Template/Pro forma for Submission

NMHS-Himalayan Institutional Project Grant

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

NMHS Grant Ref. No.:	**NMHS-2017/LG/01/475**

Date of Submission:	0	5	0	8	2	0	2	3
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PROJECT TITLE (IN CAPITAL)

INVASIVE ALIEN PLANTS IN HIMALAYAS: STATUS, ECOLOGICAL IMPACT AND MANAGEMENT

Project Duration: *from* **(22.12.2017)** *to* **(30.09.2021)**.

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NMHS-Final Technical Report (FTR) *template*

Demand-Driven Action Research Project

DSL: Date of Sanction Letter								*DPC: Date of Project Completion*							
2	2	1	2	**2**	**0**	**17**		3	0	0	9	**2**	**0**	**2**	**1**
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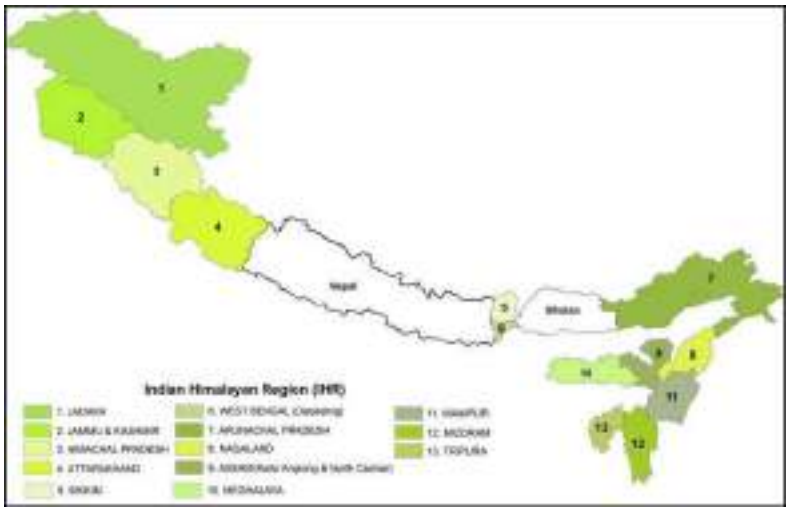
Part A: Project Summary Report

1. Project Description

i.	Project Grant Ref. No.:	**NMHS-2017/LG/01/475**						
ii.	Project Category:	Small Grant		Medium Grant		Large Grant	✓	
iii.	Project Title:	**INVASIVE ALIEN PLANTS IN HIMALAYAS: STATUS, ECOLOGICAL IMPACT AND MANAGEMENT**						
iv.	Project Sites (IHR States/ UTs covered) (*Location Maps attached*):	**Jammu & Kashmir** Jammu, Kashmir, Ladakh and adjoining areas of Himachal Pradesh. **Himachal Pradesh** District Solan, Sirmaur, Una, Bilaspur, Hamirpur, Chamba, Kullu, Shimla, Kangra, Mandi. **Himachal Pradesh and Uttarakhand** District Kinnaur, Almora, Bageshwar, Chamoli, Champawat, Dehradun, Haridwar, Nainital, PauriGarhwal, Pithoragarh, Rudraprayag, Teri Garhwal, Udham Singh Nagar, Uttarkashi. **Sikkim and West Bengal** Sikkim & Darjeeling himalayas **Mizoram & Tripura** **Mizoram**: Phawngpui NP, Murlen NP, Lengteng WLS, Pualreng WLS, Some Non-protected areas namely Sangau, Vanghmun, Murlen village, Knahlan **Tripura**: Sepahijola WLS (Clouded leopard NP), Trishna WLS (Bison NP), Rowa WLS, Gomati WLS, Some Non-protected areas namely Karbook, Gomati ditrict, Jatanbari, Panisagar. **Arunachal Pradesh, Nagaland, Manipur** **Arunachal**: Papum Pare, Old Sagalee, Lower Subansiri, Bhalukpong, Nechiphu, Dirang, Bomdila, Rupa **Manipur**: Lamdeng, Nongmaiching, Laimaton, Chhotobekra, Kwatha, Kwatha Khunou, Ukhrul, Lairouching, Kangpokpi, Keibul, Phubala **Nagaland**: Mount Tiyi, Wokha, Ryiphim, Khonoma, Jotsoma, Dhansiripar						

		
v.	Scale of Project Operation:	Local ☐ Regional ☐ Pan-Himalayan ✓
vi.	Total Budget:	Rs.4,68,39,000/- (Rupees four crore sixty-eight lakh thirty-nine thousand only)
vii.	Lead Agency	
	Lead PI/ Proponent:	Prof. R.K. Kohli Vice-Chancellor Central University of Punjab (CUP) Bathinda, Punjab
	Co-PI/ Proponent:	Prof. Vinod Kumar Garg Central University of Punjab, Bathinda
viii.	Implementing Partners	**1)Jammu & Kashmir** • Prof. Zafar A Reshi Departmenyt of Botany, University of Kashmir • Prof. Namrata Sharma Botany Department, University of Jammu • Dr. Manzoor A Shah Botany Department, University of Kashmir • Dr. Aijaz Hassan Ganie Department of Botany, University of Kashmir-Kargil Campus **2)Himachal Pradesh** • Prof. Daizy R. Batish Botany Department, Panjab University, Chandigarh • Dr. Shalinder Kaur Botany Department, Panjab University, Chandigarh • Dr. Surender Yadav Botany Department, MDU, Rohtak

		3)Uttarakhand • Prof. Harminder Pal Singh Department of Environment Studies, Panjab University, Chandigarh • Dr. Kuldip Dogra BSI, Dehradun **4)Sikkim & West Bengal** • Dr. L. B. Chaudhary, Senior Principal Scientist Plant Diversity, Systematics and Herbarium Division CSIR- National Botanical Research Institute, Lucknow - 226 001. • Dr. Soumit K. Behera, Senior Scientist Plant Ecology and Climate Change Science Division CSIR- National Botanical Research Institute, Lucknow - 226 001. **5)Mizoram & Tripura** • Dr.S.S.Dash,Scientist-E and Project Partner Botanical Survey of India, 3rd MSO building, Sector-1, Salt Lake City, Kolkata-700064 **6)Manipur,Nagaland & Arunachal Pradesh** • Dr. L.B. Singha • Prof. H.S. Yadav Department of Forestry,North Eastern Regional Institute of Science & Technology (NERIST), Nirjuli, Arunachal Pradesh

2. Project Outcomes

2.1. Abstract/ Summary

1) Jammu & Kashmir:

In the present study 401 alien vascular plant species were recorded in the three regions of Kashmir, Jammu and Ladakh that belonged to 278 genera in 84 families. Dicots were predominant with 361 species, followed by monocots with 33 species, and only 7 alien species of gymnosperms were recorded in the study region. Number of alien vascular plant species recorded in Jammu, Kashmir and Ladakh regions is 285, 279 and 76, respectively. In Jammu, 27 alien species were casuals, 118 were naturalized and 63 were invasive. Likewise in Kashmir 35 species were casuals, 96 were naturalized and 59 were invasive. In Ladakh 6 species were casuals, 28 were naturalized and 11 were invasive. The alien species mostly had perennial growth habits and the majority of these have been introduced unintentionally in the three regions. The majority of the alien plant species are native to North and northern America followed by South America, Asia Temperate and Europe. The invasion load of various habitats in the three regions varied and grasslands were the habitats with highest number of alien plant

species (43 spp.) in Kashmir Himalaya; in Jammu region, wastelands harbored the most number of alien species (34 spp.) while in Ladakh, highest number of alien plant species (54 spp.) was in arable habitats. The most noxious alien plant species that are of immediate concern in the Jammu region are *Prosopis juliflora* (Sw.) DC., *Ageratum conyzoides* (L.) L., *Parthenium hysterophorus* L., *Hyptis suaveolens* (L.) Poit. and *Lantana camara* L. Similarly, the top invasive species of Kashmir are *Anthemis cotula* L., *Leucanthemum vulgare* (Vaill.) Lam., *Datura stramonium* L., *Xanthium spinosum* L. and *Cannabis sativa* L. and from the Ladakh the species that are noxious, include *Matricaria discoidea* DC., *Datura stramonium* L., *Dysphania ambrosioides* (L.) Mosyakin & Clemants, *Amaranthus spinosus* L. and *Galinsoga parviflora* Cav. During the present field surveys, it was observed that some native species had very high abundance as well.

It has been also brought out that the select highly invasive species in the region have a suite of traits that contribute to their invasiveness, including life history trade-off, allelopathy, mycorrhizal mutualism, anti-herbivory traits, relatively higher competitive ability and very high fitness. Based on the comparison between invaded and uninvaded plots, increase in species richness at habitat-level due to invasion was noticed which has been reported previously as well but biotic homogenization (same invasive alien species growing in other habitats as well) is also on record. Change in the distribution of some select invasive alien species in relation to projected climate change was also predicted employing species distribution modelling (SDM) approach.

2) Himachal Pradesh:

Invasive Alien Species (IAS) pose a major threat to the ecology and economy in invaded regions, especially forest and Hill ecosystems. They cause a major change in vegetation at global level and threaten biodiversity. Aim of study was Identifying established and new Invasive Alien Vascular Plant Species (IAVPS) in all the 15 Indian Hilly States of Himalaya and estimating the invasion load, characterizing the IAVPS, assessment of Impact, selection of at least 10 most noxious established and 10 Neo-invasives, identification of a cross- sectoral group to assess the situation in the form of case-studies on these species. The methodology involves the survey and collection of invasive alien plants species from Himachal Pradesh (except Kinnaur and Lahaul-Spiti district) during vegetation season from different altitudes and habitats. Data on phyto-sociological aspects, elevation, geographical coordinates, were noted. During the various survey conducted we have recorded 145 plant species. We have laid a total of 475 quadrats of 1× 1 m to document various herbaceous species. The total species belonged to 42 families. Asteraceae, family had the largest proportion (~62%) of plant species. Eighty alien species were recorded with 10 of them being major invasive species. We have recorded 10 highly invasive alien species in study sites e.g. *Parthenium hysterophorus*, *Lantana camara*, *Hyptis suaveolens, Broussonetia papyrifera*, *Biden pilosa*, *Ageratum conyzoides*, *Ageratina adenophora, Sapium sebiferum,*

Ricinus communis and *Taraxacum officinale*. In addition, we have also identified some neo-invasive species which in time may acquire invasive proportion. Awareness programmes were conducted in District Sirmaur and Nahan with student in different educational institutes before lockdown which reached successful conclusions. The inventory prepared provide list of alien and native flora encountered that can be used to study species-specific distribution patterns, long-term monitoring and impact of climate change on invasive species.

3) Uttarakhand:

A significant portion of the world's terrestrial surface, the mountains, are extremely vulnerable to invasion by alien species, including important hubs of developing economies and global biodiversity hotspots. Invasive plants can displace native species, ruin ecosystems, and harm human health by altering structure and functioning of plant communities. Invasive plants have been reported to cause severe ecological, environmental, economic, and health issues in the Himalayan region. Plots (50×50 m) established in grid-based approach and systematic sampling was done in the study sites including Kinnaur and Uttarakhand). The total species belonged to 37 families. Asteraceae, family had the largest proportion (~65 %) of plant species, followed by Solanacea (~24 %), Poaceae (~22 %), Fabaceae (~19 %), Ranunculaceae (~14 %), Polygonaceae (~14 %), Euphorbiaceae (11 %) and Brassicaceae (~11 %). Out of all the species recorded, ~99% species were angiosperms, ~93% were dicots and ~7% were monocots. ~84% species were herbs, ~13 % shrubs and ~3% were trees. 100 alien species were recorded with 30 of them being major invasive species. IAS such as *Prosopis juliflora, Parthenium hysterophorus, Lantana camara, Hyptis suaveolens, Broussonetia papyrifera, Biden pilosa, Ageratum conyzoides, Senna occidentalis, Mirabilis jalapa, Euphorbia hirta* etc. were recorded during the study sites. Native species with small niches were in serious danger of going extinct. The introduction of an invasive species clearly resulted in the displacement of native species. The impact of climate change on invasive species distribution can be carried out by assessing their relationship with changing environmental.

4) Sikkim & West Bengal:

Conducting field tours, whichhave not been possible to conduct since 2020 and due to lack of fund and covid-19 restrictions but three tour were conducted in 2019 in to different regions of South, West and North Sikkim. Phytosociological analyses of invasive alien plant species (IAPS) and its associates were done by random quadrate sampling were laid between 300 m – 2700 m altitudes, however, the survey was conducted up to 5000 m altitudes in North Sikkim. Few plots were also conducted in Darjeeling Himalaya.

In Sikkim Himalaya: *Ageratina adenophora* was observed in all altitudinal gradients with highest

number of individuals. *Chromolaena odorata* was observed almost in all gradients but with lesser number of individuals.

Lantana camara was observed in all gradients with scanty distribution with lowest density. *Mikania micrantha* was distributed in lower altitudes >600 m – 1200 m with high density. These species were majorly found near human habitats along road side.

In the study 102 invasive alien plant species have been recorded, of which 93 species of dicots belong to 75 genera and 30 families while nine species of monocots fall under seven genera and three families. These species include 77 herbs (75%), 11 shrubs (11%), six grasses (6%), four climbers (4%) and two species each (2%) in sedges and trees. The region is dominated by the members of Asteraceae (27 species), followed by Fabaceae (12 species), Solanaceae (9 species), Poaceae (6 species), Malvaceae (5 species) etc. Majority of the species (76 spp.) were introduced unintentionally. *Ageratina adenophora, Ageratum conyzoides, Bidens Pilosa, Chromolaena odorata, Mikania micrantha, Tridax procumbens* etc., are some of the commonly occurring species the area. The study reveals that about 67% of invasive alien species are of American origin.

5) Mizoram & Tripura:

Based on elevation data and GIS, the study sites were selected and elevation maps of 1x1 sq.km. Grid maps were prepared. Different protected areas of Mizoram i.e. Phawngpui National park, Murlen National park, Lengteng Wildlife Sanctuary and non-protected areas like Sangau, West Vanlaiphai, Knahlan were visited for field works during 2020-2021.

A collection has been made for 163 IAPs belonging to 135 genera in 51 families have been recorded from Mizoram and 186 Invasive or potential IAPs have been recorded belonging to 135 genera in 51 families from Tripura; determining their invasive spread pattern. Invasive plants along with their spread/habitat were photographed, collected and processed for preparing of voucher herbarium specimens. Quantitative analysis of the invasive plants particularly of *Mikania micrantha* and *Ageratina adenophora* were done with their Importance Value Index. Two awareness programmes cum workshops were conducted during 2019-2020 in Mizoram University and Phawngpui National Park in Mizoram respectively. One national seminar was held at Central National Herbarium, Botanical Survey of India in 2022.

During field visit investigation of IAPs were undertaken to investigate the ecological status of IAPs and its potential threats in six protected areas of Tripura namely Trishna wls, Sepahijola wls, Gomati wls, Rowa wls, Clouded Leopard NP & Rajbari NP in Tripura.

During this period, extensive photographs of the invasive plants were taken and GPS data were recorded using Garmin Montana 680 device to keep track of the quadrate sampling points.

Quantitative analysis of the invasive plants particularly of *Mikania micrantha* and *Ageratina adenophora* were done. Associated invasive alien plants like *Ageratum conyzoides*, *Parthenium hysterophorus* and *Lantana camara*, *Chromolaena odorata* were also reported with their Importance Value Index. Plant specimens of the invasive plants were collected and dried and preserved properly for preparing herbarium sheets.

As a part of the project objective, it is essential to interact with the local stakeholders like university students, NGOs, forest department officials and local farmers who can directly or passively take part in evaluating the ecological investigation of the targeted invasive plants. Awareness programmes are the most effective way to interact with the local stakeholders.

6) Manipur, Nagaland & Arunachal Pradesh:

Invasive Alien Plants pose a major threat to the ecosystem and economy by homogenizing the vegetation and threaten the earlier existed biodiversity. Though this phenomenon has been taking place since long, yet the problem of such invasion did not engage sufficient attention in Northeast region of India. Present study was carried out in the three states, viz. Arunachal Pradesh (AP), Manipur (MN) and Nagaland (NL) of the Indian Himalayan Region to assess the distribution pattern, abundance, and other ecological parameters of these plants. Emphasis was also given to identify already established and newly invading invasive plant species and to identify their invasive load, impacts on the environment and formulation of management strategies aiming to their prevention and control. Digital Elevation Models (DEMs) @ 300m elevation gradient were prepared for the 3 states. Extensive field surveys and samplings were conducted at various localities across different climatic zones at different elevations. Invasive Alien Plants occurring in the three states were identified and information on their characteristics, distribution & population status, etc. were recorded with detail enumerations following available standard protocols. Tagging of GPS coordinates was done for respective IAPS at different locations in the 3-states and georeferenced distribution maps for respective IAPS was development using Arc-GIS software. In total, 131 IAPS were recorded and documented from the 3-states, which include 89 herbs, 33 shrubs, 6 climbers and 3 tree species. Among them, ten most noxious IAPS identified were *Ageratina adenophora*, *Ageratum conyzoides, Ageratum houstonianum*, *Bidens pilosa, Chromolaena odorata, Lantana camara, Mikania micrantha, Tithonia diversifolia, Parthenium hysterophorus,* and *Urena lobata.* Significant findings were recorded while selective IAPS were used in vermicompost units yielding nutrient rich organic composts which may act as an efficient control measure of IAPS with opportunities of income generation.

In all the IHR states, due to rising covid-19 situation in the country as well as in North-East India, the project work was impacted during 2020-2022.

2.2. Objective-wise Major Achievements

Project Objectives	Project output against each objective	Progress made against monitoring indicators (Specified in sanction letters)	Remarks
Identifying established and new Invasive Alien Vascular Plant Species (IAVPS) in all the 15 Indian Hilly States of Himalaya and estimating the invasion load Characterizing the IAVPS on the basis of their life-forms, lifespan, nativity, status of invasion and purpose of invasion/introduction	New Datasets: Complete inventory, distribution and areas infested by Invasive Alien Species in the Indian Himalayas	Areas already invaded by IAVPS have been identified in the explored localities in **9** Indian Himalayan states. Assessment of Diversity of IAVPS occurring in these **eleven IHR states** has been inventoried: ➢ **401** alien plant species from **Jammu & Kashmir, Ladakh region**; ➢ **145** alien plant species from **Himachal Pradesh**; ➢ **108** alien plant species from **Uttarakhand**; ➢ **336** alien plant species from **Sikkim Himalayas**; ➢ **163** alien plant species from **Mizoram**; ➢ **186** alien plant species from **Tripura**; ➢ **131** alien plant species from **Arunachal Pradesh, Manipur & Nagaland**. Distribution pattern with IVI for selective IAVPS in **11-**districts from **Mizoram, 6-**districts from **Tripura**, **4-**districts from **Himachal Pradesh, 4-**districts from **Uttarakhand**, **3-**districts from **Sikkim**, 3-districts of **Arunachal Pradesh**, **3**-districts of **Nagaland**, **9**-districts of Manipur at different elevations have been worked out in random plots.	Please refer **Appendix-II**

Preparing protocols for prediction, early detection and risk assessment of IAVPS	Dynamic model: Rate & mode of spread (including vectors responsible) with GPS & ground truthing	➢ Experiments were designed & observations have been initiated in permanent plots for respective IAVPS to determine their life forms as well as to document the events of different phenological characters. ➢ GPS locations were recorded for respective IAPS at random and permanent plots based on the DEM maps. ➢ Permanent plots were identified and details on the population structure, density and basal cover were recorded for accounting rate of spread per unit time. ➢ Exhaustive baseline ecological data in the invasive load for the state Himachal Pradesh, Uttarakhand, Mizoram, Tripura, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Jammu, Kashmir & Ladakh was prepared from permanent plots. ➢ Species distribution modelling for ***Anthemis cotula*** L., ***Erigeron canadensis*** L., ***Hyptis suaveolens*** (L.) Poit. was prepared.	Please refer **Appendix-III**
Assessment of Ecological & Environmental Impact of invasion and spread with special reference to phytodiversity and soil especially in relation to climate change; This will include the level of disappearance of native species	Base line studies & Assessment Reports to state agencies of the disappearance of native plant species (If any).	➢ The ecological impact of the noxious invasive alien plants on the associated native vegetation was determined in terms of their phytosociological status like frequency, abundance, density and importance value index. ➢ Detail analyses for the physico-chemical impact on soil parameters like pH, % moisture, available NPK of the microhabitats have been carried out in study sites of IHR states.	Please refer **Appendix-II**
Selection of at least 10 most noxious established and 10 Neo-invasives and consolidation of all available information including their biology, itemizing at the same time the knowledge	Value addition and sustainable utilization of bio-resources for livelihood of local communities	➢ Identified 10 noxious IAVPS, which show high rate of invasion in different forest types at Tropical, Sub tropical and Temperate regions in all the Himalayan states. ➢ Open ended questionnaire and interaction with local communities are collected during each field visit to collect data on possibilities of value addition and livelihood options. ➢ Three IAVPS used in local livelihood, namely *Ageratina adenophora* , *Ageratina riparia* & *Chromolaena odorata* were reported by the local inhabitants of Mizoram .Based on the information a database on their ethno-botanical use was prepared.	Please refer **annexure-II**

gaps		➢ Identified five IAVPS viz. *Ageratina, Ageratum, Chromolaena, Lantana and Miikania,* as potential source of nutrients in the vermicompost.	
Identification of a cross-sectoral group to assess the situation in the form of case-studies on these species, and also to formulate workable management strategies aiming to prediction, prevention and control.	Policy and legislative mechanisms for management / eradication / mitigation will get framed.	➢ Multiple Awareness programmes and workshops have been conducted at respective states to ensure interaction with the local stakeholders preferably forest officials, students, NGOs and nature enthusiasts. ➢ A stage-based inventory for the invasive alien plants in Jammu, Kashmir, Ladakh, Mizoram and Tripura were prepared and published. Management framework based on the stage of invasion of alien plant species has been suggested to the local stakeholders. ➢ Ethnobotanical knowledge for uses of the IAPs in different IHR states was gathered to prepare a database on their potential to be used as a bioprospecting resource. ➢ Additionally, in Manipur and Nagaland, vermicomposting experiment using the IAPs were performed to understand their bioprospecting potential. ➢ Easy identification guides to identify the most noxious IAPs was distributed in the form of leaflets to make the local people aware of the IAPs & their impact on natural forests in Mizoram and Tripura.	Please check **annexure-IV** for photographs

