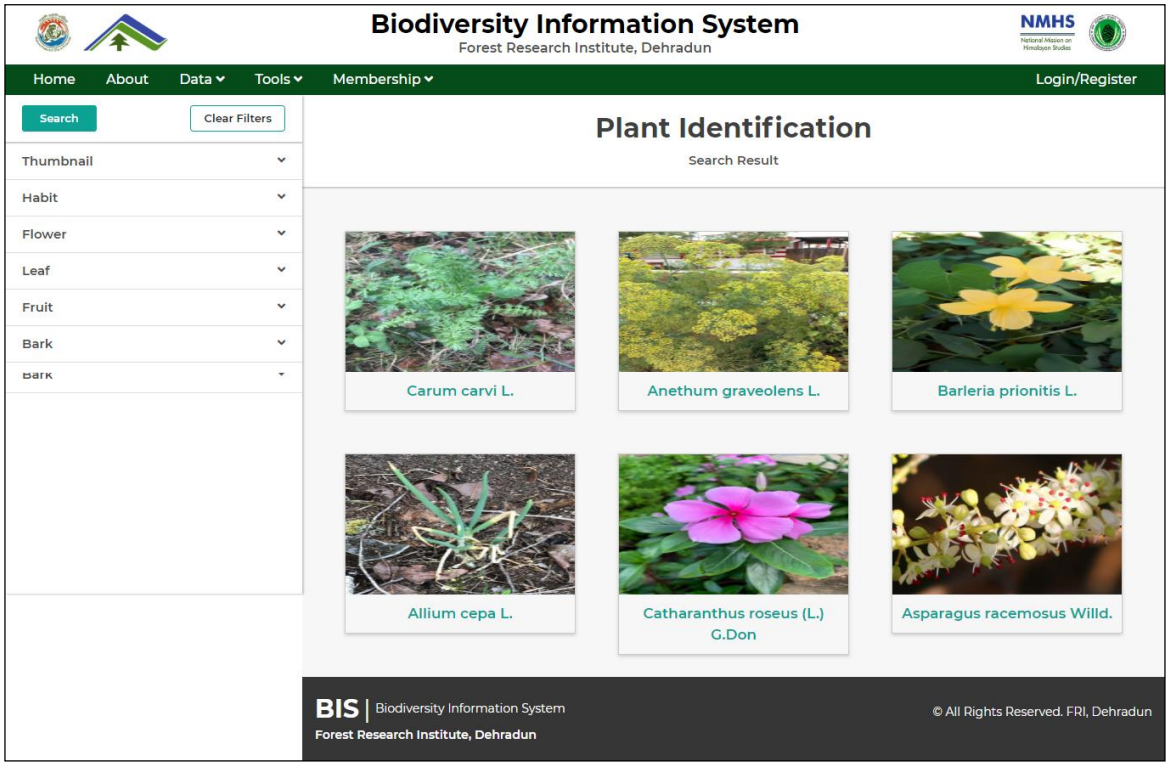

Fig. 29: Plant identification tool as a part of the B

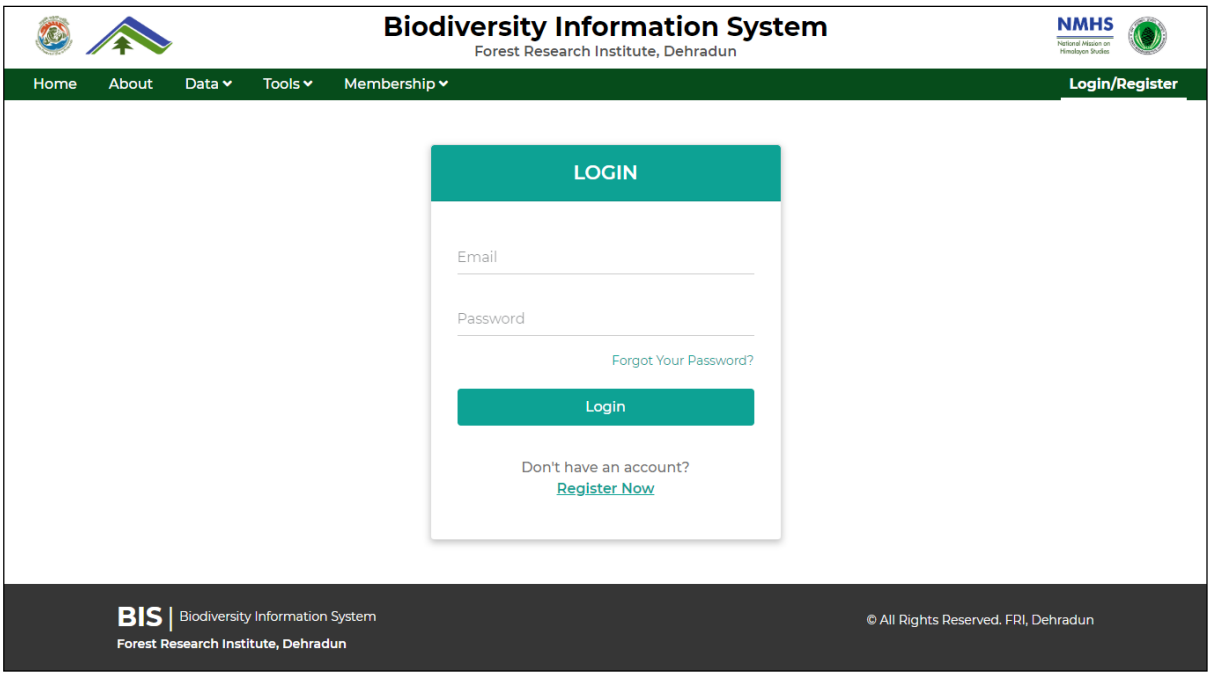

Fig.30: Login system for the access to data base restricted through password for the selected users

4.2 Key Results (max 1000 words in bullets covering all activities)

- Experts and locals reported a total of 89 plant species of NWFP value. Weightage was assigned to selected parameters in order to prioritise the species. *Aconitum heterophyllum* is the highest ranked species, followed by *Dactylorhizahatagirea, Paris polyphyllum, Angelica glauca, Gentiana kurroa, and Podophyllum hexandrum.*

- Six plant species, viz., *Aconitum heterophyllum, Gentiana kurroo, Taxus wallichiana, Podophyllum hexandrum, Swertia chirayita,* and *Asparagus racemosus*, for which sufficient geo-coordinates were available, were considered for species distribution modelling.

- Topographic aspect induces soil moisture and exposure to sunlight, wind, and rain, which hence contributes significantly to the habitat of plant species. Sunny slopes retain less moisture due to higher evaporation and stronger solar radiation, whereas shady sites have higher soil moisture retention. Forest cover is shown in three density classes; viz., very dense forest (VDF) with more than 70% canopy density; moderately dense forests (MDF) with canopy density between 40% and 70%; and open forests (OF) with canopy density between 10% and 40%.