Note: Further details may be summarized in DPR Part-B, Section-5. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

2.3. Outputs in terms of Quantifiable Deliverables*

Individual project partners:

Jammu, Kashmir & Ladakh

.No #	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations, if any, & Remarks thereof:
1	New Datasets: Complete inventory of Invasive alien	Monitoring in comparison to baseline information	New databases which are significantly improved over the existing databases or have been for the first time developed (e.g. for Jammu and Ladakh regions)	No deviation, strictly in accordance with the project guidelines
2	Dynamic model: Rate & mode of spread (including vectors responsible) with GPS and ground truthing	• New Database/ Datasets developed. • New Models developed	Databases of three regions (Jammu, Kashmir and Ladakh) prepared in which each species is appended with life-form, life cycle, purpose/mode of introduction/	No deviations from the standard procedures and protocols employed during the present study and these are followed globally for

			current invasion status has been given. Species distribution models for select species have been developed and predictions of their potential spread under the projected climate change have been made. Such approach can be now extended to other species as well.	similar types of studies.
3	Baseline studies about disappearance of native plant species' Assessment of ecological and environmental impact	• Publication of assessment of reports about the disappearance of native species	Comparative studies at sites invaded and uninvaded by select invasive species performed to assess the difference in the species composition and abundance of species in such sites. Not much previous record is available on the basis of which displacement of native species by invasive species could be reported. However, in Kashmir *Cotula anthemoides* is not as prevalent as it used to be because the same habitat is now invaded by *Anthemis cotula*.	No deviation as such, but more well replicated studies on biotic homogenization by invasive alien species need to be undertaken.
4	Value addition and sustainable utilization of bio-resource for livelihood of local communities	. No. of livelihood options generated along with no of beneficiaries	Three species, one each from the regions of Jammu, Kashmir and Ladakh selected and information about their biology and invasiveness consolidated on the basis of field and experimental studies carried out during the present study and the already available information about these species, if available. These species are *Hyptis suaveolens* from Jammu, *Anthemis cotula* from Kashmir and *Lepyrodiclis holosteoides* from Ladakh. Bioprospection of abundant and widespread invasive alien species could be a strategy for	Continuous monitoring of not only currently invasive species but also the naturalized species likely to spread needs to be undertaken. A special effort aimed at bioprospection of invasive alien species for their utilization in local livelihood generation needs to initiated. It could not be meaningfully done during the present project because of unforeseen circumstances due to COVID-19 and other reasons.

			generation of livelihood options for local communities, on one hand and on the other hand, the management of these species could be accomplished. In this regard, chamomile tea from *Anthemis cotula* could be explored. Likewise, the huge biomass of aquatic invasive species in the Dal Lake could be exploited for composting and biogas generation.	
	Policy and legislative mechanisms for management/eradication/mitigation	No. of policy guidelines and legislative mechanisms prepared.	During the project sufficient data on the invasive alien plant species has been generated which needs to be collated with similar information from other parts of IHR for formulation of policy guidelines vis-à-vis casuals/naturalized and invasive species. Pre- and post-introduction protocols for predicting species invasions are possible given the data collected. The legislative framework needs to be thought of at the appropriate level of authority. However, inputs for such a framework can be provided.	--

Himachal Pradesh

S#	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations, if any, & Remarks thereof:
1	Identifying established and new Invasive Alien Vascular Plant Species (IAVPS) in all the 15 Indian Hilly States of Himalaya and estimating the invasion load.	Identification of invasive flora in Himachal Pradesh	80 alien and 10 invasive species identified.	
2	Characterizing the IAVPS on the basis of their life-forms, lifespan, nativity, status of invasion and purpose of invasion/introduction	Assessment of most dominant invasive species group	Annual herbs identified as dominant group.	
3	Preparing protocols for prediction, early detection and risk assessment of IAVPS	Protocol building	-	
4	Assessment of Ecological & Environmental Impact of invasion and spread with	Assessment of negative impact of invasive plant on native flora and habitat of Himachal	Phytosociological assessment done.	

	special reference to phytodiversity and soil especially in relation to climate change; This will include the level of disappearance of native	Pradesh		
5	Selection of at least 10 most noxious established and 10 Neo-invasives and consolidation of all available information including their biology, itemizing at the same	Identifying alien species at different stages of invasion	10 invasive species identified in Himachal Pradesh.	
6	Identification of a cross- sectoral group to assess the situation in the form of case-studies on these species, and also to formulate workable management strategies aiming to prediction, prevention and control	Generating awareness in stake-holders	Awareness programmes conducted.	

Uttarakhand

S#	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations, if any, & Remarks thereof:
1	Identifying established and new Invasive Alien Vascular Plant Species (IAVPS) in all the 15 Indian Hilly States of Himalaya and estimating the invasion load.	Identification of invasive flora in Uttarakhand and Kinnaur district of Himachal Pradesh	100 alien and 30 invasive alien species was identified..	
2	Characterizing the IAVPS on the basis of their life-forms, lifespan, nativity, status of invasion and purpose of invasion/introduction	Assessment of most dominant invasive species group	Annual herbs identified as dominant group	
3	Preparing protocols for prediction, early detection and risk assessment of IAVPS	Protocol building	-	
4	Assessment of Ecological & Environmental Impact of invasion and spread with special reference to phytodiversity and soil especially in relation to climate change; This will include the level of	Assessment of negative impact of invasive plant on native flora and habitat of Himachal Pradesh	Phytosociological assessment done.	

	disappearance of native			
5	Selection of at least 10 most noxious established and 10 Neo-invasives and consolidation of all available information including their biology, itemizing at the same	Identifying alien species at different stages of invasion	100 alien species were identified, out of 30 are invasive alien species in some states of Uttarakhand and Kinnaur district of Himachal Pradesh	
6	Identification of a cross- sectoral group to assess the situation in the form of case-studies on these species, and also to formulate workable management strategies aiming to prediction, prevention and control	Generating awareness among stake-holders	Awareness programmes conducted	

Sikkim & West Bengal (Darjeeling Himalayas)

Objectives	Objective-wise Deliverables
Survey, documentation and characterization of invasive vascular alien plants on the basis of their life-forms, lifespan, nativity, status of invasion in Sikkim and Darjeeling Himalaya	Four field surveys were conducted during 2018 – 2020 in various regions across different altitudinal gradients ranging between 300 m to 5700 m of Sikkim Himalaya and Darjeeling Himalaya to collect and document invasive alien plant species. A list of 336 alien plant species of Sikkim Himalaya, comprising of 298 dicot species and 38 monocot species under 224 genera and 69 families has been prepared with details about each species' life forms, lifespan, and nativity.
Selection of major noxious invasive species in the study area.	Identified 10 most noxious invasive species for Sikkim Himalaya. Also identified 05 neo invasive species for same region.
Assessment of ecological impacts of alien plant invasion on native plant community.	Assessed the ecological impacts of 04 targeted invasive species by comparing the biomass production patterns in invaded vs. non-invaded plant communities across different altitudinal gradients in Sikkim Himalaya.
Monitoring the distribution patterns and population dynamics of different invasive species in various ecosystems across the altitudes.	Studied the distribution patterns, phytosociology and population dynamics in four selected invasive species (*Ageratina adenophora*, *Chromolaena odorata, Lantana camara* and *Mikania micrantha)* along seven altitudinal gradients in the Sikkim Himalayas and Darjeeling Himalaya ranging from 600 m to 2700 m altitudes by laying 211 quadrates of 5 m x 5 m covering a total area of 5275 m^2. Detailed assessment of the magnitude of spread, distribution patterns, species association of *Ageratina adenophora*, along seven altitudinal gradients in the Sikkim Himalaya was

	completed, which is considered to be one of the top noxious invasive alien plant species in Indian Himalayan Region.

Mizoram & Tripura

S. No.	Objectives	Monitoring Indicators	Major achievements (in bullets points)	Deviations, if any, & Remarks thereof:
1.	To evaluate the rate of spread of *Ageratina* and *Mikania* by analyzing their abundance, rate of aboveground growth during different seasons in different ecological habitats	Identification of invasive flora of Mizoram and Tripura with special reference to *Ageratina* and *Mikania*.	⇨ A comprehensive inventory of 163 IAVPS is documented for Mizoram. ⇨ A comprehensive inventory of 186 IAVPS is documented for Tripura. ⇨ Ecological investigation in both the states was conducted. (For details, see Appendix 1)	None. The work under this objective was strictly followed for preparation of invasion load.
2.	To determine the reproductive potential by analyzing their seed production and seedling recruitment and characteristic	Assessment of the propagation traits of the targeted species.	⇨ Reproductive potential was studied analysing their vegetative propagation in natural forest. (For details, see Appendix 1)	None. The work under this objective was strictly followed for ecological understanding of invasion dynamics as per global studies.
3.	To study the similarities and differences in spread pattern and invasive load on early recovery successional landscapes, and its impact on the natural flora	Understand the ecological status of invasion in different landscapes.	Ecological status of invasion of the most invasive species and neo-invasive plants were investigated. (For details, see Appendix 1)	None. Due to Covid-19 lockdown the data collection was slow.

4.	To undertake awareness programmes among all the stalk holders including local people through an interactive local level capacity building programme regarding the consequences of invasive species, if not managed.	Conduct outreach programmes to create awareness among the local people.	⇨ An awareness programme has been conducted at Phawngpui National Park with school students (40 persons) on 23rd February, 2019. ⇨ A "One day Awareness Programme cum Workshop on Invasive Alien Plants in Himalayas: Status, Ecological Impact and its Management" was conducted in 26th April, 2019 at Mizoram University Campus. A "One day national seminar on Invasive Alien species in India" was conducted in 30th March, 2022 at Central National Herbarium Campus, Kolkata with a targeted audience of more than 226 participants from different areas of India. (For details, see Appendix 3)	None.

Arunachal Pradesh, Nagaland & Manipur

S#	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved
1.	Identifying established and new Invasive Alien Vascular Plant Species in all the 12 states of the Indian Himalayan Hills and estimating the invasion load	New Datasets: Complete inventory, distribution and areas infested by Invasive Alien Species in the Indian Himalayas.	A comprehensive checklist of new and established IAVPS in Arunachal Pradesh, Manipur and Nagaland is developed.
2.	Characterizing the	Dynamic model: Rate & mode of	GPS coordinates of the selected

	Invasive Vascular Alien Plants on the basis of their life-forms, lifespan, nativity, the status of invasion and purpose of invasion/ introduction	spread (including vectors responsible) with GPS & ground truthing.	IAVPS dominated locations in Arunachal, Manipur and Nagaland were tagged and extrapolated in the DEMs. Appen
3.	Preparing protocols for prediction, early detection and risk assessment of alien invasive plant species for each region	Baseline studies and Assessment Reports to state agencies of the disappearance of native plant species	Assessment reports and significant findings were presented in national and international seminars, workshops and conferences.
4.	Assessment of Ecological & Environmental Impact of invasion and spread with special reference to biodiversity and soil especially in relation to climate change; This will include the level of the disappearance of native species	Value addition and sustainable utilization of bio-resources for the livelihood of local communities	Ethnobotanical notes of IAVPS in the past and the current days are recorded and were reported to be underutilised. Vermicomposting of IAVPS was identified as a means of value addition and sustainable utilization of bio-resources for the livelihood of local communities.
5.	Selection of at least 10 most noxious invasive species from different regions and consolidation of all available information including their biology, itemizing at the same time the		Most noxious species across the region were selected and their comprehensive information about their nativity, introduction, status, distribution, seed biology, etc was recorded.

	knowledge gaps		
6.	Identification of a cross-sectoral group to assess the situation in the form of case studies on these species, and also to formulate workable management strategies aiming to prediction, prevention and control.	Policy and legislative mechanisms for management/eradication/ mitigation will get framed.	Recorded concrete information from the State Forest Department and villagers who thrive on NTFS and timber species for livelihoods about the status of invading IAPS in different forest types of Arunachal Pradesh, Nagaland and Manipur, were trained for the effective control and management tools.

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

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

S#	Particulars	Number/ Brief Details	Remarks/ Attachment
1.	New Methodology/ Technology developed, *if any*:	Terminology with respect of characterization of alien species has been standardized	Comprehensive inventories of alien plants for the assigned states were prepared and their status of invasion was recorded whereas available.
2.	New Ground Models/ Process/ Strategy developed, *if any*:	Species distribution models (SDM) were developed for predicting distribution of some select invasive species/native widespread species under future climate change scenarios. GIS mapping was also performed for selected invasive alien plants.	
3.	New Species identified, *if any*:	Some new plant species alien plants were recorded for the states of Indian Himalayan Region.	Some new invasives like *Cotula anthemoides, Oxalis corniculata, Ageratina riparia, Tithonia diversifolia* were identified.
4.	New Database established, *if any:*	Complete database of alien plant species from 11 states of IHR have been prepared.	Invasion load for 11 states have been prepared.

S#	Particulars	Number/ Brief Details	Remarks/ Attachment
5.	New Patent, *if any*:		
	I. Filed (Indian/ International)		
	II. Technology Transfer, *if any*:		
6.	Others, *if any*		

Note: Further details may be summarized in DPR Part-B, Section-5. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

3. New Data Generated over the Baseline Data

S#	New Data Details	Status of Existing Baseline	Addition and Utilization New data
1	The inclusive and detailed databases of alien plants of 11 IHR states were prepared based on extensive field surveys across the study regions. Online literature (online sources FoP, FoC, POWO, WFO, IPNI) was followed for nomenclature. We assigned the native distribution range of each species using the online database of the Plants of the World online (POWO 2022 https://powo.science.kew.org/). The alien plants are classified into different alien categories according to (Richardson 2002). The alien flora introduced for anthropocentric purposes were divided into four main categories; namely, agriculture (cultivated), fodder, forestry etc (Rondal 2016).	There were only few studies carried out in the region for the documentation of alien plant species in IHR states. No comprehensive database regarding alien flora was available for the IHR regions like Jammu, Mizoram, Manipur, Sikkim, Nagaland etc region except mention of some alien plants in various publications. The alien load across various habitats of the IHR states were also assessed for the first time	The previous studies were literature survey based. There were many gaps in these studies. The plant species included in the current investigation provide necessary information, regarding invasion status, mode of introduction, invasion load across different habitats in all the three study regions. The data generated is crucial for management practices, policy framework and early detection of these alien plants in these biodiversity hotspot regions of the Indian Himalayan Region.

Note: Further details may be summarized in DPR Part-B. Database files in the requisite formats (Excel) may be enclosed as annexure/ appendix separately to the soft copy of FTR.

4. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S#	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	ST	Women	Total
1.	Workshops	**2**	Local stakeholders including local communities, students, forest officials, tourist guides etc.	**87**	**64**	**94**	**216**
2.	On-Field Trainings	**2**	Local stakeholders including local communities, students, forest officials, tourist guides etc.	**37**	**34**	**67**	**146**
3.	Skill Development	**2**	Local stakeholders including local communities, students, forest officials, tourist guides etc.	**87**	**64**	**94**	**216**
4.	Academic Supports	**2**	Students of Local higher secondary school in Sangau; BSc,MSc,PhD students of Mizoram university, University of Calcutta, Punjab University, University of Kashmir, NEHU, BSI etc	**65**	**28**	**83**	**138**
	Others (if any)						

Note: Further details may be summarized in DPR Part-B. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

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

S#	Linkages /collaborations	Detail of activities (No. of Events Held)*	No. of Beneficiaries

1.	Sustainable Development Goals (SDGs)/ Climate Change/INDC targets addressed	The work related to SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.	216
2.	Any other:		

Note: Further details may be summarized in DPR Part-B, Section-6. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

6. Project Stakeholders/ Beneficiaries and Impacts

S#	Stakeholders	Support Activities	Impacts in terms of income generated/green skills built
1.	Line Agencies/ Gram Panchayats:	Workshop was conducted and officers from different departments (Forest, Wildlife, Lakes and wetland development, Agriculture. Representatives from other universities in the region) participated. Awareness about invasive alien species and information about the plant invasions was shared with the representatives of different departments and other participants.	216
2.	Govt Departments (Agriculture/ Forest/ Water):		
3.	Villagers/ Farmers:		
4.	SC Community:		
5.	ST Community:		
6.	Women Group:		
	Others, *if any*:		

Note: Further details may be summarized in DPR Part-B, Section-6. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

7. Financial Summary (Cumulative)

To be Submitted.

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

Prof. Zafar A Reshi			
Name of Equipment	Quantity	Cost (INR)	Utilisation of the Equipment after project
1. Handheld GPS Mobile Mapper 50	1	2,94,882	Scientific research of the project implementing institute
2. Thermo-scientific oven (400 ltr) Model OG5400	1	4,40,764	
Prof. Daizy R. Batish			
3. GPS (Trimble TDC-100)	1	1,77,000	
4. Automated Kjeldahl digester (KD1040, BOROSIL)	1	3,34,635	Scientific research of the project implementing institute
5. Integrated Photosynthesis system CI-340	1	19,87,440	
Prof. Harminder Pal Singh			
6. GPS (TDC 600)	1	2,30,475	Scientific research of the project implementing institute
7. CHLOROPHYLL FLUORESCENCE METER	1	4,95,390	
8. CNS ANALYZER FOR PROTEIN AND ORGANIC MATTER	1	13,60,878	
9. PORTABLE LEAF AREA	1	3,65,000	
Dr. L. B. Chaudhary			
10. GPS	1	1,53,000	Scientific research of the project implementing institute
Dr. S. S. Dash			
11. GPS (Garmin Montana 680)	1	53,200	Scientific research of the project implementing institute
12. Imaging device	1	64,500	
13. Takemura Soil pH & Moisture meter	1	8,909	
14. Mitutoyo Slide Caliper 150 mm	1	11,505	
15. Camera	1	28,000	
16. SYSTAT 13.2	1	99,225	
17. SIGMAPLOT 14.5			

Dr. L.B. Singha			
18. Fluorescence Spectrometer (BioEra Life Sciences Pvt. Ltd. Model-Quo)		6,14,250/-	Scientific research of the project implementing institute
19. Cooling Centrifuge 20. (BioEra Life Sciences Pvt. Ltd. Model-Cogent)		.5,35,500/-	
21. GPS (TRIMBLE TDC 100)		.1,53,400/-	
22. SYSTAT 13.2 (SYSTAT Software Inc. USA)		.47,250/-	
23. SIGMAPLOT 14 (SYSTAT Software Inc. USA)		37,800/-	

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

9. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States/ UTs covered:	12	Please see appendix-??
2.	Project Sites/ Field Stations Developed:	35+	Project sites was developed in different districts of the thirteen IHR states. Please see appendix-??
3.	Scientific Manpower Developed (PhD/M.Sc./JRF/SRF/ RA):	15	JRF and FA were trained.
4.	Livelihood Options promoted	2	Generated techniques for bioprospecting using IAPs for bio-composting and nutritional aspect.
5.	Technical/ Training Manuals prepared	12	One brochure and 11 posters developed up to 2018-2022.
6.	Processing Units established, if any		
7.	No. of Species Collected, if any	1000+	Please see appendix-??
8.	No. of New Species identified, if any		
9.	New Database generated (Types):	3	Inventory, status of invasives and their mode of introduction.
	Others (if any)		

Note: Further details may be summarized in DPR Part-B. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

11. Knowledge Products and Publications:

S#	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal – Research Articles/ Special Issue:		20		Please see appendix-II
2.	Book – Chapter(s)/ Monograph/ Contributed:				
3.	Technical Reports:		4		
4.	Training Manual (Skill Development/ Capacity Building):				
5.	Papers presented in Conferences/Seminars:		8		
6.	Policy Drafts/Papers:				
7.	Others, if any:				

Note: Please append the list of KPs/ publications (with impact factor, DOI, and further details) with due Acknowledgement to NMHS. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

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

Particulars	Recommendations
1. Monitoring of alien species 2. Prevention of entry of alien species 3. Impact assessment & utilization of invasive alien species	1. It is recommended that monitoring of alien species in the IHR regions should be mainstreamed into the work plan of relevant departments (Forest, Agriculture, Horticulture departments, Lakes and waterways department). 2. Creation of state-level/region-level statutory bodies tasked with the development and implementation of stringent quarantine regime is recommended. 3. Invacost methodology needs to be followed for computing economic costs of invasive alien species and EICAT (Environmental Impact Classification for Alien Taxa; Blackburn et al. 2014) adopted by IUCN for assessing the ecological and environmental cost. 4. It is recommended that the difficult-to-control highly invasive species be bioprospecting for any resource-use value. The huge biomass available could be used for producing biogas, compost and other utilizable products which on one hand can boost the local economy and on the other hand contribute to control of such invasive species.
➢ Utility of the Project Findings:	➢ The updated alien plant database based mostly on extensive field survey is a valuable knowledge product which could pave the way for better prevention, monitoring, and control of invasive species. ➢ The modes of transport and regions of origin of alien species identified during the present study can be utilized for blocking the transport pathways and vectors of introduction of alien invasive species which has been recognized and emphasized in The Convention on Biological Diversity. ➢ Categorization of alien species on the basis of invasion stage (casual, naturalized, invasive) could help in prioritizing the invasive species that need urgent attention and profitable

	deployment of scarce economic and other allied resources. ➢ A robust framework based on the data obtained during the present study could be developed for predicting the potential invasive species from amongst the already introduced alien species. ➢ The species distribution modelling could be extended to other species with additional model inputs (local abiotic and biotic factors of importance to a species) for better model reproducibility, model transferability and prediction of areas in the IHR that are vulnerable to invasions in future under projected climate change. ➢ The frontline staff who were trained under the project can be used by the respective forest management units to enhance capacity of the other staff by identifying them as trainers.
Replicability of Project/ Way Forward:	➢ The scope of the data produced by this project is highly replicable. The database will be the baseline data for the further studies, such as studying the effect of climate change on plant invasion, and also effect of different anthropogenic activities on interaction between alien and native plants and ultimately on the biodiversity of the particular region. For the Ladakh region, this has been the first study to assess the extent of plant invasion in the region. Owing to its climate and topography there is little area available for agriculture, and hence the study will provide the necessary baseline data for the management of alien plants in the region. ➢ Understanding of reproductive biology of the widespread plant species is imperative for their effective management
Exit Strategy:	➢ The databases generated under the present project and similar such databases could be woven together in the form of an online tool with information about the extent of invasion in the IHR, and details about the distribution and abundance of the worst invasive species and their impact and control. This online tool could be interactive so that new alien species are reported on their first sighting which is a prerequisite for early warning and rapid response strategy for alien species management. It is cost-effective and can be implemented

	without any impediments. At some point in future, such a database can be integrated with global online databases with sufficient safeguards about data mining. Long term studies on their habitat suitability in relation to the climate change and their impacts on the edaphic properties and floral diversity due to their invasion is much recommended.

(**PROJECT PROPONENT/ COORDINATOR**)

(Signed and Stamped)

(**HEAD OF THE INSTITUTION**)

(Signed and Stamped)

Place: ……..
Date: …../……/……

PART B: DETAILED PROJECT REPORT

1 EXECUTIVE SUMMARY

Jammu, Kashmir & Ladakh

In the present study 401 alien vascular plant species were recorded in the three regions of Kashmir, Jammu and Ladakh and these species belonged to 278 genera in 84 families. Dicots were predominant with 361 species, followed by monocots with 33 species, and only 7 alien species of gymnosperms were recorded in the study region. Asteraceae was the most species-rich family with 43 species, followed by Fabaceae (35 spp.), Amaranthaceae (21 spp.), Brassicaceae and Solanaceae each with (20 spp.), Rosaceae (17 spp.), and Malvaceae (14 spp.). The number of alien species outside cultivation was 289 species and number of alien species under cultivation in the three regions was 112.

Three comprehensive databases of alien plant species for the three regions of Jammu, Kashmir and Ladakh were prepared. Number of alien vascular plant species recorded in Jammu, Kashmir and Ladakh regions is 285, 279 and 76, respectively. However, the number of alien species outside cultivation was 208, 190 and 45 in Jammu, Kashmir and Ladakh, respectively. The alien species were predominantly dicotyledonous with representation of 192, 167 and 44 species respectively in the three regions. Irrespective of the region, the alien species were mostly herbaceous with 139, 141 and 31 species in Jammu, Kashmir and Ladakh, respectively. In Jammu, 27 alien species were casuals, 118 were naturalized and 63 were invasive. Likewise in Kashmir 35 species were casuals, 96 were naturalized and 59 were invasive. In Ladakh 6 species were casuals, 28 were naturalized and 11 were invasive. About 60% of species in Jammu and Kashmir regions had perennial habit while only 48% were perennial in Ladakh alien flora. Most of the alien species have been introduced unintentionally in the three regions. The number of such species in Jammu is 127 (61%), 104 (55%) in Kashmir and 21 (47%) in Ladakh. The second most important mode of transport of alien species is through introduction as ornamentals, particularly in Jammu and Kashmir regions. As far as the native region of the alien plant species in the three regions is concerned, the majority of the alien plant species were native to Northern America with 126 species (26%), followed by Southern America and Asia Temperate each with 104 species (21%) and 99 species (20%) were native to Europe. The majority of alien plant species found in the Jammu region are native to Northern America with a total of 98 species, followed by Southern America with 91 species, and Asia Temperate with 82 species.In Kashmir, most of the species are native to Asia Temperate with 102 species followed by Northern America with 75 species and Europe 69 species. Majority of the alien plant species of Ladakh are native to Asia Temperate (27 spp.), followed by Northern America (24 spp.) and Europe (21 spp.).

The invasion load of various habitats in the three regions was also investigated and it varied across habitats. In Kashmir the grasslands were the habitats with highest number of alien plant species (43 spp.) followed by roadside (42 spp.), forest (33 spp.) and orchards (31 spp.). Similarly in the Jammu region, the wastelands are the habitats that harbour the most number of alien species (34 spp.) followed by forest (32 spp.) and scrub (31 spp.). In Ladakh, arable land are the habitats with highest number of alien plant species (54 spp.) followed by wasteland (20 spp.) and roadside (19 spp.).

The most noxious alien plant species that are of immediate concern in the Jammu region are *Prosopis juliflora* (Sw.) DC., *Ageratum conyzoides* (L.) L., *Parthenium hysterophorus* L., *Hyptis suaveolens* (L.) Poit. and *Lantana camara* L. Similarly, the top invasive species of Kashmir are *Anthemis cotula* L., *Leucanthemum vulgare* (Vaill.) Lam., *Datura stramonium* L., *Xanthium spinosum* L. and *Cannabis sativa* L. and from the ladakh the species that are noxious, include *Matricaria discoidea* DC., *Datura stramonium* L., *Dysphania ambrosioides* (L.) Mosyakin & Clemants, *Amaranthus spinosus* L. and *Galinsoga parviflora* Cav.

Identifying and managing potential invasive alien plant species before they become a problem is an important aspect of invasive species management. Such plant species that can spread and become invasive in Jammu region include *Gomphrena serrata* L., *Ipomoea carnea* Jacq., *Solanum viarum* Dunal, *Argemone mexicana* L. and *Amaranthus viridis* L., Similarly for the Kashmir region; *Ageratum conyzoides* (L.) L., *Robinia pseudoacacia* L., *Spartium junceum* L. and *Lupinus polyphyllus* Lindl. could become invasive with passage of time. Furthermore from Ladakh; *Xanthium spinosum* L.,*Oxalis corniculata* L., *Erigeron canadensis* L., *Anthemis cotula* L., and *Bassia scoparia* (L.) A.J.Scott are the potential invasive plant species.

It is pertinent to mention that during the course of the present study some native species had very high abundance as well as very wide distribution like those of invasive alien species. The widespread native plant species of Ladakh are *Lepyrodiclis holosteoides* (C.A. Mey.) Fenzl ex Fisch. & C.A. Mey, *Lactuca serriola* L., and *Aconogonan tartosum* (D. Don) Hara, *Aconogonon rumcifolium* (Royle ex. Beb) Hara and *Arenaria bryophylla* Fernald in Ladakh. In Kashmir the widespread native species are *Sambucus wightiana* Wall. ex Wight & Arn., *Conium maculatum* L., *Centaurea iberica* Trevir. ex Spreng. and *Trifolium repens* L. and from Jammu Anagallis arvensis L., *Tripidium bengalense* (Retz.) H.Scholz, Cichorium intybus L., *Echinochloa colonum* (L.) Link and *Saccharum spontaneum*

The impact of three invasive plant species, namely *Anthemis cotula* L., *Erigeron canadensis* L. (syn *Conyza canadensis* L.) and *Sisymbrium orientale* L. on the plant species richness was studied by comparing species richness at the otherwise comparable sites invaded and uninvaded by the

three invasive alien species. In case of *A. cotula* invaded and uninvaded plots, 55 (12 naturalized, 28 invasive and 15 native) plant species were recorded in the invaded plots and only 44 (16 naturalized, 19 invasive and 9 native) plant species were recorded in uninvaded plots. 28 invasive species occurred in invaded plots compared to only 19 invasive species in uninvaded plots. In *E. canadensis* invaded plots, 61 (1 cultivated, 17 naturalized, 27 invasive, 16 native) plant species were recorded and only 49 (1 cultivated, 1 casual or naturalized, 12 naturalized, 19 invasive, 16 native) plant species were recorded in uninvaded plots. 27 invasive species occurred in invaded plots compared to 19 in uninvaded plots. It was also recorded that 71 (1 casual or naturalized, 2 casual, 20 naturalized, 24 invasive, 24 native) plant species were present in *S. orientale* invaded plots and 69 (1 cultivated, 3 casual or naturalized, 1 casual, 17 naturalized, 22 invasive, 25 native) plant species were recorded present in *S. orientale* uninvaded plots. 24 invasive species occurred in invaded plots and 22 invasives in uninvaded plots.

Reproductive biology of *Lepyrodiclis holosteoides, Hyptis suaveolens* and *Anthemis cotula* including pollination, matting system, pollen viability, stigma receptivity and reproductive output was studied and it was observed that these species employ of host of traits for their spread in the region. Species distribution modelling of three species, namely *Anthemis cotula, Conyza canadenis* and *Hyptis suaveolens* was studied using ensemble modelling approach and Biomod2 package on R platform. It is noteworthy to mention that *Anthemis cotula* and *Hyptis suaveolens* are predicted to expand their suitable range. In particular *H. suaveolens* which at present has no suitable area in Northwest stretch of the Himalaya, is expected to occur in northwest as well as northeast Himalaya under predicted future climate conditions. Management implications of the present study are also highlighted in the report.

Himachal Pradesh

Invasive Alien Species (IAS) pose a major threat to the ecology and economy in invaded regions, especially forest and Hill ecosystems (Rai and Singh 2020; Ahmad et al. 2021). They cause a major change in vegetation at global level and threaten biodiversity (Tecco *et al.* 2010). Though this phenomenon has been occurring since long, yet the problem of invasion has gained momentum in the last 2 decades because of global economic growth. The methodology involves the survey and collection of invasive alien plants species from Himachal Pradesh (except Kinnaur and Lahaul-Spiti district) during vegetation season from different altitudes and habitats. Apart from the collections of specimens, observations were made on the habitat of species, habit and spread of species. All known localities were surveyed to document them and know their status. The random sampling was done by laying quadrats of 1 m x 1 m for herbs, 5 m x 5 m for shrubs, and 20 m x 20 m for trees. Soil samples were also collected for recording moisture, nitrogen, potassium, phosphorus and organic matter content. Data on elevation, geographical coordinates, understory, habitat type, disturbances, grazers, etc., were noted. Density, Frequency, Abundance,

Relative density, Relative frequency and Relative abundance were calculated along with Importance Value Index, for all target species. For recording coordinates and altitude data, Trimble TDC-100 was used. Kjeldahl was used for estimating Nitrogen content in soil and plant samples collected for various purposes. In addition, Infrared gas analyzer was used to record photosynthetic and other physiological parameters of some selected invasive plant species to understand their invasiveness. We have laid a total of 475 quadrats of 1× 1 m to document various herbaceous species. We have recorded 10 invasive alien species in study sites so far. During the various survey conducted we have recorded 145 plant species (listed in Appendix I). The total species belonged to 42 families. Asteraceae, family had the largest proportion (~62%) of plant species, followed by Polygonaceae (~31%), Ranunculaceae (~19%), Poaceae (~17%), Lamiaceae (~14%), Rubiaceae (~12%), Fabaceae (~12%), and Apiaceae (~12%). Out of all the species recorded, ~98% species were angiosperms, ~94% were dicots and ~6% were monocots. ~87% species were herbs, ~10 % shrubs and ~3% were trees. 80 alien species were recorded with 10 of them being major invasive species. *Parthenium hysterophorus*, *Lantana camara*, *Hyptis suaveolens, Broussonetia papyrifera*, *Biden pilosa*, *Ageratum conyzoides*, *Senna occidentalis* were dominant at <1000 m. *Parthenium hysterophorus*, *Lantana camara, Cirsium arvense, Bidens pilosa, Ageratina adenophora* at 1000 - 2000 m. *Ageratina adenophora* was dominant at at 2000-3000 m. *Taraxacum officinale* and *Achillea millefolium* were found at 3000 m–4100. Awareness programmes were conducted in District Sirmaur and Nahan with student in different educational institutes before lockdown which reached successful conclusions. The awareness programmes included interactive sessions with the project staff for understanding the harmful impacts of invasive plants and successfully identifying some major invasive plants of their region. The project before COVID-19 lockdown was successful in identifying the different alien plants in different altitudes of Himachal Pradesh. In addition, awareness was generated in the people for understanding the harmful impacts of invasive plants, and identification of major harmful invasive plant species. Major invasive plants identified like *Lantana camara*, *Parthenium hysterophorus*, *Calyptocarpus vialis, Hyptis suaveolens, Ageratum conyzoides, Ageratina adenophora, Bidens pilosa, Broussonetia papyrifera, Sapium sebiferum. Species like Parthenium hysterophorus, Ageratum conyzoides, Ageratina adenophora, and Lantana camara* were responsible for causing major socio-economic harm, especially in agricultural, and cattle and human health sector. Invasive species alter the vegetation composition of the invaded area by causing vegetation homogenization. Habitat degradation is evident with alteration of soil properties and lowering of soil health and fertility during altered nutrient cycling. Native species with narrow niche width were under extreme threat of extinction. Native species displacement was evident with introduction of an invasive species. Project finding will be useful to governmental organizations and forest department of different districts of Himachal Pradesh. The inventory prepared provide list of alien and native flora encountered that can be further used to study species-specific distribution

patterns. The awareness programmes generated curiosity in students to understand the implications and process of plant invasion, that will empower many other associated stake-holders to participate in different management strategies. Improvement wherever necessary can be done in the methodology used in current project. Long-term monitoring of invasive species can be carried out. The impact of climate change on invasive species distribution can be carried out by assessing their relationship with changing environmental factors like temperature, rainfall, soil moisture, and ambient CO_2.

Uttarakhand

Many people have benefited socially and economically from globalization, but it has also introduced new concerns, of which are invasive alien species (IAS). A significant portion of the world's terrestrial surface, the mountains, are extremely vulnerable to invasion by alien species, including important hubs of developing economies and global biodiversity hotspots. Invasive plants can displace native species, ruin ecosystems, and harm human health by altering structure and functioning of plant communities. Invasive plants have been reported to cause severe ecological, environmental, economic, and health issues in the Himalayan region. Plots (50×50 m) established in grid-based approach and systematic sampling was done in the study sites including Kinnaur and Uttarakhand. The plot was further categorized into quadrats of 5×5 m for shrubs and 1×1 m for herbs for quantifying spatial pattern of species in randomized manner. Density, abundance, and frequency, and IVI of plant species were analyzed. To characterize the soil conditions, soil samples were collected from all the study sites from the center of each 5 × 5 m quadrat within 5–15 cm depth, and mixed thoroughly to obtain three replicates (n = 3) per site. After air drying and sieving the soil through a mesh (pore size: 2 mm), these were analyzed for pH (soil: water = 1:2, w/v), total nitrogen (TN [%]; Kjeldahl method), total phosphorous (TP [%]; ammonium vanadate molybdate method), total potassium (TK [%]; ammonium acetate extraction method) and organic carbon (OC [%]) in the laboratory as per the methods given by Tandon (1993). Soil samples were also used to determine electrical conductivity (EC; mmhos $cm^{-1)}$ by subjecting the soil suspension (soil: water = 1:2, w/v) to digital conductivity meter (Century CC601 Model; calibrated with 0.01 M KCl solution which gives EC of 1.413 mmhos cm^{-1}). Trimble TDC-600 was used for recording coordinates and altitude information. Portable leaf area meter was used for measuring leaf area in the field during sampling the flora of Kinnaur and Uttarakhand. Kjeldahl was employed to calculate the nitrogen content of soil and plant samples that were obtained for a variety of reasons. Moreover, CNS analyzer was used for estimating protein and organic matter present in some selected invasive species collected during the survey. During the survey, the invasive plant was categorized into high or moderate or least invasive species. Highly invasive species were identified for the future prediction of its spread and favorable niche expansion (Ahmad et al 2021).

During the various survey conducted we have recorded 108 plant species (listed in Appendix 1).

The total species belonged to 37 families. Asteraceae, family had the largest proportion (~65 %) of plant species, followed by Solanacea (~24 %), Poaceae (~22 %), Fabaceae (~19 %), Ranunculaceae (~14 %), Polygonaceae (~14 %), Euphorbiaceae (11 %) and Brassicaceae (~11 %). Out of all the species recorded, ~99% species were angiosperms, ~93% were dicots and ~7% were monocots. ~84% species were herbs, ~13 % shrubs and ~3% were trees. 100 alien species were recorded with 30 of them being major invasive species. IAS such as *Prosopis juliflora, Parthenium hysterophorus, Lantana camara, Hyptis suaveolens, Broussonetia papyrifera, Biden pilosa, Ageratum conyzoides, Senna occidentalis, Mirabilis jalapa, Euphorbia hirta* etc. were recorded during the study sites. With changing soil characteristics and decreased soil health and fertility due to altered nutrient cycling, habitat degradation is evident. Native species with small niches were in serious danger of going extinct. The introduction of an invasive species clearly resulted in the displacement of native species. The project's findings will be valuable to the forest departments and governmental agencies in several districts of Uttarakhand and Himachal Pradesh. The list of alien and native plants was recorded would help the researcher to further research the distribution patterns of each species. Students' curiosity about the effects and causes of plant invasion was sparked by the awareness campaigns, and this eagerness would enable many other related stakeholders to take part in various management techniques. In addition to that this study would help the concerned government authorities and NGOs to devise specific management strategies to conserve the native flora.

Sikkim and West Bengal

Recent studies on invasive alien plant species in Indian Himalayan Region raised many questions which need to be resolved through participatory scientific approaches and the development of management strategies for long-term monitoring and rehabilitation of the Himalayan ecosystem. To address this issue the project was initiated to conduct baseline study of invasive alien plants in Sikkim Himalaya. Seven different elevational gradients were surveyed between 600 and 2700 m (600–900 m, 900–1200 m, 1200–1500 m, 1500–1800 m, 1800–2100 m, 2100–2400 m, and 2400–2700 m. Exhaustive information on floristic composition and distribution of targeted plant species (*Ageratina Adenophora, Lantana camara, Mikania micrantha* and *Chromolena odorata*) was compiled from both primary and secondary data, of the respective surveyed sites. A check list of Invasive alien plant species was also documented to facilitate management strategies and further scientific studies. The findings provided in the present report are the first of its kind in Indian Himalayan Region (IHR) on plant distribution, their ecology, with scientific value. To achieve this target, we conduct five field visits to collect valuable data for further extensive ecological studies.

Mizoram & Tripura

Alien plant invasion is considered to be one of the five major drivers of global environmental change, causing rapid biodiversity loss. Invasive alien plant species alter ecosystem equilibrium by degrading native biodiversity. The rapid invasion by alien plants is aggravated with increased global communication causing accidentally or consciously introducing IAPs to different ecosystems of world crossing their native range causing significant proliferation and irreversible biodiversity loss. critical component of global environmental change because, after establishment, they randomly proliferate in all direction; mainly when the environment is conducive as in a rough and sloppy mountain terrains (Rumlerová, Vilà, Pergl, Nentwig, & Pyšek, 2016). The recent global climate change has also catalysed the rate of introduction and spread of alien species into areas where they were previously absent, or increased their performance as compared to native species. Recent studies are indicating that the biodiversity of the state has been increasingly threatened due to various anthropogenic activities, unsustainable practices, waste generation and climate change. Hence an integrated scientific approach is need of the hour to understand the vegetation of the state, their conservation and management.

Sporadic information is available on alien species, particularly on Indian Himalayan regions. Ecological studies on invasive plants, mainly on *Ageratum conyzoides*, *Parthenium hysterophorus* and *Lantana camara* were reported from the north-western Himalayan region (Kohli, Batish, Singh, & Dogra, 2006); 571 alien species enumerated from the Kashmir Himalayas (Khuroo, Reshi, Rashid, & Dar, 2011); 190 alien species identified from Indian Himalayan region (Sekar, Manikandan, & Srivastava, 2012); 497 alien species enumerated. However, accurate estimation on the spread of invasive species and its potential threats is not available from North-eastern states of India, particularly from Mizoram and Tripura. A proper estimation of floristic elements or landscapes infested with invasive alien plants is the need of the hour to build appropriate strategies for conservation and management of natural flora.

Therefore, As a pilot study, the project aimed to evaluate the rate of spread of *Ageratina* and *Mikania* by analysing their abundance, rate of aboveground growth during different seasons in different ecological habitats; to determine the reproductive potential by analysing characteristic; to study the similarities and differences in spread pattern and invasive load on early recovery successional landscapes, and its impact on the natural flora and also to undertake awareness programmes among all the stake holders including local people through an interactive local level capacity building programme regarding the consequences of invasive species, if not managed.

The methodology involves the survey and collection of invasive alien plants (IAPs) from Mizoram & Tripura during various seasons from different altitudes. Phytosociological analysis of IAPs and its associate species were carried out by quadrat sampling (Mishra, 1968) in

Mizoram & Tripura during 2018-2021. Sampling was done by randomly placing quadrats of 5 x 5 m^2 size, and within those 5 x 5 m^2 quadrats of 1x1 m^2 were performed to study the phytosociological data. Severe infested areas with IAPs were marked & tagged for future survey. Tagging was made in selected sites for the study various phytosociological data in the subsequent visit. Mostly the areas highly infested with IAPs were studied i.e., protected & non-protected areas, roadsides, fallow lands, agricultural fields, landslide areas, wetlands, wastelands etc. which experienced major anthropogenic disturbances. Understory vegetation which was included in the sampling were majorly herbs & shrubs also including few trees. Quadrats were sampled at regular intervals. Data on vegetation, including elevation (altimeter), geographical coordinates (GPS) and the presence of disturbances or human interference were recorded. Soil samples of individual IAPs which are highly infested were also collected for analysing soil parameter attributes. Seed samples were also collected to study the parameters such as, rate of seed production Diameter of all herbs/shrubs was taken about 2 cm above ground. Recorded species were preserved and identified by reference to literature in various herbaria in the country. During field surveys, 300 m altitudinal gradient range was covered for each study site. Data on frequency, density and dominance and IVI were calculated for all target species. A list of top 10 most obnoxious & top 5 neo-invasives IAPs was made based on their IVI values. Rate of spread of selected IAPs was worked out by generating temporal multi-layered maps such as, distribution map.

The invasion load of the two states exhibited 163 invasive alien plants in Mizoram and 186 invasive alien plants in Tripura. Out of the total reported 186 plant species from protected areas in Tripura, 56.98% (106 taxa) were represented by herbs, 16.12% (30 taxa) were trees, 9.67% (18 taxa each) were shrubs and climbers, and 3.22% (6 taxa each) were represented by grasses and sedges. Out of the total alien species in Tripura, 34.40% (64 taxa) were from Tropical American origin followed by 16.12% (30 taxa) from South American, 10.21% (19 taxa) from Tropical African, 5.91% (11 taxa each) from Mexican, and Australian origin and 5.37% (10 taxa) from European origin. Total reported 163 plant species from protected areas in Mizoram belonging to 135 genera and 51 families were identified. Out of these, 147 species belong to 122 genera and 43 families were dicotyledons; 11 species belong to 9 genera and five families were monocotyledons. Five species of gymnosperms under four genera and three families were also recorded.