- Different results with variations in accuracy were obtained for all six plant species. *A. heterophyllum* showed higher habitat suitability at high elevation sites, whereas *Asparagus racemosus* showed higher habitat suitability at low elevation sites.

- The Intergovernmental Panel on Climate Change (IPCC) estimates the extinction of 20–30% of species before the end of the 21st century due to the rise in global temperatures. Temperatures in high-altitude areas are expected to rise much faster, by up to 4-5 ^{0}C by 2100. Mapping suitable habitat for *A. heterophyllum* was done for the Indian Western Himalayas (IWH) with geo-coordinates collected during field visits and secondary data from other sources. Four integrated scenarios, viz., SSP 126, SSP 245, SSP 370, and SSP 585, and two RCP scenarios, were considered.

- A total area of 32,168 km^2 was found to be suitable for *A*. *heterophyllum* (Atis) under current climatic conditions. RCP 4.5 and RCP 8.5 projected suitable habitat areas of 42,141 km^2 and 37,351 km^2, respectively. Similarly, under SSP 126, a total suitable habitat of 38,241 km^2 was projected. Similarly, SSP 245 and SSP 370 showed suitable habitat of 38,363 km^2 and 38,129 km^2 respectively. Whereas, SSP 585 showed the highest projected suitable area of 39,894 km^2.

- A multi-collinearity test was performed on 24 variables using the ENMTools package in R. Variables that had a correlation coefficient greater than or equal to 0.8 were excluded. 8 variables, viz. bioclim1, bioclim3, bioclim4, bioclim18, FC, FT, SLP, and ASP were used in the SDM.

- Four integrated scenarios, namely SSP 126, SSP 245, SSP 370, and SSP 585, as well as two RCP scenarios, namely RCP 4.5 and RCP 8.5, were taken into consideration for mapping suitable habitat under a future climate change scenario. In the IAM literature, SSP126 stands for low future radiative forcing paths. It predicts a warming of less than 2 ^{0}C by 2100. The mid-pathway in the SSP 245 scenario is one in which trends continue to follow their historical patterns with few notable deviations. The medium to high end of potential future pathways is represented by SSP 370. This scenario envisions substantial land use and land cover and also a high concentration of Near-Term Climate Forcers (NTCF) viz. SO_2, NH_3 and PM2.5. The SSP 585 scenario assumes relatively optimistic trends for human development, substantial investments in education and health, rapid economic growth, and well-functioning institutions.

- The variation in accuracy when using various approaches has been summarised. A vulnerability assessment for the future climate change scenarios revealed an increase in the climate suitable area under future climate scenarios. The most influential variable guiding the suitability was an increase in temperature, which might be one of the reasons for having increased suitable habitat in the colder region, which is expected to warm to achieve suitable habitat temperature. Loss of suitable habitat was projected at lower elevations, whereas suitability increased at higher elevations. Landscape metrics and zonal statistics were successfully calculated for the present as well as future scenarios.

- A web-based Biodiversity Information System (BIS) was developed as the fifth and last objective of the project to provide critical information on important NWFP and RET species of the study region. The present version of BIS can be up-scaled for the entire Himalayan region. The information is

segregated into two broader categories where the first category information would be accessible to everyone while the second category information will be available to selected users.

4.6 Conclusion of the study (maximum 500 words in bullets)

- This study reveals the locality and extent of the distribution of six priority RET species, *Aconitum heterophyllum, Gentiana kurroo, Taxus wallichiana, Podophyllum hexandrum, Swertia chirayita,* and *Asparagus racemosus*; and the areas identified through the modelling approach as suitable habitat can be protected to ensure the conservation and cultivation of RET species like *A. Heterophyllum* and *A. racemosus* for the current as well as future changing climatic scenarios.

- NWFPs are significant components of households' daily lives in the study area. Similar to other rural places in the area, a nearby forest serves as the only viable source of income for a large portion of the study area's poor residents. It serves as their primary supply of food, medication, animal feed, gums, and raw materials for regional industries.

- MaxEnt and ensemble modelling approaches can be adopted for mapping the suitable habitats of different species that are under the influence of physiographic, topographic, and climatic factors.

- *A. heterophyllum* showed higher habitat suitability at high elevation sites, and Asparagus racemosus was more commonly found at low elevation sites for each of the six plant species studied. For the Maxent model, the presence-only model, a train, and a test sample of 22 and 9 points, respectively, were used to validate the model.

- The IHR reserves the habitat of these NWFP/RET species, and thus it must have a focused conservation approach for the protection of the viable number of these species. There is a need to identify the suitable habitat of selected priority species for conservation and protection, especially those which are on the verge of extinction.

- The wide spread of NWFPs demonstrates great potential for meeting multiple needs and generating income, which is supported by the current findings. Adequate innovative research and development are required to encourage rural communities to invest in NWFPs through the preservation and use of indigenous knowledge, particularly for the above-mentioned species.

5 OVERALL ACHIEVEMENTS

5.5 Achievement on Project Objectives [Defining contribution of deliverables in overall Mission (max. 1000 words)]

Project objective:

- Identification of priority species of conservation in tribal blocks dominated by Jaunsari community in Kalsi, Chakrata and Tiuni tehsils of Dehradun.

- Develop model for mapping the potential sites of cultivation and conservation for the identified priority species.
- Projected impacts of climate change on habitat suitability of identified priority species and its resilience planning.
- Development of web based biodiversity information system (BIS) for the study region.