The most noxious invasive alien plant species observed in Tripura and Mizoram are *Mikania micrantha* Kunth.(Asteraceae) , *Ageratina adenophora* (Spreng.) King & Robinson. (Asteraceae), *Ageratum conyzoides* (L.) L. (Asteraceae), *Chromalaena odorata* (L.) R.M.King & H.Rob.(Asteraceae) , *Lantana camara* L. (Verbenaceae) , *Ageratum houstonianum* Mill.(Asteraceae) , *Bidens pilosa* L. (Asteraceae), *Alternanthera sessilis* (L.) R.Br. ex DC.

(Amaranthaceae), *Imperata cylindrica* (L.) Raeusch, *Ip*omoea carnea Jacq (Convolvulaceae) and *Urena lobata* L. (Malvaceae).

In protected areas of Mizoram, *Ageratina adenophora* , *Hypoestis phyllostachya* , *Ageratina riparia* were the most dominant invasive alien species with associated native species like *Lobelia pyramidalis* , *Lindenbergia grandiflora* , A*nisochilus carnosus* and *Ainsliaea latifolia* occurring between 1400-2250 m of elevation whereas *Chromolaena odorata* , *Mikania micrantha* , *Imperata cylindrica* were observed dominant over native species like *Strobilanthes maculata* and *Impatiens stenantha* up to 1550 m of altitude only.

Between 400-1250 m of altitude, *Impatiens stenantha*, *Oplismenus burmanii, Strobilanthes maculata* and *Osbeckia chinensis* were dominant associated native species with invasive alien plants like *Chromolaena odorata, Lantana camara.* Whereas in between 1250-2141 m of elevation, the spread of *Ageratina adenophora* , *Ageratina riparia* , *Mikania micrantha* were most abundant suppressing associated native species like *Lobelia pyramidalis* , *Lindenbergia grandiflora* , *Anisochilus carnosus* and *Ainsliaea latifolia*.

As a part of the project objective, it is essential to interact with the local stakeholders like university students, NGOs, forest department officials and local farmers who can directly or passively take part in evaluating the ecological investigation of the targeted invasive plants. Two awareness programmes were conducted in Mizoram and one National seminar was conducted with more than 300 participants cumulatively in all the events.

Due to the COVID-19 Pandemic situation globally, execution of work as planned was hampered but sincere efforts were put into to fulfill the key mandates of the programme.

Mizoram & Tripura are biodiversity-rich states and invasion of alien species is emerging as a significant concern for the conservation of native flora. Majority of the population are forest dwellers and mainly dependant on forest resources. Therefore, first-hand information on native flora and invasive flora is needed for formulating scientific management strategy for long-term sustainable utilization. Controlled practices of traditional slash-and-burn cultivation, strict quarantine measures for importing of food crops and introduction of exotic plants are needed to be streamlined to strengthen a strategy for proper utilization, generate livelihood and wellbeing of the society. Regular awareness programmes may also to be conducted to appraise the local inhabitants about the impacts and control of invasive alien plants. Therefore, early interventions such as creating strict quarantine measures for importing of food crops, and strict vigilance on the introduction of exotic plants are needed to be streamlined.

Arunachal Pradesh, Nagaland, Manipur

The present study was carried out in the three states, namely Arunachal Pradesh (AP), Manipur (MN) and Nagaland (NL) of the Indian Himalayan Region. Various localities were explored, surveyed and samplings were carried out in forty locations including the premises of the Loktak lake in Manipur. Altogether, 131 alien and invasive plant species were observed and documented till date which include 89 herbs, 33 shrubs, 6 climbers and 3 trees. Plant specimens of the plants were collected from each site for the preparation of herbarium sheets and identified. A total of ten noxious IAPS were identified and recorded viz., *Ageratina adenophora*, *Ageratum conyzoides, Ageratum houstonianum*, *Bidens pilosa, Chromolaena odorata, Lantana camara, Mikania micrantha, Tithonia diversifolia, Parthenium hysterophorus,* and *Urena lobata*. Digital Elevation Model maps for Arunachal Pradesh, Nagaland and Manipur according to four climatic zones i.e., Tropical, Subtropical, Temperate and Alpine were developed. Furthermore, new sets of DEMs according to 300m elevation gradient were prepared for each of the three states. GPS locations of the species recorded were extrapolated on the DEM maps. In tropical open forests, *Mikania micrantha, Ageratum conyzoides and Chromolaena odorata* were recorded in pure patches as well as in mixed population, where both the species were recorded from low to high elevations. *Lantana camara* was localized in open forests and not recorded under the tree canopies occurring in both tropical and sub-tropical belts. Densely regenerated population of *Ageratum conyzoides* succeeds most forest floors. *Parthenium hysterophorus* was recorded near the roadsides adjoining to the evergreen forests at higher range of tropical belt, but with limited population in all the states while its aggressive growth was observed in disturbed roadsides near human habitations. *Ageratina adenophora* and *Tithonia diversifolia* were absent in tropical belt in Arunachal Pradesh but were observed at sub-tropical forests. Dense populations of *Chromolaena odorata* and *Lantana camara* were widely grown in tropical belts of Papum Pare and pockets of Lower Subansiri, Arunachal Pradesh and in many places of Manipur at higher tropical regions. These two species were also dominating in the lower tropical plain areas in Nagaland while *Ageratina adenophora* dominated in the higher subtropical hills. It was ascertained that *Lantana camara* was used as live fencing and *Ageratina adenophora* as soil binder in different parts of Manipur. *Ageratina adenophora* was found to be growing frequently and thickly on the sub-tropical locations while *C. odorata* and *L. camara* were found to be growing dominant on localities having elevation less than 300m. Only *Ageratina adenophora, Artemisia nilagirica* and *Tithonia diversifolia* were the invasive plants to observed at 2600 m amsl altitudes, but with a limited population. Aggressive growth of these plants led to outcompeting the growth of other existing plants in the area and gradually cover the area. Detail investigation of soil properties considering parameters like pH, moisture, available NPK were carried out by collecting samples from both the invaded and non-invaded from different

study sites of Arunachal Pradesh, Manipur and Nagaland. Alien invasive plants have the potential to alter ecosystem function. However, generalizations were difficult to make because impacts appeared to be species- and site-specific. *Ageratina adenophora* was observed less deteriorating the soil nutrients whereas other IAVPs, *Ageratum conyzoides, Mikania micrantha, Chromolaena odorata* and *Lantana camara* were observed deteriorating the soil nutrients most in all 3 states at the different elevation gradient irrespective of their dominance. Germinative capacities of the selected IAVPS were also carried out in petridish experiments. *Bidens pilosa* seeds were found to be having the highest germinating potential with 94±2.79 percent germination percent. *Lantana camara* seeds failed to germinate under the same treatment. It was ascertained from the observation study that its seeds were germinated from the bird droppings. As birds feeds on the berries and as a result the seeds are transported or introduced into other places, thus took part in the introduction through their droppings. Regarding the value addition and control of IAVPS from our surroundings, selected IAVPS were used as feeding materials in vermicomposting. Thus, composting of invasive species was identified as the potential control tool and can help in income generation which eventually will keep the population of plants under too. *Hyptis suaveolens,* a highly invasive plant is also identified as a potential crop plant for its nutritious seeds and its harvesting of the plant will also create livelihood income provided if taken up in larger scale. Thus, there is more need of identification of such value addition of bioresources so that the invasion is controlled while the humankind is benefitted.

Two workshops cum training programme were organized separately at Manipur and Arunachal Pradesh. These findings were discussed and talked in the workshops among people of different groups including academicians, students, researchers and villagers. These research outcomes were also presented in seminars and conference.

2 INTRODUCTION

2.1 Background (max. 500 words)
2.2 Overview of the major issues addressed (max. 500 words)
2.3 Baseline Data and Project Scope (max. 500 words)
2.4 Project Objectives and Target Deliverables (as per the NMHS-Sanction Order)

3 METHODOLOGIES/STARTEGY/ APPROACH – *supporting documents to be attached.*

3.1 Methodologies used (max. 500 words)
3.2 Data collected and Equipments utilized (max. 500 words)
3.3 Details of Field Survey conducted, if any (max 500 words)
3.4 Strategic Planning for each activity with time frame (max. 200 words)

4 KEY FINDINGS AND RESULTS – *supporting documents to be attached.*

4.1 Major Activities/ Findings (max. 500 words)
4.2 Key Results (max. 500 words in bullets covering all activities)
4.3 Conclusion of the study (max. 500 words in bullets)

5 OVERALL ACHIEVEMENTS – *supporting documents to be attached.*

5.1 Achievement on Project Objectives/ Target Deliverables (max. 500 words)]
5.2 Interventions (max. 500 words)
5.3 On-field Demonstration and Value-addition of Products, if any (max. 500 words)
5.4 Green Skills developed in in State/ UT (max. 500 words)
5.5 Addressing Cross-cutting Issues (max. 200 words)

6 PROJECT'S IMPACTS IN IHR – *supporting documents to be attached.*

6.1 Socio-Economic impact (max. 500 words)
6.2 Impact on of Natural Resources/ Environment (max. 500 words)
6.3 Conservation of Biodiversity/ Land Rehabilitation in IHR (max. 500 words)
6.4 Developing Mountain Infrastructures (max. 200 words)
6.5 Strengthening Networking in State/ UT (max. 200 words)

7 EXIT STRATEGY AND SUSTAINABILITY – *supporting documents to be attached.*

7.1 Utility of project findings (max. 500 words)
7.2 Other Gap Areas (max. 200 words)
7.3 Major Recommendations/ Way Forward (max. 200 words)
7.4 Replication/ Upscaling/ Post-Project Sustainability of Interventions (max. 500 words)

8 REFERENCES/BIBLIOGRAPHY

9 ACKNOWLEDGEMENTS

APPENDICES

Appendix 1 – Details of Technical Activities
Appendix 2 – Copies of Publications duly Acknowledging the Grant/ Fund Support of NMHS
Appendix 3 – List of Trainings/ Workshops/ Seminars with details of trained resources and dissemination material and Proceedings
Appendix 4 – List of New Products (utilizing the local resources like NTFPs, wild edibles, bamboo, etc.)
Appendix 5 – Copies of the Supporting Materials like Manual of Standard Operating Procedures (SOPs) developed under the project

Appendix 6 – Details of Technology Developed/ Patents filled, if any
Appendix 7 – Any other

******

Annexure-I

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

For the Period: ……

1.	Title of the project/Scheme/Programme:	
2.	Name of the Principle Investigator & Organization:	
3.	NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand Letter No. and Sanction Date of the Project:	
4.	Amount received from NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand during the project period (Please give number and dates of Sanction Letter showing the amount paid):	
5.	Total amount that was available for expenditure (Including commitments) incurred during the project period:	
6.	Actual expenditure (excluding commitments) incurred during the project period:	
7.	Unspent Balance amount refunded, if any (Please give details of Cheque no. etc.):	
8.	Balance amount available at the end of the project:	
9.	Balance Amount:	
10.	Accrued bank Interest:	

Certified that the expenditure of **Rs._____ (Rupees _____)** mentioned against Sr. No. 6 was actually incurred on the project/scheme for the purpose it was sanctioned.

Date:

(Signature of Principal Investigator)	(Signature of Registrar/ Finance Officer)	(Signature of Head of the Institution)

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALAYAN STUDIES (GBP NIHE)

Statement of Consolidated Expenditure

[Institution Name here]

Statement showing the expenditure of the period from
Sanction No. and Date :

1. Total outlay of the project :

2. Date of Start of the Project :

3. Duration :

4. Date of Completion :

a) Amount received during the project period :

b) Total amount available for Expenditure :

S. No.	Budget head	Amount received	Expenditure	Amount Balance/ excess expenditure
1	Salaries			
2	Permanent Equipment Purchased (Item-wise			
3				
4				
5				
6				
7				
8				
9				
10	Institutional charges			
11	Accrued bank Interest			
12	**Total**			

Certified that the expenditure of **Rs._____ (Rupees:_____)** mentioned against Sr. No.12 was actually incurred on the project/ scheme for the purpose it was sanctioned.

Date:

(Signature of Principal Investigator)	(Signature of Registrar/ Finance Officer)	(Signature of Head of the Institution)

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALYAN STUDIES (GBP NIHE)

Annexure-II

Consolidated Interest Earned Certificate

Please provide the detailed interest earned certificate on the letterhead of the grantee/ Institution and duly signed.

Annexure-III

Consolidated Assets Certificate

Assets Acquired Wholly/ Substantially out of Government Grants

(Register to be maintained by Grantee Institution)

Name of the Sanctioning Authority: _____

1. Sl. No. _____
2. Name of Grantee Institution: _____
3. No. & Date of sanction order: _____
4. Amount of the Sanctioned Grant: _____
5. Brief Purpose of the Grant: _____
6. Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant-in-aid Sanction Order: _____
7. Particulars of assets actually credited _____ or acquired_____
8. Value of the assets as on _____
9. Purpose for which utilised at present _____
10. Encumbered or not _____
11. Reasons, if encumbered _____
12. Disposed of or not _____
13. Reasons and authority, if any, for disposal_____
14. Amount realised on disposal _____

Any Other Remarks: _____

_____

(PROJECT INVESTIGATOR) **(FINANCE OFFICER)**

(Signed and Stamped) **(Signed and Stamped)**

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Annexure-IV

List or Inventory of Assets/ Equipment/ Peripherals

S. No.	Name of Equipment	Quantity	Sanctioned Cost	Actual Purchased Cost	Purchase Details

(PROJECT INVESTIGATOR)

(Signed and Stamped)

(FINANCE OFFICER)

(Signed and Stamped)

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Annexure-V

Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department

To,

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

Sub.: Transfer of Permanent Equipment purchased under Research Project titled "...." funded under the NMHS Scheme of MoEF&CC – reg.

Sir/ Madam,

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

1. .....
2. .....
3. .....
4. .....
5. .....
6. .....
7. .....

Head of Implementing Organization:
Name of the Implementing Organization:
Stamp/ Seal:
Date:

Copy to:

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

Annexure-VI

Details, Declaration and Refund of Any Unspent Balance

Please provide the details of refund of any unspent balance and transfer the balance amount through RTGS (Real-Time Gross System) in favor of **NMHS GIA General** and declaration on the official letterhead duly signed by the Head of the Institution.

Kindly note the further Bank A/c Details as follows:

Name of NMHS A/c:	NMHS GIA General
Bank Name & Branch:	Central Bank of India (CBI), Kosi Bazar, Almora, Uttarakhand 263643
IFSC Code:	CBIN0281528
Account No.:	3530505520 (Saving A/c)

In case of any queries/ clarifications, please contact the NMHS-PMU at e-mail: nmhspmu2016@gmail.com

DETAILED PROJECT TECHNICAL REPORT OF EACH PROJECT PARTNERS

FOR JAMMU, KASHMIR & LADAKH (Prof. Zafar Reshi)

Introduction

- **Background**

Alien plant inventories are necessary for understanding the extent, causes and consequences of plant invasions and these inventories provide baseline information required for management of invasive species. Thus, there is an urgent need for comprehensive national databases on alien plant species, especially in developing countries. Development of such databases has assumed urgency in view of multiple and far-reaching ecological and economic impacts of invasive alien species. For example, recent studies have documented their role in extinction of native species (Sax and Gaines 2008), disruption of essential ecosystem processes (Wandrag et al 2020). Though the work on various facets of alien plant species has been initiated (Panda and Behera 2019; Lepcha and Chandra 2022), still a lot needs to be done to not only prevent new introductions of species but also to control of already introduced species. In particular, the Indian Himalayan region needs focused attention in view of it being the abode to many prized indigenous and native species. Previously it was thought that mountain regions owing to their harsh climatic conditions, particularly in the alpine areas, are not vulnerable to alien plant invasions, but recent research has indicated that the alien species are shifting upwards into the alpine regions. Given anthropogenic disturbance, climate change and economic developmental activities, the Indian Himalayan region (IHR) is now at a higher risk of plant invasions (Tripathi et al. 2022).

Kashmir Himalaya, located at the bio-geographically pivotal position, represents a unique biospheric unit in the northwestern Himalaya. The region covers an area of c. 222 235 km2 and is divided into three provinces: Jammu, Kashmir and Ladakh (Romshoo et al 2020). Owing to the vast variety of edapho-climatic and physiographic heterogeneity, the region harbours diverse habitats, including lakes, springs, swamps, marshes, rivers, cultivated fields, orchards, subalpine and alpine meadows, montane slopes and terraces, permanent glaciers, etc., which support equally diverse floristic elements. It is in this backdrop that the present study on the invasive alien species across all the states of Indian Himalayan Region was piloted.

- **Overview of major issues:** The important issues that were primarily addressed in this project include:

1. **Identifying established and new Invasive Alien Vascular Plant Species (IAVPS) in Jammu, Kashmir, Ladakh and adjoining regions of Himachal Pradesh and estimating the invasion load**

- **Methodology:**
- **Documentation of alien species data**

The alien plant diversity of the study areas was documented through extensive field surveys in the region (Fig. 1). To survey all the vegetation types/habitats in the area, random sampling was undertaken across the regions.

The plant specimens were identified using relevant taxonomic literature and protocols after being processed using standard herbarium techniques. In some cases, the identifications were confirmed using previously identified herbarium specimens from the University of Kashmir Herbarium (KASH).

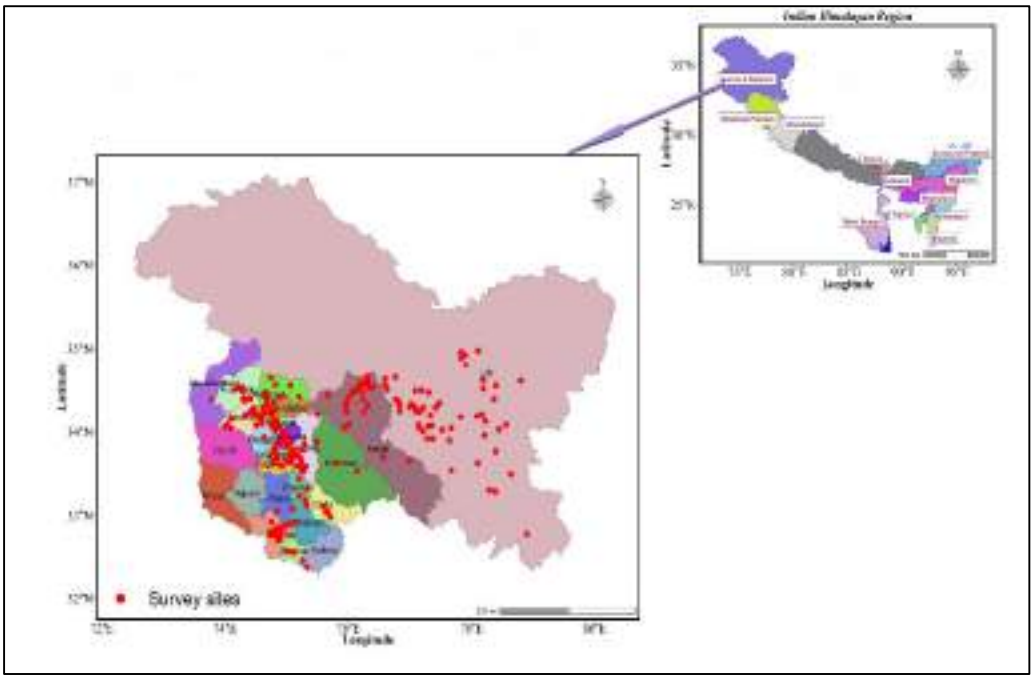


Fig. 1. Map of study area showing the survey sites.

Nativity

We assigned the native distribution range of each species using the online databases (POWO, 2022; Hooker 1875 and GRIN-Germplasm Resources Information Network. For analysis purposes, we aggregated the native distribution range of each species into a 'continent' according to the plant distribution scheme developed by Taxonomic Databases Working Group (TDWG; currently named Biodiversity Information Standards; Brummitt, 2001).

Growth form

Each species in the database was assigned growth-form categories (namely herb, shrub, subshrub, tree, and climber) based on field observations, supplemented with authentic secondary sources, such as e-floras (http://www.efloras.org). For growth-form categories, a standard terminology was adopted

Life span category

The life span category of each species in the inventory was assigned based on field observations, supplemented with authentic secondary sources, such as e-floras (http:// www.efloras.org/). For life span categories we adopted a standard terminology of Mabberley (2008).

Introduction pathways

The deliberate (ornamental and other uses) or accidental introduction was determined based on literature survey. To get an indication of the potential reason for introduction, we extracted the known economic uses of each alien species from the World Economic Plants (WEP) database (GRIN-2023;https:// npgsweb. ars- grin. gov gringlobal/ taxon/ taxonomy search) and Randall 2017 was used.

Habitat-wise alien plant species

One of the important aspects of the current study was to assess alien species load across various habitats in the three regions. For this purpose field surveys were conducted in the three regions across the different habitats to document the alien plant load. The habitats included wastelands, cultivated fields (rice fields, maize fields, saffron fields, wheat fields etc), river banks, forests, grasslands, roadsides and aquatic habitats etc. IUCN habitat classification was followed for habitat characterization.

- **Invasion status**

Species were classified into three categories along the introduction–naturalization invasion continuum (INIC) that describes how species proceed in the invasion process by

overcoming geographical, environmental and biotic barriers (Richardson et al.,2010 & 2014).

Based on this concept we used the following categories to describe the invasion status of an alien species:

(i) **Casua**l **species** are those alien species that do not form self-sustaining populations in the invaded region; they may flourish and reproduce occasionally in an area but their persistence depends on repeated introductions of propagules.

(ii) **Naturalized species** (synonym: established species) form self-sustaining populations for several life cycles without direct intervention by people, or despite human intervention; they often recruit offspring freely, usually close to adult plants and their persistence does not depend on ongoing input of propagules.

(iii) **Invasive species** are a subset of naturalized species; they form self-replacing populations over many life cycles, produce reproductive offspring, often in very large numbers at considerable distances from the parent and/or site of introduction, and have the potential to spread over long distances.