Deliverables

Suitable habitat of *Aconitum heterophyllum* (Atis) under future climate change scenarios:

In these deliverables we did the suitable habitat mapping by using Species Distribution Modelling for the six RET plant species such as *Aconitum heterophyllum*, *Gentiana kurroo*, *Podophyllum hexandrum*, *Swertia chirayita*, *Asparagus racemosus,* and *Taxus wallichiana* based on the number of presence points recorded from the field survey. These species were selected for modelling based on preliminary observations collected from the field, while for other species, sufficient numbers of presence locations are not available. Hence, the modelling work could not be done for a few priority species. Many species, like *Lilium polyphyllum,* due to their rarity and limited geographic area, impose challenges for coordinated collection. The different models used for the habitat suitability mapping tested were Maxent, Logistic Model, Random Forest, and Neural Network.

A total of 31 presence points were recorded from the field survey for *A. heterophyllum*. For the Maxent model, which is a presence-only model, a train and test sample of 22 and 9 points, respectively, were used to validate the model. An area of 32,168 km^2 has been found to be suitable for *A. heterophyllum (*Atis) under current climatic conditions. Using RCP 4.5 and RCP 8.5, we projected suitable habitat areas of 42,141 km^2 and 37,351 km^2, respectively. Under RCP 4.5, climate refugia of 14912 km^2 were projected, with a further decrease to 12670 km^2. Under RCP 8.5, SSP 585 showed the highest projected suitable area of 39,894 km^2. Even though suitable habitat increased under future climate scenarios, there was a drop in each successive SSP and RCP scenario. Landscape metrics were calculated using the landscape metrics package in R. The core of the package includes functions to compute landscape metrics with raster data as input. Zonal statistics performed using the elevation layer revealed the 3000–3500 m altitudinal range to be most suitable for *A. heterophyllum*.

5.6 Establishing New Database/Appending new data over the Baseline Data (max. 1500 words, in bullet points)

We have developed a web-based Biodiversity Information System (BIS) to provide critical information on important NWFP and RET species of the study region. However, the present version of BIS can be up-scaled for the entire Himalayan region. The information is segregated into two broader categories

where the first category information would be accessible to everyone and the second category information would be available to selected users only after a password-based login.

5.7 Generating Model Predictions for different variables (if any) (max 1000 words in bullets)

Prioritization of species for the conservation and propagation

Endemism is one of the important parameters for the prioritisation of species for conservation. Threat status is a central indicator of the relative risk of species extinction. Species facing a higher threat should be given higher conservation priority. The use value of a species can also be considered as part of the criteria for conservation priority. Plant species whose roots are extracted are more prone to extinction and hence require priority conservation. Therefore, the scoring for prioritisation would also depend upon the parts being used and extracted from the field of natural occurrence of a species. The project site has considerable altitudinal variation, ranging between 400 and 2960m. Plant species were grouped as per their respective altitudinal gradients to suggest the altitudinal preference of conservation sites. We have identify the six priorities RET plant species such as *Aconitum heterophyllum*, *Gentiana kurroo*, *Podophyllum hexandrum*, *Swertia chirayita*, *Asparagus racemosus,* and *Taxus wallichiana* based on the number of presence points recorded from the field survey. *Aconitum heterophyllum,* commonly known as Atis, is categorised as endangered by the IUCN. The root of the species is used in Ayurveda and Chinese medicine. *Gentiana kurroo* and *Lilium polyphyllum* are categorised as critically endangered and endangered, respectively.

The elevation of an area is a critical habitat parameter for a plant species. Soil is normally not stable at slopes greater than 35%. Forest cover is shown in three density classes, viz., very dense forest (VDF), moderately dense forests (MDF) and open forests (OF). Pre-existing, pre-processed or remotely sensed secondary data are essential input layers to the SDM. Climate is the main determinant of species ranges at a regional scale, while other parameters like topography contribute more at a local scale. Essential variables like moisture, gradients, solar radiation, air temperature, and rockiness all correspond with topography. *Asparagus racemosus* showed higher habitat suitability at high elevation sites, and *A. rhamnifer* was found to be equally good at both high and low elevation locations for each of the six plant species.

5.8 Technological Intervention (max 1000 words)

5.9 On field Demonstration and Value-addition of Products (max. 1000 words, in bullet points)

5.10 Promoting Entrepreneurship in IHR

- The Indian Himalayan Region (IHR) is endowed with fertile soils, minerals, water resources, biodiversity-rich forests, and diverse population groups. Despite these obvious advantages, the physical challenges and disadvantages of the mountains far outweigh the advantages. Mountain communities continue to deal with challenges pertaining to disaster risk, agriculture and bio-resources management, and environmental degradation, often resulting in migration.

- With slower economic growth than the rest of the country, entrepreneurship development is critical to assisting in the alleviation of the IHR's unemployment problem. The impact of entrepreneurship on the economy and people's lives has yet to be seen by the IHR. The majority of the people in the area are wage earners, with only a few job creators. Entrepreneurship development requires an enabling ecosystem.

- Interventions have to include people's participation in the development process as well as the equitable distribution of benefits among various groups. Non-wood forest products provide employment opportunities for young people, women, and the elderly.

- This could be supported by the fact that collecting NWFPs was the single most important secondary occupation in the area, with 30% of households involved, followed by commerce (Deafalla et al., 2014). When other options (rain-fed agriculture) are unavailable during the summer season, the NWFPs must be considered as a source of employment.

- It could also play an important role in rural areas where resources are scarce and the community's weaker members are unable to migrate to seek employment elsewhere or engage in more labor-**intensive activities.**

5.11 Developing Green Skills in IHR

5.12 Addressing Cross-cutting Issues (max. 500 words, in bullet points)

- Environmental variables (in the form of average precipitation, temperature, and other developed climatic indexes) being widely used in climate change studies were also included while developing models for predicting and mapping the probable extent of its cultivable space.
- Thus, the model has been used to predict its probable extent, shift in extent, etc. for future climate change scenarios.
- Gender equality has been attained by including the female while prioritising species to be selected for this project, seeking the concern of women for their preferences. Information on selecting species

which are linked with the market and livelihood of the region and their potential cultivable lands has encouraged farmers to adopt this species for cultivation.

- Once the model of biodiversity conservation has been successfully tested and implemented through this action-based research project, the information is expected to be disseminated through community mobilisation in adjacent areas of project implementation.
- People of the region have gradually adopted identified species for their cultivation and as a source of livelihood. However, to sensitise the people, information was communicated to the farmers through extension activities for which a fund has been included in the project as an integral part of the project. The output of the project has been disseminated through the following communication strategy:
- Submission of executive summary and products to the various relevant ministries of state and country, such as AAYUSH, MoE&F, Agriculture, Horticulture, etc. A separate fund is allocated within the project total cost for these activities.

I. Conference presentation, Research paper publication.

II. General Articles and Pamphlets

III. Media coverage

6 PROJECT'S IMPACTS IN IHR

6.5 Socio-Economic Development (max. 500 words, in bullet points)

- A symbiotic relationship between forests and forest dwellers must be maintained for community empowerment and sustainable forest management in order to provide food security for forest dwellers and income generation for the tribal people. Because of the nature of their production, quantity, collection procedure, processing, and local selling, women are primarily dependent on NWFPs. As a result, programmes to ensure food security would be required to improve subsistence levels with a special focus on the landless, hunter-gatherers, and primitive tribes.

- A better understanding of NWFPs' overall socioeconomic contributions to local communities' subsistence and income, as well as national economies, enables better programme response. NWFPs are critical to food security, nutrition, and community health. Their benefits are relatively more important for poorer households, women, and disadvantaged groups, which has important implications for NWFP activity planning.

- There is no doubt that NTFPs are crucial to the ability of a significant portion of the world's population to sustain themselves and earn a living. According to studies from all tropical regions, the households in rural areas that rely the most on NTFPs are frequently the poorest.

- However, in the current study, local people were found to be less aware of the market value of much produce and thus unable to generate significant income from NWFPs, despite the fact that they offer enormous opportunities. As a result, NWFPs are the next major alternative business to improve tribal economies in the study area. Many non-timber forest products (NTFP's) are being used by locals for the improvement of their livelihood status; these include leaves, flowers, fruits, branches, gums/resins, roots (Schaafsma et al., 2014).