- **Prediction, early detection and risk assessment of alien invasive plant**

It was based on grouping alien species into casual, naturalized and invasive categories with presently invasive species considered as high risk species for other regions where such species do not occur as of today. However, there are pre-introduction and post-introduction protocols available for predicting the potential invasive species which could be utilized based on the data generated during the present study.

We used species distribution modelling for predicting the distribution of some select invasive species under future climate change. For this georeferenced geographic coordinates of occurrence of each target species were collected from both primary (field surveys) and secondary (GBIF, CABI etc) sources and these were cleaned, spatially thinned using '*Spatially Rarefy Occurrence Data'* function in SDM ToolBox v2.2c. Additionally, 19 grid-based bioclimatic variables Bio1 to Bio19 for the current period and future time periods at a spatial resolution of 2.5 arc-minutes corresponding to a pixel size of approximately (~ 5 sq km) were downloaded from the most popular source for climatic data namely WorldClim database, version 1.4 (Hijmans et al. 2005, http://www.worldclim.org). Ensemble species distribution modelling was employed in the present study and the predictive performance of each algorithm was calculated by split sampling (cross-validation). Appropriate indices (Boyce, AUC, Kappa) were utilized for model evaluation. Finally the change in habitat suitability of each target species (expansion

or contraction) for current and future scenarios (2050, 2070 and 2080) under all the available RCPs namely 2.6, 4.5, 6.0 and 8.5 were computed.

- **Impact assessment of invasive species**

For the purpose of assessing the impact of invasive species, three species highly invasive in Kashmir Himalaya, namely *Anthemis cotula* L., *Erigeron canadensis* L. and *Sisymbrium orientale* L. were selected and sites invaded and uninvaded (control sites) were surveyed to document any change in the diversity and abundance of species due to invasion. The invaded and uninvaded sites were more or less comparable and were selected so as to ensure that these were more or less similar to each other in aspect, elevation, exposure, history etc other than some being invaded and others being invaded.

Consolidation of information for most noxious invasive species (10 for entire IHR region)

For this purpose we selected three species, one each from Jammu, Kashmir and Ladakh. *Hyptis suaveolens* (L.) Poit. was selected from Jammu region because modelling has predicted its spread and shift to Kashmir Himalaya and other IHR regions. *Anthemis cotula* was selected from Kashmir Himalaya since the species is highly invasive in this region and *Lepyrodiclis holosteoides* was selected from Ladakh. It is pertinent to mention that this species was selected despite being native to the region but is wreacking havoc to the crops grown in this region.

Identification of cross-sectoral groups and formulation of workable management strategies aiming at protection, prevention and control of invasive species.

As such no specific methodology was employed for this objective, instead based on the field experience and interaction with the stakeholders we could identify cross-sectoral groups. The sectors that should be involved in the management of invasive species include agriculture, horticulture, forestry, plant protection and quarantine, academic institutions, local NGOs having interest in biodiversity management. During our field studies it was noticed that the awareness about invasive alien species among all the governmental and non-governmental stakeholders is very minimal and awareness about the ecological and economic consequences of invasive species should be highlighted to elicit appropriate response from the concerned authorities.

- **Results**

Taxonomic composition

In the present study 401 alien plant species were recorded from the regions of Jammu, Kashmir and Ladakh (JKL), out of which 112 species were under cultivation in the three regions while 289 species were the alien species that were not cultivated, instead were

growing wild. These 401 species belonged to 278 genera in 84 families. Of these 81 families belonged to angiosperms (75 are dicot and 6 monocot families), and 3 to gymnosperms.

Table 1. Taxonomic conspectus of alien plant species (including both under and outside cultivation species) in Jammu, Kashmir and Ladakh.

Plant group	**Species**	**Genus**	**Family**
Dicot	**361**	**246**	**75**
Monocot	**33**	**26**	**6**
Gymnosperm	**7**	**6**	**3**
Total	**401**	**278**	**84**

However, for the purpose of this project the number of alien plant species outside cultivation alone was considered for further analyses and characterization. The taxonomic conspectus of such species is presented in Table 2. Perusal of the data in Table 2 reveals that 289 species belonging to 198 genera and 64 families are alien plant species outside cultivation in the three regions. Dicots are predominant with 263 species spread over 179 genera and 56 families. Monocots are represented by only 24 species and gymnosperms by 2 species (Table 2).

Table 2. Taxonomic conspectus of alien plant species outside cultivation in Jammu, Kashmir and Ladakh.

Plant group	**Species**	**Genus**	**Family**
Dicot	263	179	56
Monocot	24	17	6
Gymnosperm	2	2	2
Total	**289**	**198**	**64**

Majority of these species (180 spp.) are naturalized and only 50 species could be included in the casual category. In all 81 species are invasive in the study regions (Table 3). However, it needs to be mentioned that the invasion stage of the species is not the same

in all the three regions and a species which is invasive in one region may not be invasive in another region.

Table 3. Distribution of alien species in different invasion stage categories.

Invasion stage	Species	Genus	Family
Casual	50	44	29
Naturalized	180	131	54
Invasive	81	60	27

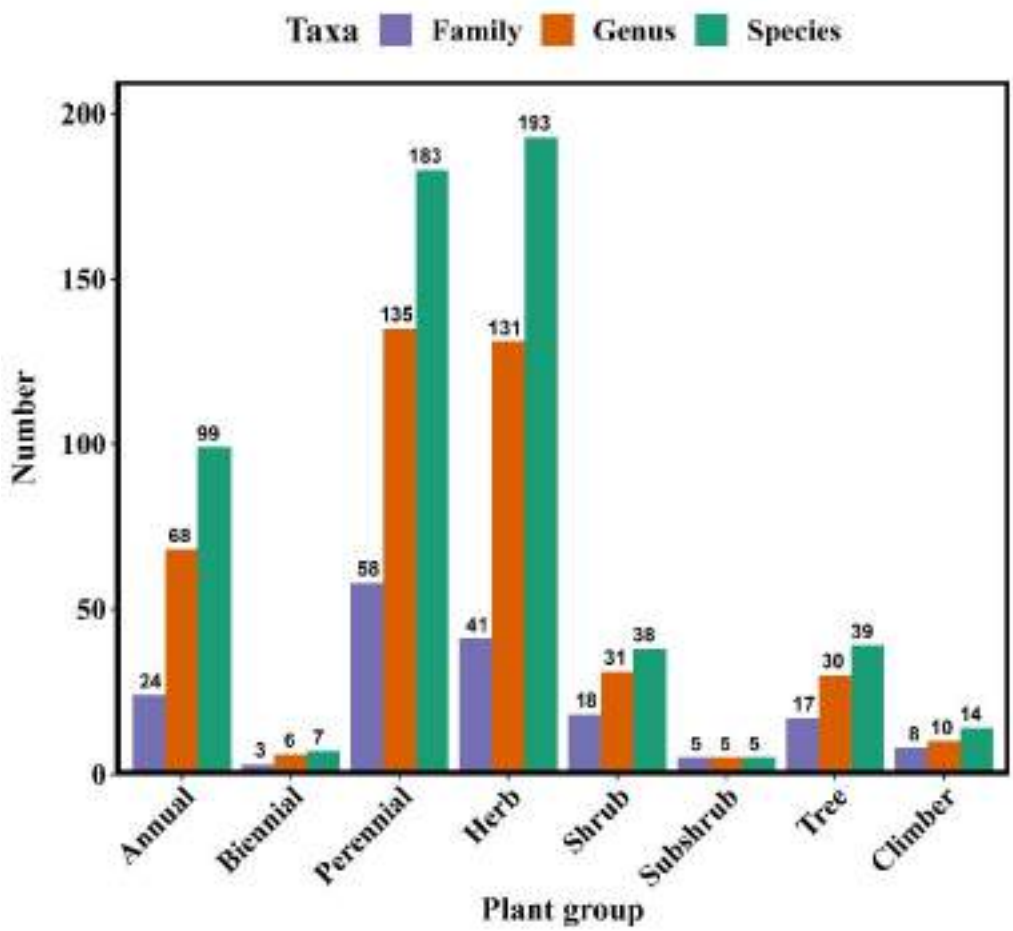


Fig. 2. Number of alien vascular plant species belong to different groups

Data in Fig. 2 depicts that the alien species have predominantly perennial and herbaceous habit as these two groups are represented by 183 and 193 species, respectively. 99 species had an annual life cycle while just 7 species were biennials. Trees and shrubs were almost equally represented. Asteraceae was the dominant family with 43 species followed by Fabaceae (35 spp.), Amaranthaceae (21 spp.) and Brassicaeace and Solanaceae with 20 species each (Table 4). The dominant genera were *Solanum* with 9

species followed by *Amaranthus* and *Iris* with 8 and 7 species respectively. The other dominant genera are given in Table 4.

Table 4. Ten dominant families and genera in the alien flora

Family	**Number of species**	**Genus**	**Number of species**
Asteraceae	43	*Solanum*	9
Fabaceae	35	*Amaranthus*	8
Amaranthaceae	21	*Iris*	7
Brassicaceae	20	*Ipomoea*	6
Solanaceae	20	*Brassica*	5
Rosaceae	17	*Oenothera*	5
Malvaceae	14	*Salix*	5
Poaceae	12	*Senna*	5
Lamiaceae	11	*Erigeron*	4
Plantaginaceae	11	*Euphorbia*	4

Most of the alien plant species (57.44 %) have been introduced unintentionally, and a sizeable proportion has been introduced for ornamental (22.84%) and agricultural (10.38%) purposes (Fig. 3).

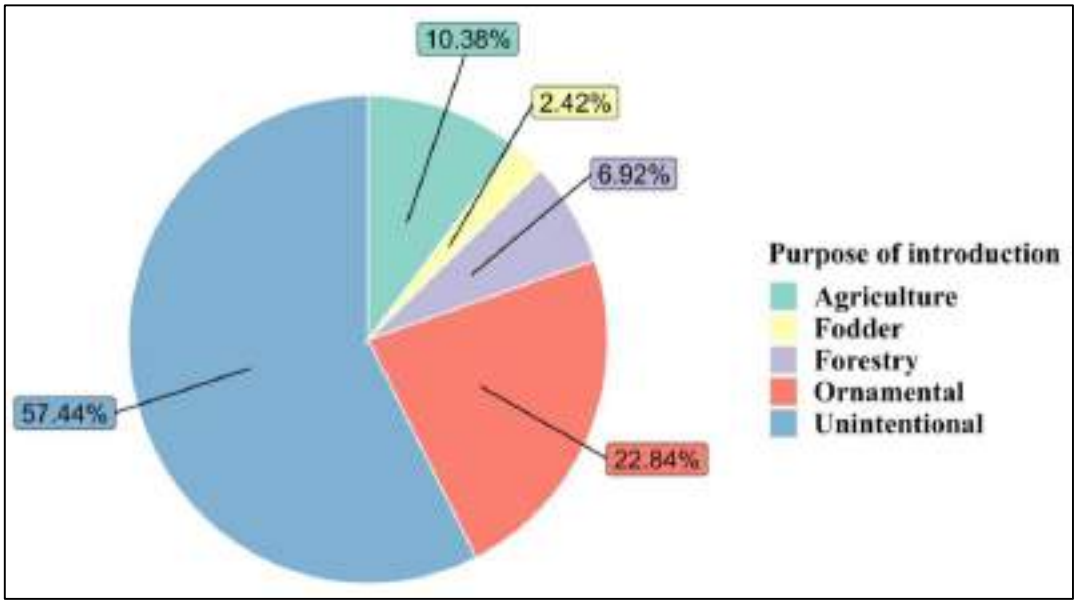


Fig. 3. Proportion of alien plant species introduced for various purposes.

Most of the alien species are of Northern American origin but the elements from temperate Asia, Europe and Southern America are also well represented. Very less percentage of species had African or Australian origins (Fig. 4).

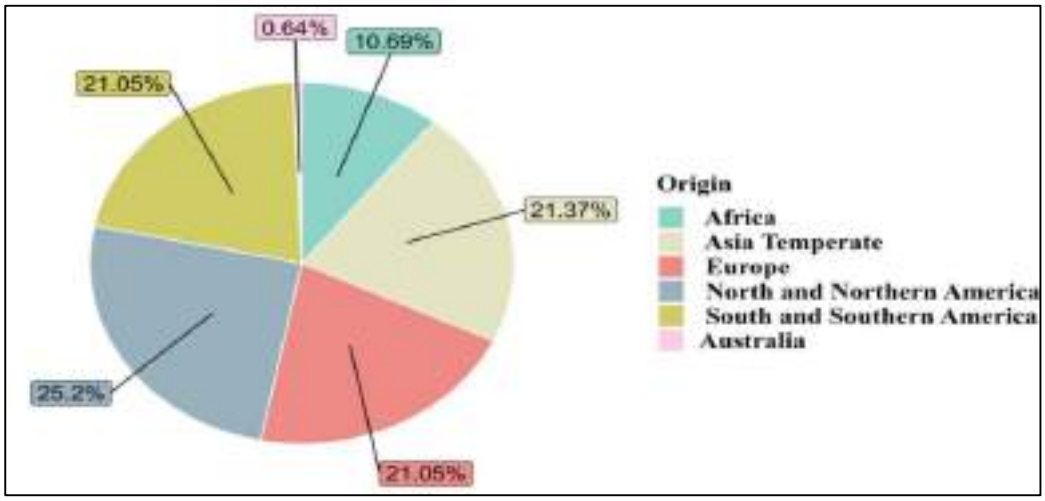


Fig. 4. Proportion of alien plant species in the study area from various continents of the world.

Region-wise alien flora

The region-wise number of alien plant species (excluding cultivated alien plant species) is presented in Fig. 5. Highest number of alien plant species was recorded in Jammu with 208 species belonging to 149 genera in 57 families. In Kashmir, 190 alien plant species were recorded which belonged to 131 genera in 49 families. In Ladakh, 45 alien plant species belonging to 33 genera and 18 families were recorded during the present study (Fig. 5).

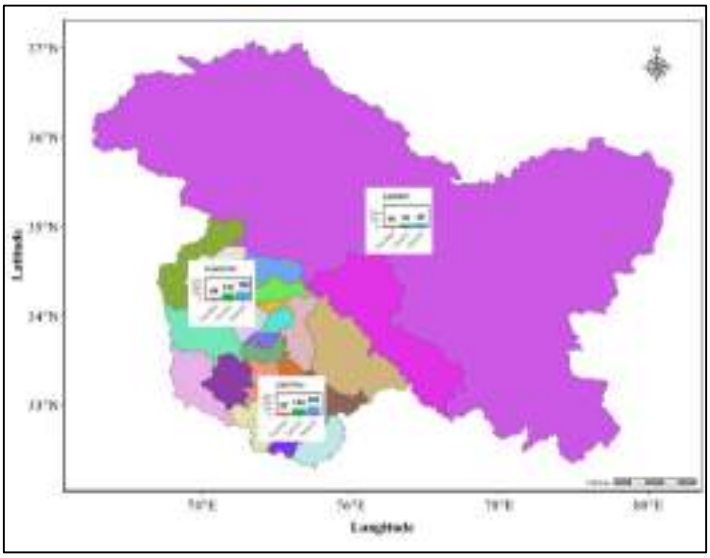


Fig. 5. Map of the study area showing number of alien species in three regions of Jammu, Kashmir and Ladakh.

Of the recorded 285 alien plant species from Jammu, 77 plant species are alien under cultivation and the remaining 208 are alien outside cultivation belonging to 149 genera in 57 families (Fig. 6). The largest families in terns of number of species include: Asteraceae (30 spp.), Fabaceae (21 spp.), Solanaceae (17 spp.) Amaranthaceae (14 spp.) Brassicaceae (11 spp.), Convolvulaceae, Euphorbiaceae, Malvaceae each with (7 spp.), Onagraceae, Papaveraceae (6 spp.) each, which contributes ca. 51% to the total recorded plants. Amongst these, 27 are casuals belonging to 23 genera and 17 families, 63 are invasive belonging to 46 genera and 25 families and 118 are naturalized aliens belonging to 94 genera and 46 families (Fig.7).

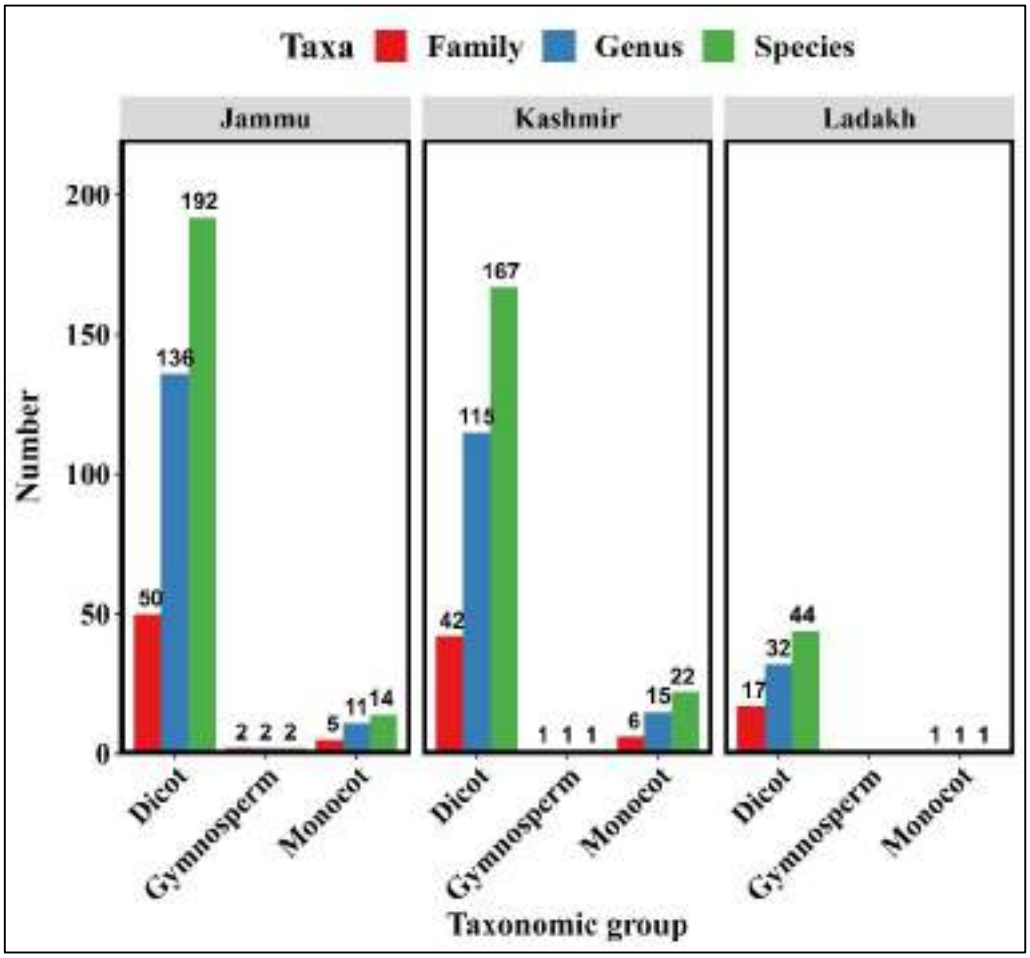


Fig. 6. Distribution of alien flora under different taxonomic groups

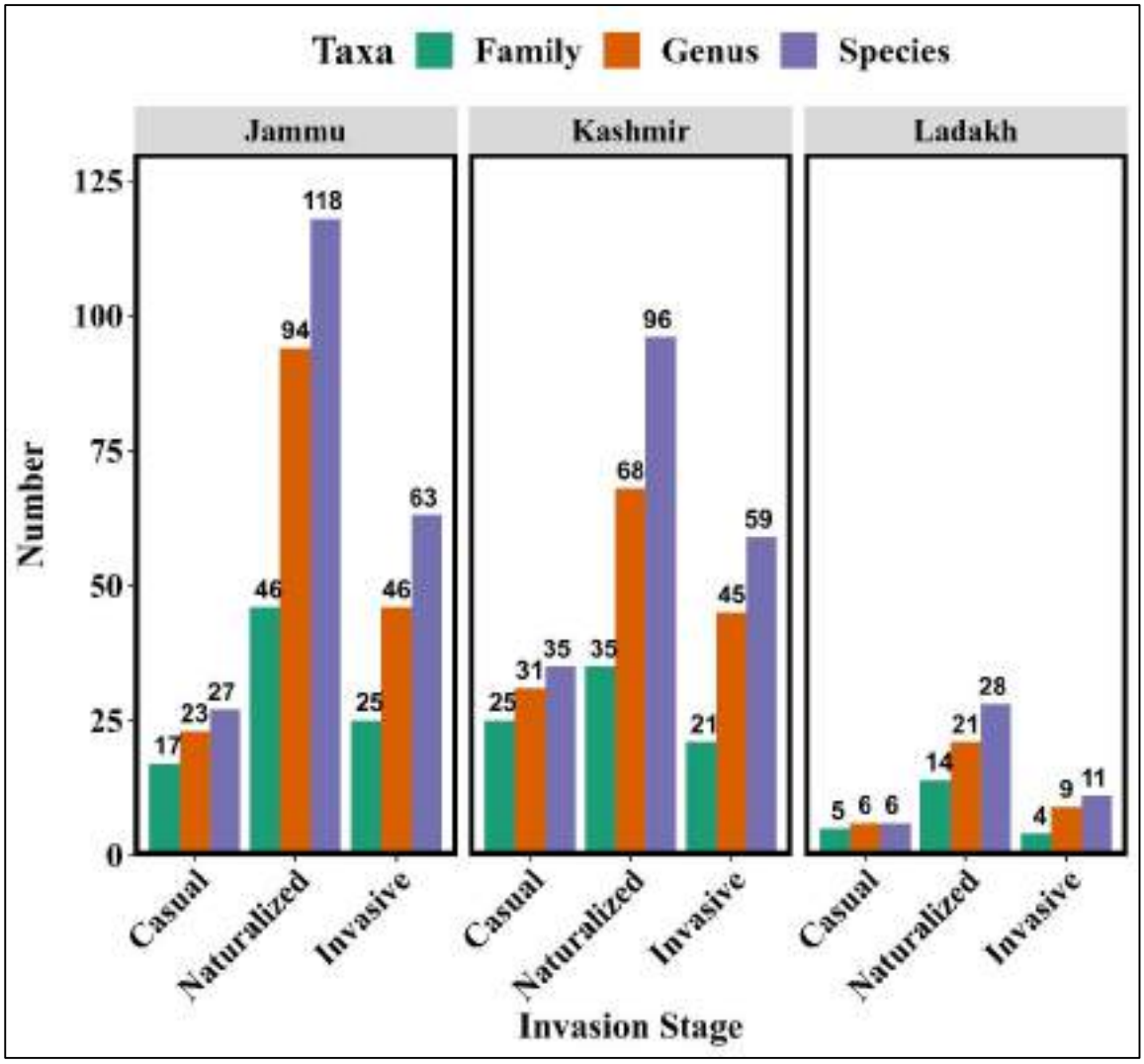


Fig. 7. Distribution of invasion categories under different taxonomic groups

As far as the number of species across different stages of invasion under various plant groups is concerned, it was observed that amongst 118 naturalized species, 110 species are dicots, 6 are monocots and 2 gymnosperms, similarly it was also observed that of the 63 invasive species, 58 are dicots and 5 are monocots, and among 27 casuals, 24 are dicots and 3 are monocots (Fig.8). Among the 118 naturalized species, 67 species are herbs followed by trees (24 spp.), climbers (5 spp.) and subshrubs (2 spp.). In the invasive category the herbs are predominant (55 spp.) followed by trees and climbers (3 spp. each) and subshrub (2 spp.). In casual category, 17 species are herbs followed by 5 shrubs, 3 tree and 1 species each of subshrub and climber (Fig. 9)

In the casual category, 15 species are perennials and 9 species annuals. Moreover, in the naturalized category of alien plant species, perennials are predominant with 67 species followed by 28 annuals and 4 biennials, and in the invasive category, 25 species are perennials, 21 species are annuals and 1 species is biennial (Fig.10). Out of 208 alien plant species, 127 species were introduced unintentionally, these species belong to 100 genera in 42 families followed by ornamental (46 species, belonging to 33 genera and 21

families), agriculture (20 species belonging to 16 genera and 12 families), forestry (10 species belonging to 9 genera and 6 families) and fodder (5 species belonging to 3 genera and 3 families) (Fig. 11).

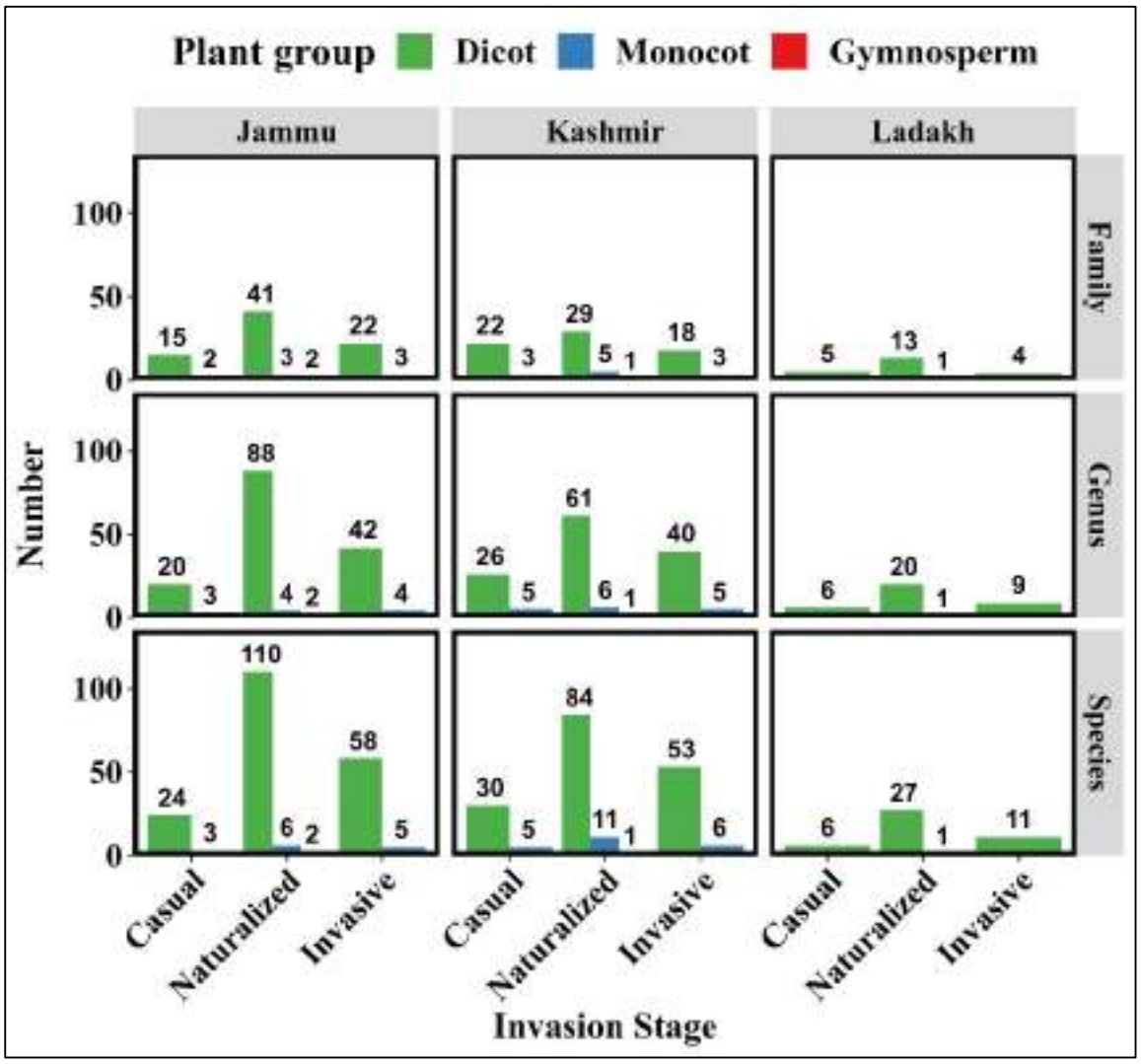


Fig.8. Invasion stages distributed under plant groups

There are a total of 279 alien plant species in Kashmir, of these 89 species are under cultivation and the remaining 190 species are aliens outside cultivation. These species belong to 131 genera in 49 families (Fig.6). The most dominant families include Asteraceae (24 spp.) followed by Amaranthaceae (17 spp.), Fabaceae (14 spp.), Brassicaceae (13 spp.), Plantaginaceae (8 spp.), Salicaceae, Iridaceae, Poaceae with 7 spp each, Lamiaceae and Rosaceae 6 spp each, which contribute ca.57% to the total recorded species. Of the outside cultivation alien species, casuals are 35 species belonging to 31 genera in 25 families, 59 species are invasive belonging to 45 genera in 21 families, and 96 species are naturalized belonging to 68 genera in 35 families (Fig.7). The number of invasion stages varies across different plant groups in Kashmir, our study revealed that out of 118 naturalized alien plant species, 110 are dicots, while monocots and gymnosperms make up only 6 and 2 species respectively. Similarly, out of the 63

invasive alien plant species, 58 are dicots, and only 5 are monocots. Among the 27 casual alien plant species, 24 are dicots, and the remaining 3 are monocots (Fig. 8).

Out of the 96 naturalized species, 64 species are herbs, followed by 17 species of trees, 11 species of shrubs, 3 species of climbers, and 1 species of subshrub. Among the invasive species, herbs are the most predominant with 55 species, followed by 2 tree species , and 1 species each of climbers, and subshrubs. In the casual category, herbs are the dominant group with 22 species, followed by 6 species of shrubs, 4 species of climbers, 2 species of trees, and 1 species of subshrub (Fig.9).

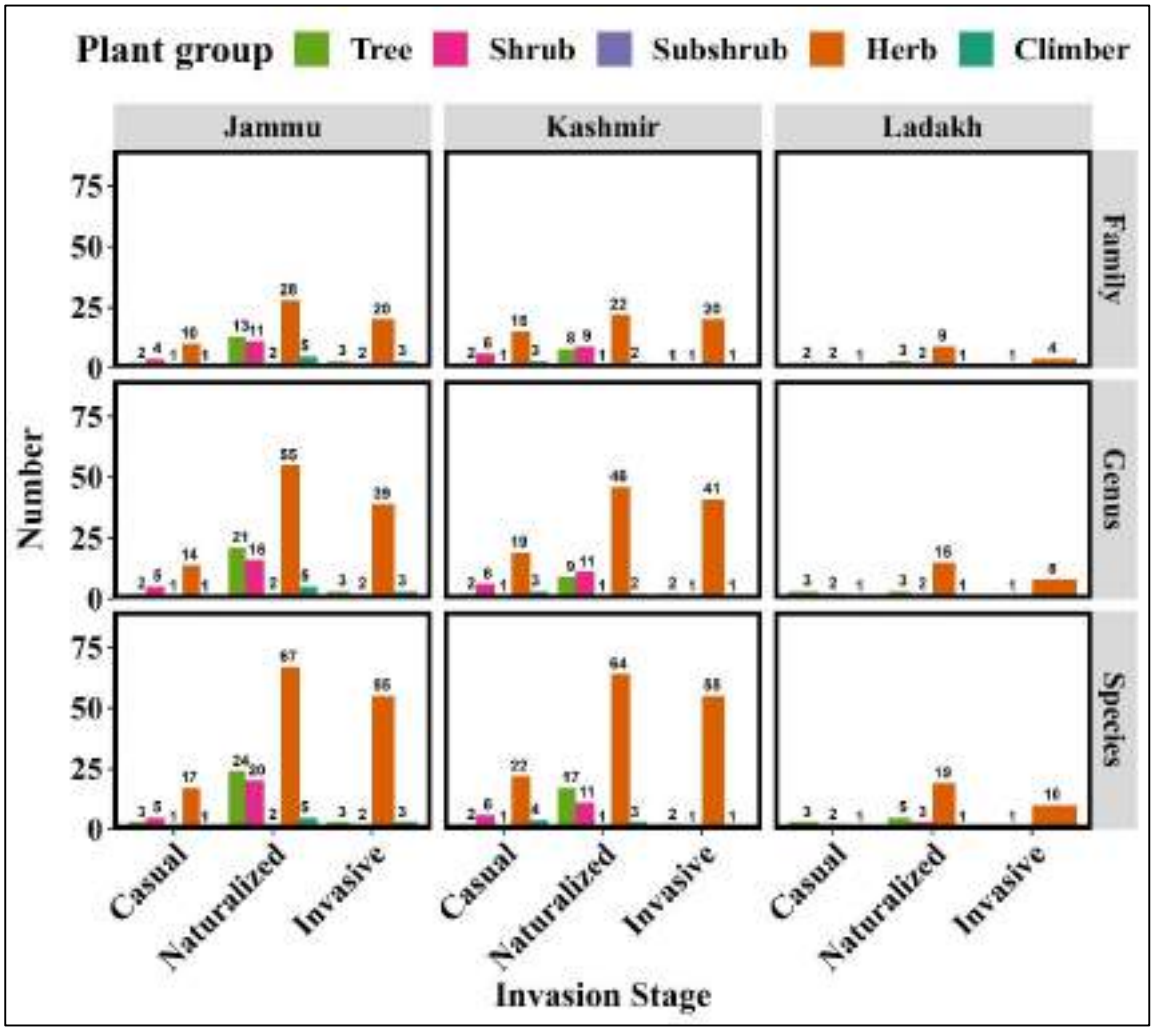


Fig. 9. Growth forms of the alien species in the alien flora according to invasion status (casual, naturalized and invasive).

Among the casual alien species, 26 species are perennial and 9 species are annual. In the naturalized category, perennials are the most common with 63 species, followed by annuals with 28 species and biennials 5 species. In the invasive category, 33 species are annual, 24 species are perennial, and 2 species are biennial (Fig.10). The study also revealed that there are several means of introduction and out of 190 alien plant species, 104 plant species have been introduced unintentionally that belong to 81 genera in 37 families followed by ornamental (46 species, belonging to 31 genera in 22 families),

agriculture (20 species belonging to 16 genera in 12 families), forestry (14 species belonging to 8 genera in 6 families) and fodder (6 species belonging to 4 genera in 3 families) (Fig.11).

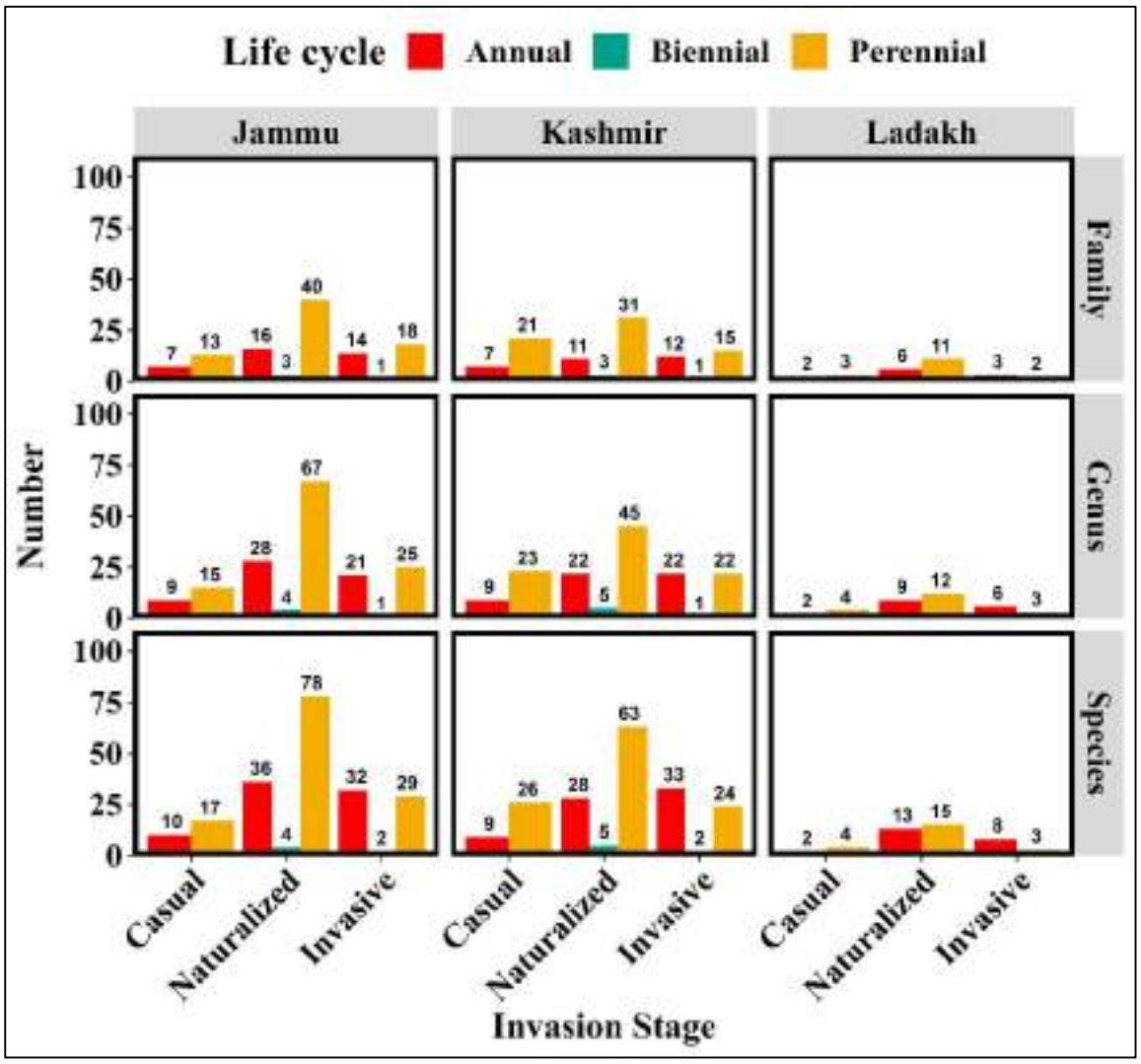


Fig. 10. Distribution of lifespan categories of under different stages of invasion

Out of the total 76 alien plant species recorded from Ladakh, 31 species are under cultivation and the remaining 45 species are outside cultivation. These 45 species belong to 33 genera in 18 families (Fig.6). The top 10 species-rich families include Amaranthaceae (10 spp.), followed by Asteraceae (9 spp.), Salicaceae (6 spp.), Fabaceae (3 spp.), Brassicaceae (7 spp.), Apiaceae, Rosaceae and Solanaceae (2 spp. each), Brassicaceae, Cannabaceae and Lamiaceae each with 1 species, which contribute ca. 82% to the total aliens outside cultivation. Of the total alien plant species outside of cultivation, 6 species are casuals belonging to 6 genera in 5 families, 28 are invasive belonging to 9 genera in 4 families, and 11 are naturalized belonging to 21 genera in14 families (Fig.7).The number of invasion stages varies across different plant groups in Ladakh, our study revealed that out of 28 naturalized alien plant species, 27 are dicots,

and 1 monocot. Similarly, out of the 11 invasive alien plant species, all are dicots. Among these 6 species are casual alien plant species, and all casual species are dicots (Fig. 8).

28 alien species are naturalized and amongst the naturalized species, 19 species are herbs, followed by 5 tree species, 3 shrubs, and 1 species of climber. Amongst 10 invasive species, herbs are the most predominant with 10 species, followed by tree (1 species). In the casual category, trees are the dominant with 3 species, followed by 2 species of herbs, and 1 species of climber (Fig. 9).

Within the casual category, 4 species are perennials and 2 species are annuals. In the naturalized category, perennials are the most common with 15 species, followed by 13 nnuals. In the invasive category, 8 species are annual, and 3 species are perennial. (Fig.10).

Out of the 45 alien species recorded, 21 seem to be introduced unintentionally and these species belong to 17 genera in 8 families. Agriculture has contributed to the introduction of 9 alien plant species belonging to 8 genera in 7 families. Forestry also contributed to the introduction of 8 species, belonging to 4 genera in 3 families. Fodder was responsible for the introduction of 5 species, belonging to 3 genera in 3 families, and 2 species were introduced for ornamental purposes, belonging to 2 genera in 2 families (Fig.11).

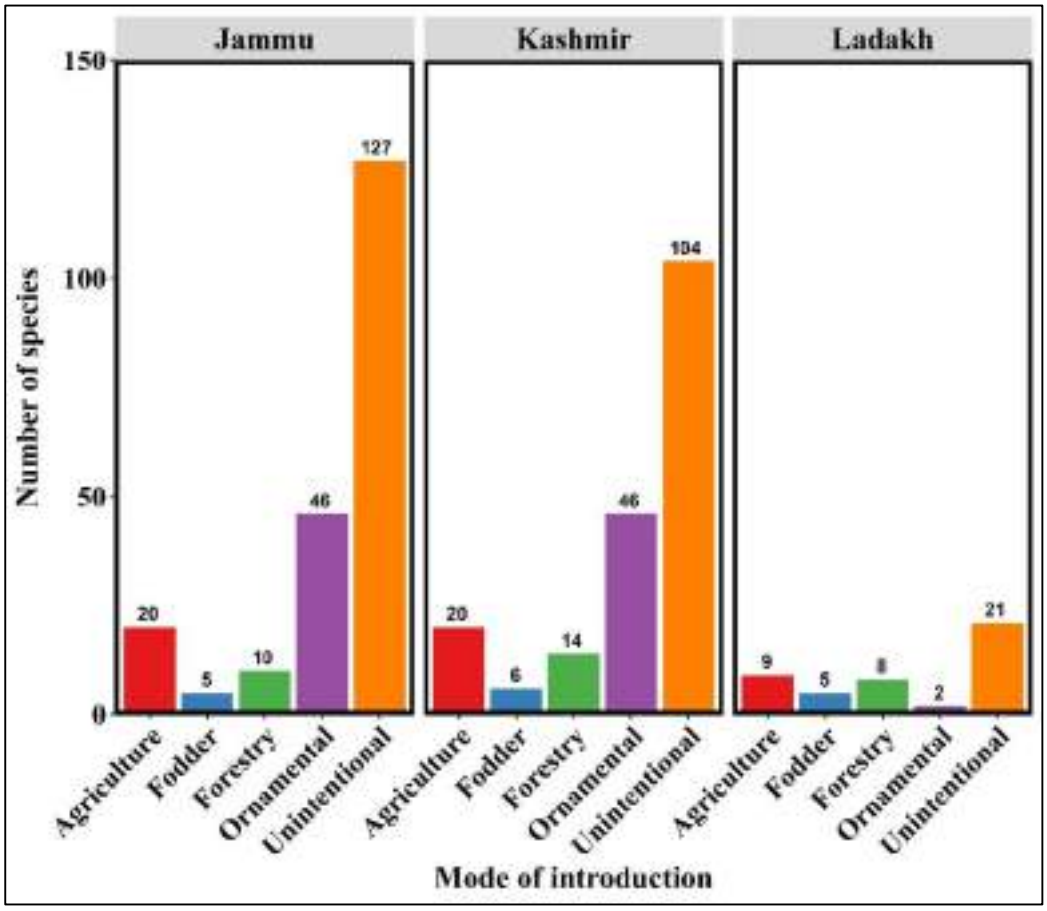


Fig. 11. Pathways of introduction of alien species under different taxonomic groups

Invasion load across different regions of study area

a. Jammu Region

The invasion load across various habitats depicts that wastelands harbour the highest number of alien plant species (34 spp.) followed by the scrubs and deciduous forests (32 spp. each), wheat (26 spp.) and paddy fields (23 spp.) (Fig.12).