- Based on the present study, the forest provides a diverse range of goods that contribute to people's basic needs. The people in these villages were found to be extremely reliant on various minor forest products. Several minor forest products are used by aboriginals for daily needs, and many of them generate income for them.

6.6 Scientific Management of Natural Resources in IHR (max. 500 words, in bullet points)

- Natural resources provide fuel, wood, fodder, food, and other materials to rural populations. They may generate non-farm revenue from supplementary ventures like tourism. Therefore, it is crucial to conserve and use land, water, biodiversity, and forest resources responsibly in order to protect rural populations' livelihoods and social well-being while also ensuring the profitability of agriculture (Sarma, 2018.).

- Natural resources are classified into two types based on their availability: renewable and non-renewable resources. Renewable resources have the ability to recycle, reproduce, and replace themselves. Natural resources, on the other hand, can be classified as biotic or abiotic. Biotic resources are forest, agriculture, fish, and wildlife, and abiotic resources are petrol, land, minerals etc.

- Land use planning and sustainable land management practises are crucial for the long-term management of natural resources in the Indian Himalayan region. Capacity building in is required for the development of natural resource plans, intervention implementation, and ownership, particularly at the block and district levels and tribal areas. Plans must be developed in accordance with the characterization of biophysical resources, as well as an understanding of resource variability and the dynamics of socioeconomic realities.

- A method that recognises the functional relationship between soils, water, biodiversity and forests, as well as the impact on ecosystem services provided, is required. It would be beneficial to re-emphasize the watershed approach, which integrates multiple resource uses and conservation.

- Increased investment in (research, training and education, partnerships, policy) raising public understanding of the social costs of ecosystem degradation and the value of ecosystem services will strengthen human resources in the support of natural capital.

- Promote research through innovative two-way learning processes in research and development, monitoring, and policy formation to enable less exploitative NRM and improved methods for resource resilience, protection, and renewal.

- In order to shape Natural Resource Management policy in collaboration with the public and private sectors, we must, create a climate that is supportive of stakeholders and their organisations developing their NRM capability and understanding of NRM.

- Create networks among farmer organisations, NGOs, the government, and the private sector to facilitate long-term natural resource management and maximise the benefits of natural resources for the common good.

6.7 Conservation of Biodiversity in IHR (max. 500 words, in bullet points)

- The main threat to the conservation and management of NWFPs in Uttarakhand is unsustainable harvesting of NWFPs, mostly medicinal and edible plants. This study examined the distribution of suitable habitat for priority plant species in the Indian Himalayan region. The plant species *Aconitum heterophyllum, Dactylorhiza hatagirea, Paris polyphyllum, Angelica glauca, Gentiana kurroo,* and *Podophyllum hexandrum* are listed by the International Union for Conservation of Nature (IUCN). The *A. heterophyllum* species' root is used in Ayurvedic and Chinese medicine, and it is also one of the most widely cultivated medicinal plant species. Both *Gentiana kurroo* and *Lilium polyphyllum* are classified as critically endangered and endangered, respectively.

- The main concern is overharvesting as a result of trade pressure. Furthermore, habitat destruction, livestock grazing, forest fires, and other factors contribute to the extinction of many species. In the Indian Himalayan region, the conservation and cultivation of Himalayan medicinal plants is a top priority. NWFP conservation and management are being hampered by a variety of factors.

- A significant gap is the lack of appropriate policies and regulations for long-term collection, use, trade, and management of NWFPs. Many species' wild populations have recently declined as a result of continuous habitat destruction and over-exploitation. Lack of management may also result in overexploitation, diminished population vigour, and economic exhaustion of the resource, depending on the plant part harvested.

- Many important NWFPs are on the verge of extinction due to high levels of collection from the wild, a lack of baseline data on their harvesting potential, a lack of field identification guides, and a lack of trained staff. According to gatherers, traders, and forest field staff, there has been a decrease in the quantity of some species harvested and a subjective ocular assessment of their population status.

- The impact on the natural populations of NWFP species, particularly the vulnerable ones, is anticipated to increase further due to the rising global demand for herbal products, which needs immediate attention. Therefore, conservation and management of habitat loss are necessary at the earliest. Thus, the future habitat suitability distribution maps would benefit biodiversity conservators and policymakers in formulating future strategies and plans for conservation and management of the selected Himalayan range-restricted NWFP and RET species (Masoodi and Sundriya, 2020).