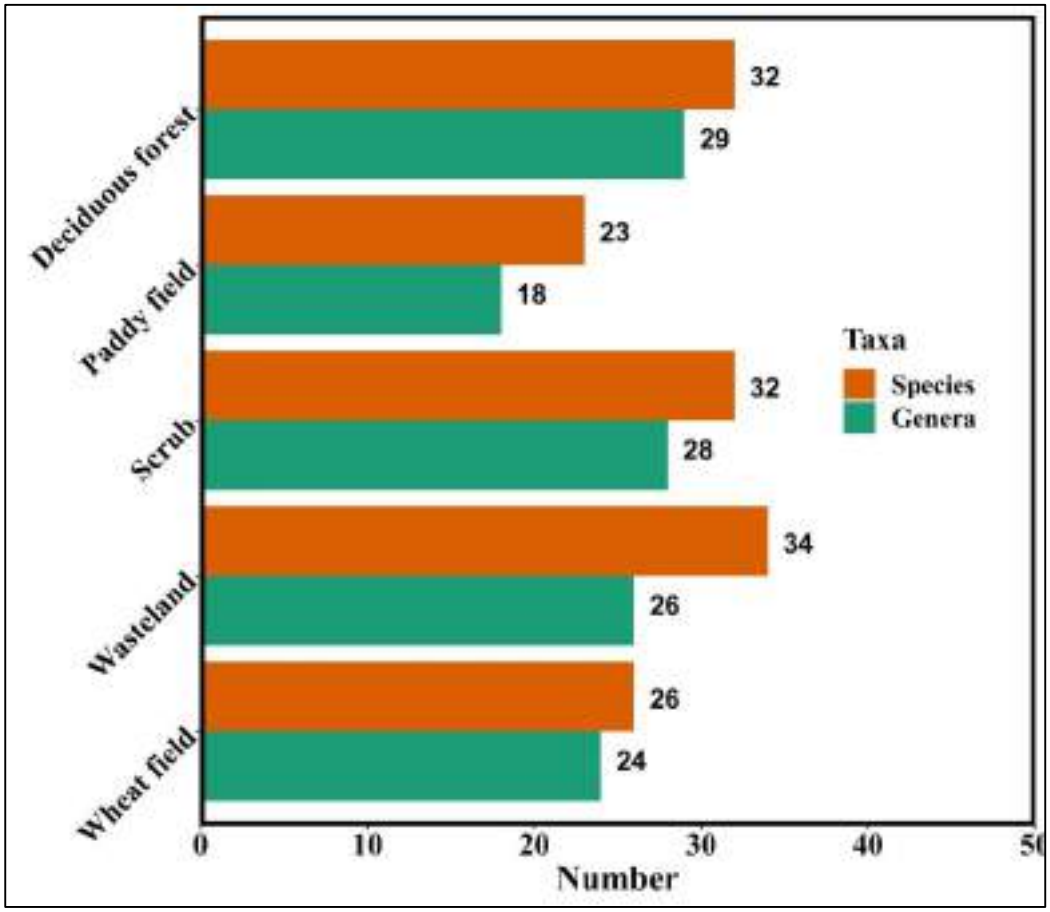


Fig.12. Number of alien taxa in various habitats in Jammu region

The habit-wise classification revealed that herbs form the dominant life form across the habitats. For instance, in wheat fields all the alien plant species were herbs (26 spp.). In deciduous forest and paddy field 23 alien species each were recorded while as the least number of aliens as herbs. was recorded in scrubs (10 species) (Fig. 13).

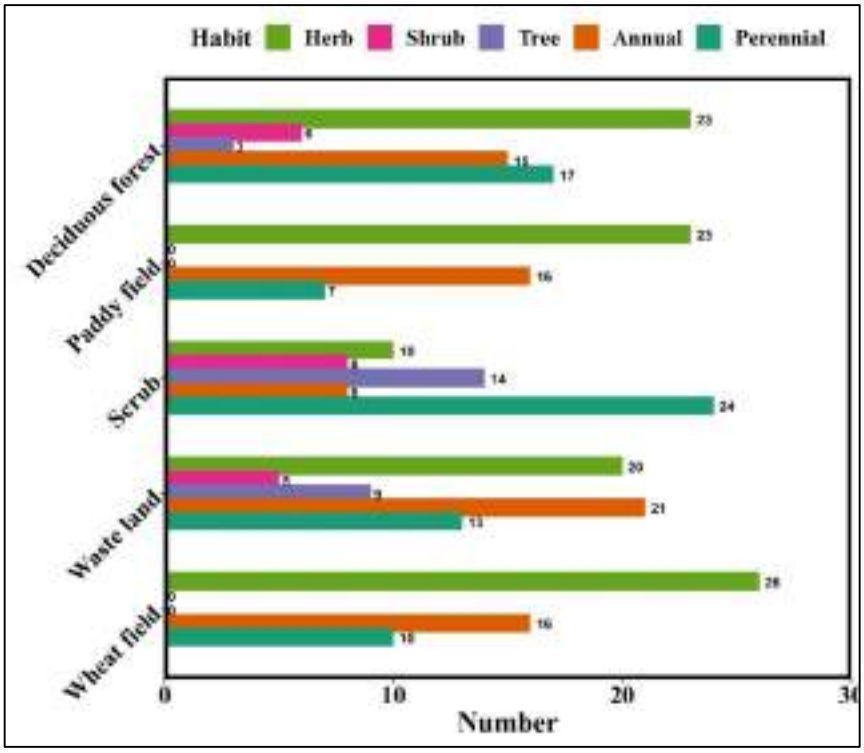


Fig. 13 Lifespan categories of alien plant species in different habitats of Jammu region

Our results also depicted the habitat-wise composition of alien species. Among the five surveyed habitats, the highest number of alien species was recorded in wastelands (34 spp.) followed by forest and scrub each with 32 spp., and wheat fields with 26 spp. However, the least number of alien species was recorded in paddy fields (23 spp), while the highest number of alien naturalized species was in wasteland and scrub with 16 and 14 species, respectively (Fig.14). The proportion of alien invasive in the alien flora of Jammu across various habitats is depicted in the Fig. 14**.** The most widespread invasive plant species are presented in Tables 7-9.

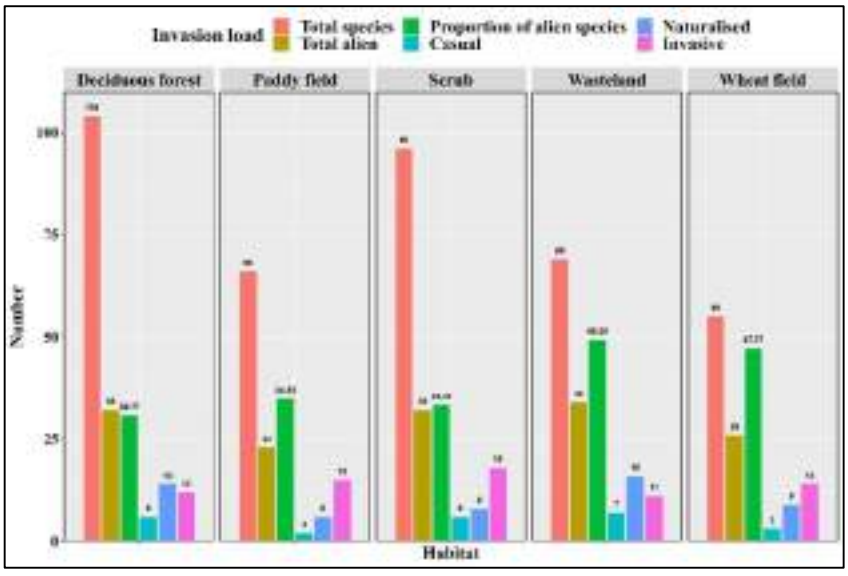


Fig. 14: Alien species load in different habitats in Jammu

b. Kashmir

Due to its topographical diversity, which ranges from the valley floor to terraced karewas, dense woods, and alpine meadows, the Kashmir harbours a rich floristic diversity. The valley floor is home to a variety of habitats, including grasslands, croplands, wastelands, orchards, wetlands, and spiritually significant protected lands. These habitats inhabit a wide variety of plant species, but they have been overrun by invasive plant species, thereby endangering biodiversity of these habitats.

The extent of alien species load across various habitats in Kashmir valley revealed that wastelands had the highest invasion load (44 spp.), followed by roadside habitats (42 spp.), grassland (37 spp.), orchards (31spp.), forests (27 spp.), rice field (26 spp.), and maize and mustard field each with 23 species (Fig.15).

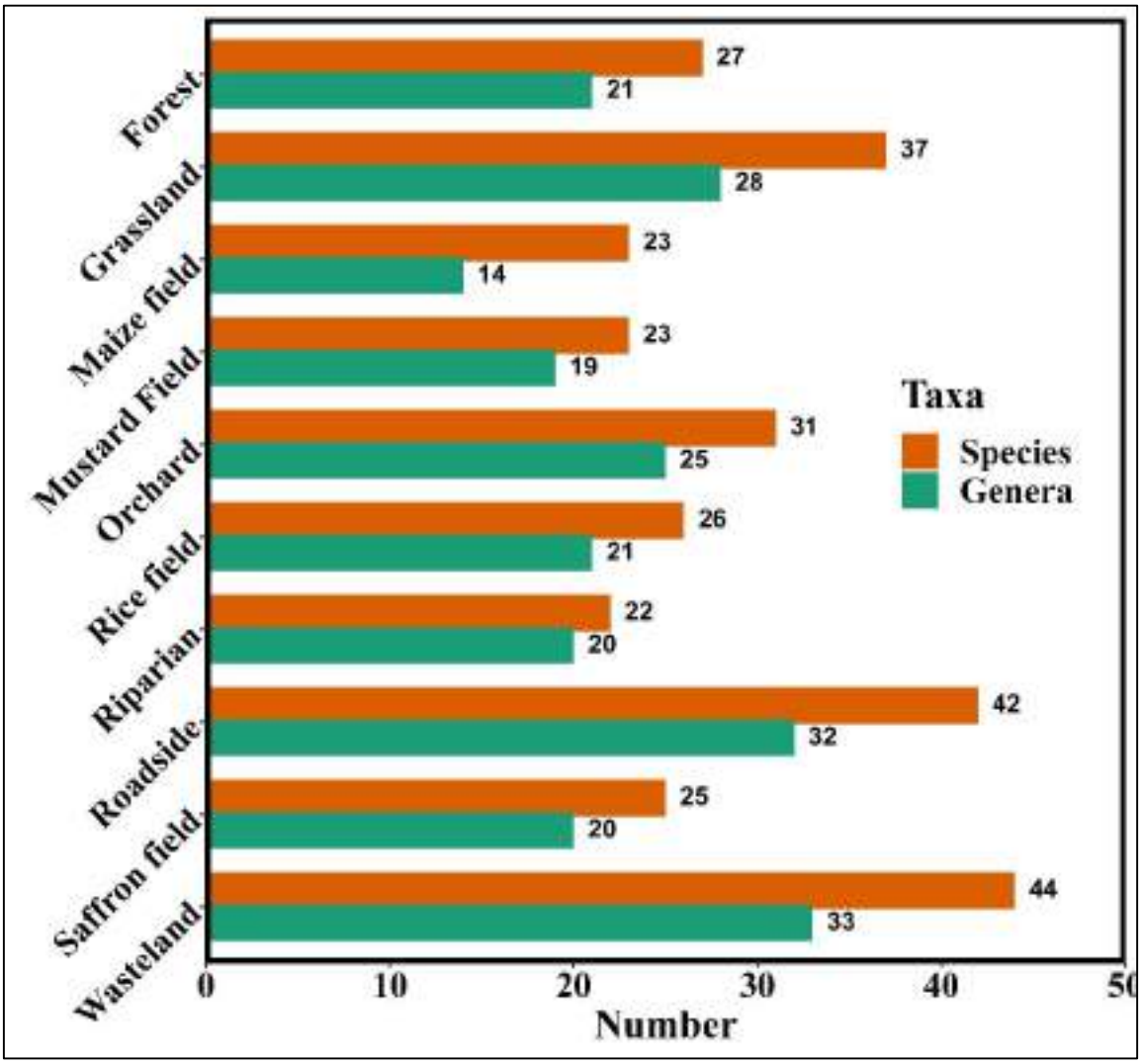


Fig. 15: Number of alien taxa in various habitats in Kashmir region.

Annuals are predominant in wasteland (28 spp.) followed by roadside (26 spp.) orchards (20 spp.), maize field (17 spp.), rice fields (15 spp.) and grasslands (14 spp.), while the riparian habitats had the least number of annuals (10 spp.). On the other hand,

perennials were more prevalent (20 spp.) in grasslands followed by roadside and forests (13 spp. each) and saffron fields (12 spp.) (Fig.10). The wasteland and roadside habitats are dominated by herbs (39 spp.), followed by orchards (29 spp.), grassland (28 spp.), rice and saffron fields (25 spp. each), and mustard and maize fields (22 spp. each) (Fig.16).

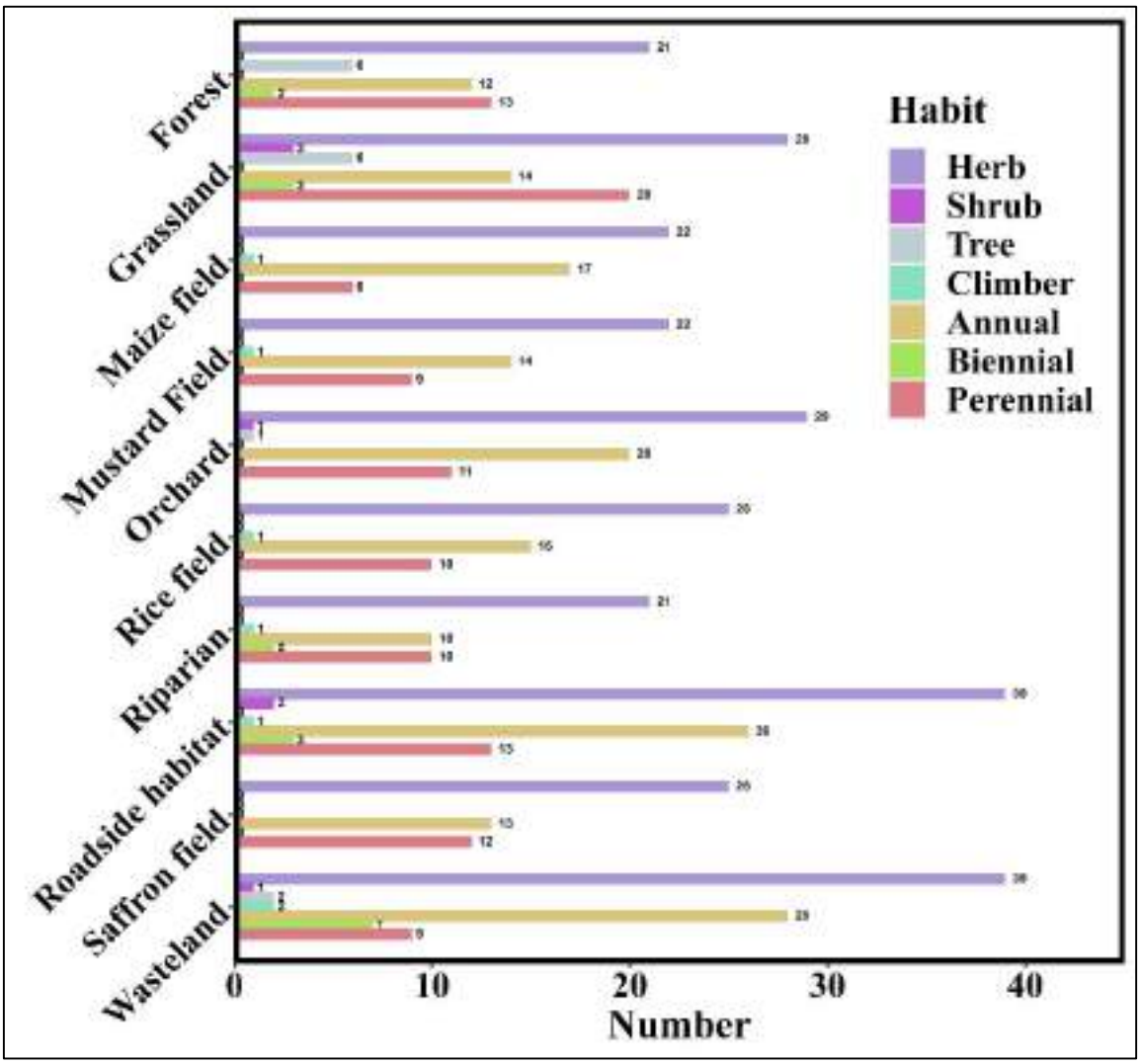


Fig. 16. Lifespan categories of alien plant species in different habitats of Kashmir region

Distribution of alien species based on habitats showed that the maximum number of species are found in the wastelands (44 spp.), followed by roadside habitats (42 spp.), grasslands (37 spp.), orchards (31 spp.) forests (27 spp.) and rice fields (26 spp.). While as the least number of alien plants were found in riparian habitat. As far as the number of invasive plants per habitat is concerned, roadside and wasteland has the highest number of invasive alien plants (19 spp. each), followed by orchards (17 spp.), rice fields (15 spp.), mustard fields (14 spp.), forests, grasslands, saffron and maize fields each with 12 species. while the riparian habitat has the least number of alien invasive plants (10 spp.) (Fig. 17).

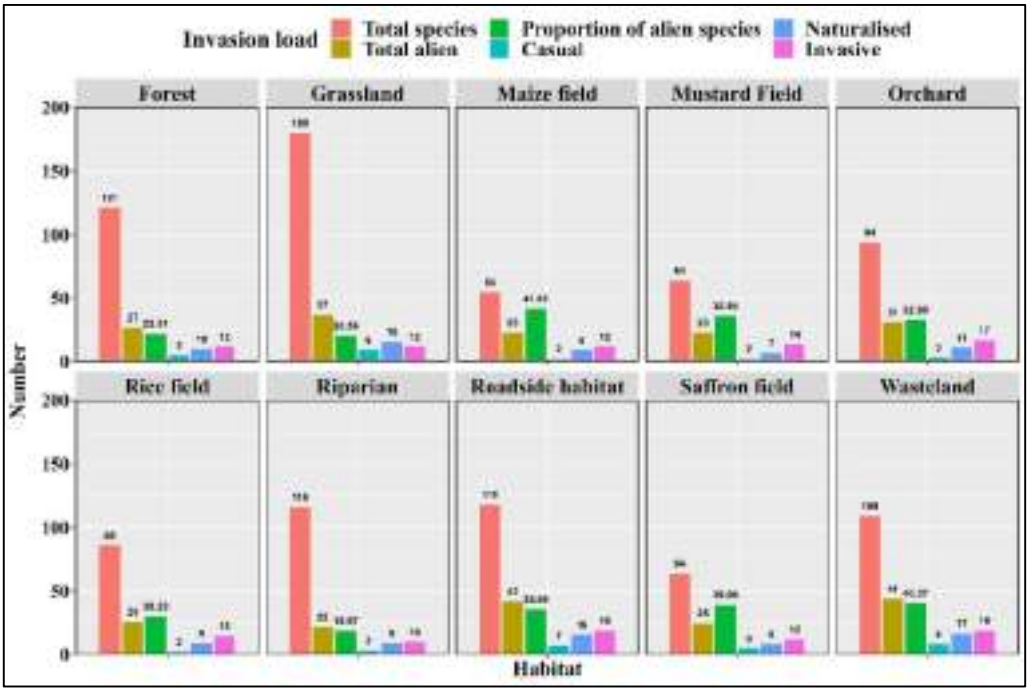


Fig. 17: Alien species load in different habitats in Kashmir

Invasion load across different habitats of Ladakh

The different types of habitats in Ladakh were surveyed for the documentation of alien plant species. Our study showed that the habitats with highest number of alien plants were arable lands (25 spp.), followed by wastelands (20 spp.), roadside habitats (15 spp.), wetland and riparian habitats (7 spp. each.), permanent river streams and creeks (6 spp.), inland cliffs (4 spp.) and sand dunes (2 spp.) (Fig.18).

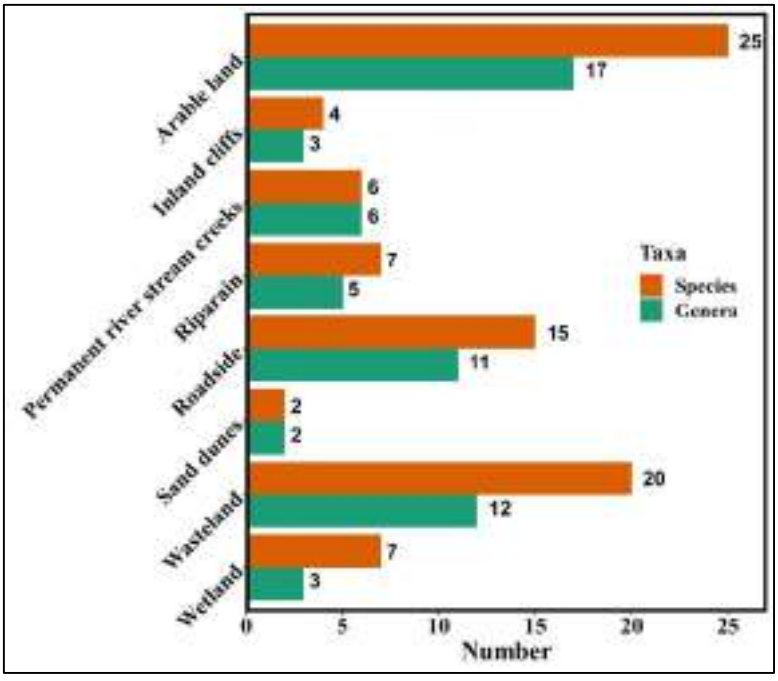


Fig. 18: Number of alien taxa in various habitats in Ladakh region.

In addition, the habitat that contains a high proportion of alien species are wasteland with 27.78%, followed by roadside, riparian habitats, sand dunes, The least number of alien species were observed in permanent river stream creeks. The wasteland and arable lands are the habitats with highest number of invasive alien plants (10 spp.each), followed by roadside (9 spp.), riparian habitats (3 spp.) and permanent river stream creeks (1 spp.). No invasive species, however, was recorded in inland cliffs. As far as the naturalized alien species are concerned, the arable lands are the habitats with the most number of naturalized.