- The majority of the country's forest resource-based policies are centred on sustainable timber exploitation, which is dictated by economic considerations for revenue generation. NTFPs have not been adequately considered in the forest management and planning process, and they are vulnerable to a variety of challenges, including economic priorities, political will, insufficient information on the potential role of NTFPs, irregular trade, and insufficient information on NTFPs. This has had a negative impact on the promotion and development of NTFPs in the IHR.

6.8 Protection of Environment (max. 500 words, in bullet points)

- Population growth, deforestation, and climate change are all putting pressure on species' realized niches. Landscapes are constantly changing as a result of natural and anthropogenic drivers, which contribute to fragmentation and habitat loss, two of the most serious threats to biodiversity and ecosystem services.

- The Intergovernmental Panel on Climate Change (IPCC) predicts that rising global temperatures will cause the extinction of 20–30% of all species by the end of the 21st century. Temperature increases of up to 4-5 ^{0}C are expected in high-altitude areas by 2100.

- The models in this study were developed using various projections, which revealed the range shifts of species under various climate change scenarios towards higher altitudes, requiring conservation planning for current and potential future distributions.
- When combined with social, economic, and political stresses, these exert constant pressure on the species' available space, making it more vulnerable to extinction. Tribal communities depend primarily on forest products, which are also becoming increasingly important in the healthcare and pharmaceutical industries.
- On the other hand, many of these important plant species are on the verge of extinction as a consequence of over-harvesting in the wild as well as the threat of climate change. As a result, it is critical to identify NWFP/RET plant species that should be prioritized for conservation.
- Land use and land cover changes (LULCC) are the main factors causing soil degradation, changing ecosystem services and functions, and reducing ecosystems' capacity to support human needs, both upstream and locally. In this approach, LULCC significantly affects (or mediates) the

susceptibility of ecosystems and human civilization to outside disturbances like climate change, national and regional policy, and other aspects of globalization.

6.9 Developing Mountain Infrastructures (max. 500 words, in bullet points)

6.10 Strengthening Networking in IHR (max. 700 words, in bullet points)

7 EXIT STRATEGY AND SUSTAINABILITY

7.5 How effectively the project findings could be utilized for the sustainable development of IHR (max. 1000 words)

The Himalayas are well-known biodiversity hotspots, with ecological and evolutionary processes helping to preserve species richness and diversity. The fragile landscapes and undulating terrains of the Indian Himalayan Region (IHR) make it particularly vulnerable to natural hazards and disasters.

Due to climate-related vulnerability, several areas of IHR are constantly degrading. The Himalayan ecosystems and the flow of ecosystem services will be significantly impacted by climate change, with implications for both upstream and downstream populations. For the purpose of creating efficient conservation strategies, predicting the likely distribution of species in the face of continued anthropogenic interference and climate change will be a beneficial tool.

People have high expectations for the role that NWFPs can play in forest conservation, sustainable and participatory forest management, and improving the livelihoods of forest dwellers. According to studies conducted under the NMHS programme in the Uttarakhand of Kalsi, Chakrata, and Tiuni, NWFPs play an important role in the livelihoods of forest dwellers. At the same time, commercial exploitation is confined to a few products, which can easily lead to overexploitation. Priority should be given to the development of multipurpose and participatory management systems that include a place for NWFPs used by local populations.

In developing such a management system, it is critical to remember that NWFP use is part of a larger livelihood strategy that includes other, often less sustainable, forms of forest and use. It is critical to understand not only the ecological parameters but also local indigenous knowledge and social and economic conditions in order to develop a sustainable commercial NWFP exploitation

system. The socioeconomic situation of forest dwelling communities cannot be improved through an extractive economy unless policymakers and development efforts priorities basic needs.

7.6 Efficient ways to replicate the outcomes of the project in other parts of IHR (Max 1000 words)

7.7 Identify other important areas not covered under this study needs further attention (max 1000 words)

7.8 Major recommendations for sustaining the outcome of the projects in future (500 words in bullets)

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