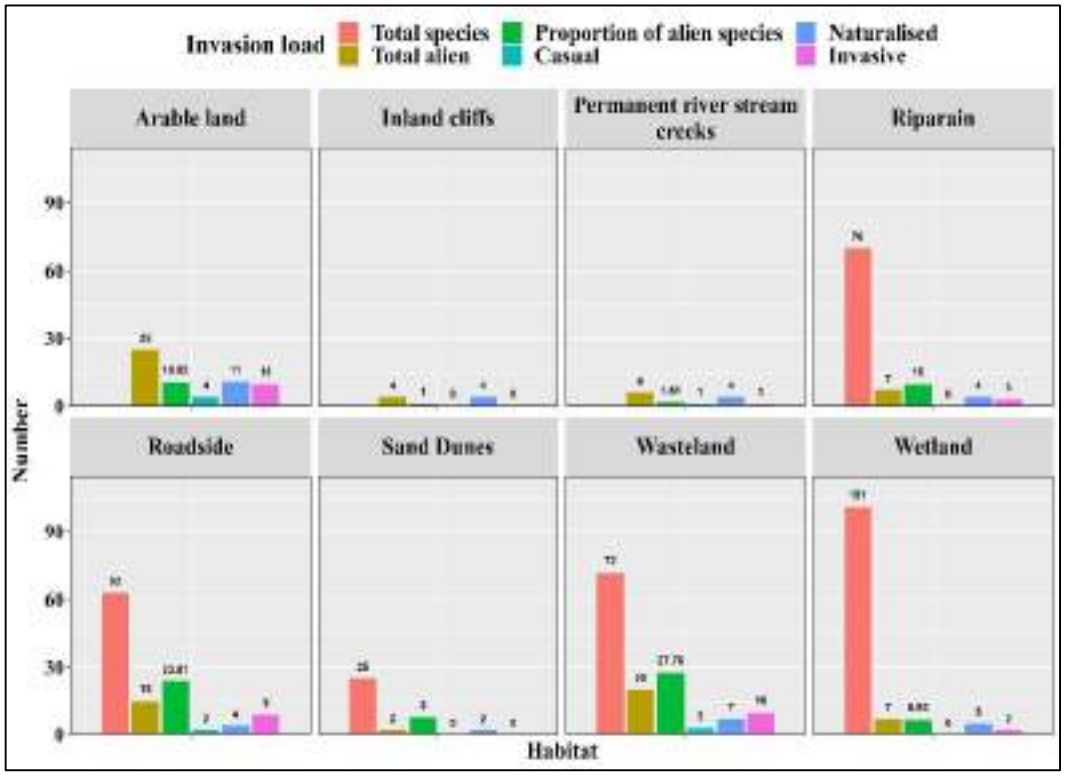


Fig. 19. Alien species load in different habitats in Ladakh Trans Himalaya

alien plants (11 spp.) followed by wasteland (7 spp.), wetlands (5 spp.), roadside, inland cliffs, permanent river creeks and riparian habitats (4 spp. each). Furthermore, 4 casual alien species were found in arable lands. Wastelands supported 3 casual species and roadside habitats had 2 casual species (Fig.19).

Annuals are the most common in arable land with 17 species, followed by wasteland with 13 species, roadside with 11 species, riparian and permanent river stream creeks with 2 species each. Conversely, in wasteland, perennials were more prevalent with 7 species, followed by wetland, riparian, and arable land with 5 species each, permanent river stream creeks and roadside with 4 species each, inland cliffs with 3 species, and sand dunes with 2 species. In terms of habit, arable land is mainly dominated by herbs with 23 species, followed by wasteland with 19 species, roadside with 12 species, wetland with 5 species, inland cliffs with 4 species, and riparian and permanent river stream creeks with 2 species each, as well as sand dunes with 2 species (Fig. 20).

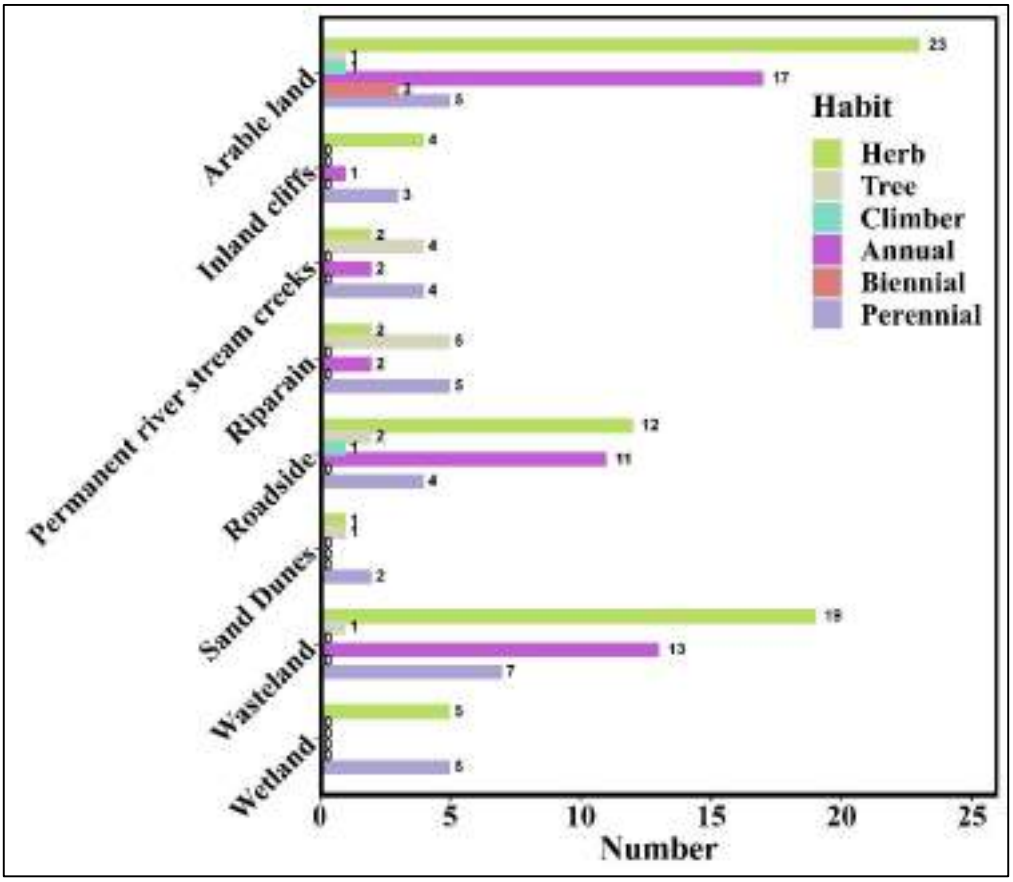


Fig. 20. Lifespan categories of alien plant species in different habitats of Ladakh region

Table 7: Ten most noxious invasive plants from Kashmir

Cannabis sativa L.	Invasive	Cannabaceae	Herb	Annual	Asia Temperate
Erigeron canadensis L.	Invasive	Asteraceae	Herb	Annual	Europe, Asia Temperate
Anthemis cotula L.	Invasive	Asteraceae	Herb	Annual	Europe, Asia Temperate, Africa
Matricaria discoidea DC	Invasive	Asteraceae	Herb	Annual	Northern America
Galinsoga parviflora Cav	Invasive	Asteraceae	Herb	Annual	Northern America
Datura stramonium L.	Invasive	Solanaceae	Herb	Annual	Northern America
Leucanthemum vulgare L.	Invasive	Asteraceae	Herb	Annual	Northern America
Nymphaea mexicana Zucc.	Invasive	Nymphaeaceae	Herb	Perennial	Northern America
Alternanthera caracasana Kunth	Invasive	Amaranthaceae	Herb	Perennial	Southern America, Northern America
Xanthium spinosum L.	Invasive	Solanaceae	Herb	Annual	Southern America, Northern America
Robinia pseudoacacia L.	Invasive	Fabaceae	Herb	Perennial	Northern America

Table 8: Ten most widespread invasive plants in Jammu region

Ageratum houstonianum Mill.	Asteraceae	Herb	Annual	Invasive	Northern America
Argemone mexicana L.	Papaveraceae	Herb	Annual	Invasive	Northern America
Ageratum conyzoides (L.) L.	Asteraceae	Herb	Annual	Invasive	Northern America
Parthenium hysterophorus L.	Asteraceae	Herb	Annual	Invasive	Northern America
Hyptis suaveolens (L.) Poit.	Lamiaceae	Herb	Annual	Invasive	Southern America

Sagittaria sagittifolia L.	Alismataceae	Herb	Annual	Invasive	Europe
Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae	Herb	Perennial	Invasive	Northern America, Southern America
Eichhornia crassipes (Mart.) Solms	Pontederiaceae	Herb	Perennial	Invasive	Southern America
Leucaena leucocephala (Lam.) de Wit	Fabaceae	Tree	Perennial	Invasive	Northern America
Lantana camara L.	Verbenaceae	Shrub	Perennial	Invasive	Northern America

Table 9: Most widespread invasive plant species in Ladakh Trans-Himalaya

Taraxacum officinale F.H.Wigg.	Invasive	Asteraceae	Herb	Perennial	Europe
Amaranthus caudatus L.	Invasive	Amaranthaceae	Herb	Annual	Europe
Medicago sativa L.	Invasive	Fabaceae	Herb	Perennial	Northern America
Dysphania ambrosioides (L.) Mosyakin & Clemants	Invasive	Amaranthaceae	Herb	Annual	Northern America
Matricaria discoidea DC	Invasive	Asteraceae	Herb	Annual	Northern America
Galinsoga parviflora Cav	Invasive	Asteraceae	Herb	Annual	Northern America
Datura stramonium L.	Invasive	Solanaceae	Herb	Annual	Northern America
Amaranthus hybridus L.	Invasive	Amaranthaceae	Herb	Annual	Northern America

B: Biology of worst invasive/widespread species to identify the traits that promotes their invasiveness

Effective management of invasive plant species requires knowledge of the traits, particularly related to reproductive biology, life history, seasonal growth patterns. Thus, the study of reproductive biology is crucial in management programmes of invasive plant species. It is in this context the reproductive biology of some of the invasive plant species of Jammu, Kashmir and Ladakh was studied and brief details about each of the studied plant species are given below.

1. *Lepyrodiclis holosteoides* (C.A. Mey.) Fenzl ex Fisch. & C.A. Mey.

Habitat: The plant species is a prolific weed species, highly obnoxious growing in arable lands (Wheat fields, Buckwheat fields, Kitchen gardens, Barley fields, Vegetable crop fields) wasteland and roadside habitats in Ladakh. This widespread plant species reportedly reduces about half the production in these crop fields (Fig.21A)

Floral morphology: The plant produces a large number of white colored flowers (Fig.-21B). Inflorescence panicle of cyme, flowers axillary or terminal and bracteate. Flower is pedicellate, actinomorphic; sepals 5, green in colour, lanceolate, distinct, margins scarious, apex acute, about 4-5 mm long; petals 5, free, white (25 C), obovate-spathulate, margin lacerate or retuse, apex entire or emarginate, 5-7 mm long; stamens 7-10, on a nectariferous or glandular annular disc at the base of ovary, filaments distinct, anthers 2-locular, nectarines present.; gynoecium unilocular; stigma 2; style 2, creamish in colour, filiform; ovary superior with large ovules, ovules 4 per ovary; fruit capsule, ovoid-globose, 2-3 mm across, dehiscing by 2 straight valves, Seeds red-brown in colour, calyx persistent shorter the fruit, carpophores present; seeds 1-2, reniform, about 1.8-3 mm across, compressed laterally, dark brown to yellowish in colour, papillate and with thick tuberculae. During the floral development different structural changes take place in essential organs of the flower. At floral bud stage (unopened flower) the two styles along with stigma are close to each other at 10-15º with respect to main axis of ovary and then at anthesis the two styles and stigma move separat apart about 75-85º with respect to main axis of the ovary (Fig. 21.)

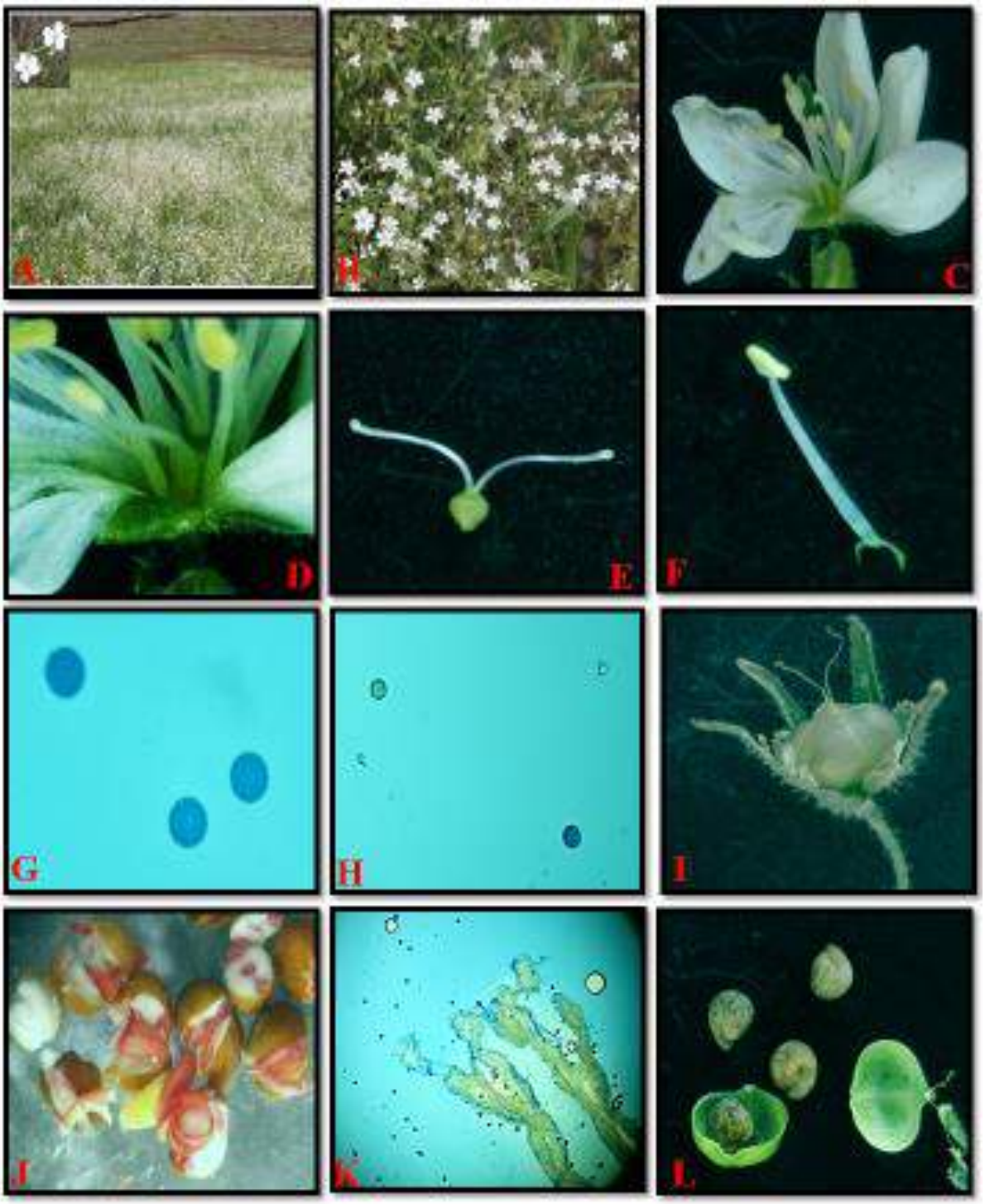


Fig.21. (A) Population, (B) Habit, (C) Flower, (D) Flower with nectary (E) Carpel with bifid stigma, (f) Stamen (h) (G,H) Viable and non-viable pollen, (I) dissected ovary with 4 ovules, (J) Viable seeds showing red embryos in TTZ, (K) Stigma with pollen load and germinating pollen, (L) Seeds

Pollen morphology: The pollen grains are yellow in color, large and spherical, with reticulate ornamentation.

Stigma receptivity: The flowers of the species have more or less capitate stigmas with well-developed papillae. The two styles and stigmas remain close to one another before

anthesis and after anthesis when anther dehiscence; the stigmas start to move apart and also away from dehiscing anthers. The stigmas become receptive when the two styles and stigma are away from each other, one branch at an angle of 85-75º and another branch at an angle 265- 270º with respect to the main axis. The stigmas become receptive one day after anthesis and receptivity lasts up to 2-3 days. The number of deposited pollen grains as well as the percentage of germinated pollen is highest on 2rd day after anthesis. Hereafter, the receptivity of stigmas gradually decreases and is completely lost on the 4th day after anthesis and stigma dries up and loses the shine which marks the end of receptivity. As the female phase proceeds male phase, it indicates protoandrous nature of the species. The proandrous nature of the species points towards the cross pollinated nature of the species. However, out of 8-10 anthers 2-3 anthers start dehisce when stigma of the same flower becomes receptive, the delayed anther dehiscence in some stamens indicates self-pollination is also operative in the species.

Pollen count, pollen viability and P/O ratio: The species produce pollen grains which range between 16,000 – 17,000 pollen grains per flower. The pollen viability is estimated to be 90-99 %. The species produces 4 ovules per flower. The pollen/ ovule ratio for the species turned out to be 4250 pollen grains per ovule

Pollination mechanism: *L. holosteoides* produces a large number of flowers (150-200) per plant. The flowers of the same plant or different plants are at various stages of development viz; male phase, female phase and fruiting stage and continue to advance from one phase to the other for about one month. The flowers are colored and have disc shaped nectar at the base of the ovary which attracts the pollinators from a distance. The flowers of the same plant or different plants in a population behave functionally as male or female at particular period of time, the insect visitors visit the flower in search of nectar which is present at the base of ovary, the trichomes present on floral parts near ovary takes some time of the insect in getting the nectar. In doing so the pollinator gets heavily loaded with pollen which ensures transfer of pollen from one flower to another of the same plant or different plants in a population. The anthers and stigmas of the same flower are separated spatially and developmental of essential organs are temporally separate which facilitate cross pollination but sometimes the delayed development of anthers of same flower helps to overcome this barrier and self-pollination takes place. The species also exhibit moderate P/O ratio, styler and stigmatic movement and continuous development of anthers in a flower in otherwise protoandrous nature of the species depicts that cross pollination is primary mode and self-pollination is secondary in nature.

Seed output: The seeds start to produce in the capsules from August-September. The species on an average produces 180 ± 25.03 berries and 720 ± 80.04 seeds per plant. After dispersal, the seeds remain dormant for 6-7 months and most (98%) of the seeds germinate after return of favorable environmental conditions mostly in the month of June. All the germinated seeds give rise to new seedlings and each plant gives rise to flowers and seeds (Fig. 25L). Therefore, a single seed has the potential of producing 700-1000 new plants in one season and in the second season 50,000 to 70,000 plants. De-weeding before flowering particularly at the time of vegetative phase can prove helpful in the management of the noxious plant species.

2. *Hyptis suaveolens* (L.) Poit.

Hyptis suaveolens is an aromatic, erect annual herb branched, entirely covered with a red or gray pubescence. The plant species is entirely pubescent, 4-angle stem marked with strong furrows, about 2.5 cm thick, branched, pubiscent, hairs white, glandular; leaves simple, opposite, oval; inflorescence axillary, loose group of small blue flowers; fruit is a nutlet black.

Distribution

This species is native to Neotropics, from Central America and the West Indies south to about the tropic of Capricorn. It has been introduced to the tropics and subtropics of the world (including some Pacific Islands), where it has become widely naturalized. The species has been introduced in Asian countries as well (Fig. 22).

Fig. 22: Map showing global distribution of *Hyptis suaveolens* (L.) Poit. (Source: POWO)

Plant and floral morphology

Hyptis suaveolens (L.) Poit. has a rough and stout aromatic stem that reaches a height averaging 63.4 ± 5.51 (30-110) cm. In most of the cases individuals become highly branched with the number of branches reaching up to 30 per plant. Leaves are arranged in opposite decussate manner; these are ovate at the base and velvety on both the sides. Majority of the plants in a population enter into flowering phase during the month of April and May, when the temperature in the study area fluctuates between 18.14ºC to 35ºC. Flowering is vigorous during September and October; thereafter it declines but continues up to the last week of January, at a time when the temperature in the area dips to a minimum of 4.8ºC. The species thus flowers both during summers and winters. Summer and winter phases of flowering vary in their intensity and details, these differences are highlighted hereafter.

Flowers are aggregated in clusters of 2 – 6 in the axils of leaves. Number of clusters per branch is high and averages 54.4 ± 8.9 (10 – 113) in summers. During winters, the same lowers down to 18.2 ± 2.4. Each flower is sessile, small, zygomorphic, bisexual, purplish in colour and tubular in appearance with average length varying between 0.50 – 0.95 mm (Table 10). Sepals are five in number; these are fused to form green tubular structure, each being topped with short bristles that turn brown in colour after the corolla is shed. The flower is bilabiate. The upper lip is divided into two lobes having dark purple nectary guides, and the lower lip is divided into three lobes with the central carinal lobe enclosing four epipetalous, didynamous stamens. Ovary is syncarpous, bicarpellary and tetralocular and each locule carries one ovule. A fleshy nectary disc is present at the base of the ovary, however; the amount of nectar secreted is very less. Fig. 23

Fig 23. A & B Flower of *Hyptis suaveolens* (L.) Poit.

Table 10: Data on floral morphology of *Hyptis suaveolens* (L.) Poit.

S. No.	Characters (n=15)	Value
1.	Length of flower (cm)	0.76* ± 0.02 (0.50-0.95)**
2.	Length of sepal(mm)	3.47 ± 0.21 (2-5)
3.	Length of petal (mm)	6.56 ± 0.27 (5-8)
4.	Length of bristles (mm)	2.4 ± 0.10 (2.0-3.0)
5.	Length of lower stamens (mm)	2.94 ± 0.08 (2.5-3.5)
6.	Length of upper stamens (mm)	1.93 ± 0.10 (1.5-3.0)
7.	Length of anther (µm)	672.6 ± 14.10 (619.4-815)
8.	Width of anther (µm)	991.04 ± 7.49 (945.11-1026.9)
9.	Ovary size (µm)	1155.14± 7.09 (1122.5-1173.6)
10.	Length of style (mm)	5.4 ± 0.070 (5.0-5.6)
11.	Length of stigma (µm)	264.06 ± 7.02 (195.6-293.4)

Mean * ±Standard Error; Range **

Floral Biology: Flowers of a single cluster do not open together, they do so in two days with 2 -3 flowers of the cluster opening on day 1, while the rest open on the next day. Anthesis initiates around 8.00 a.m. in the morning and continues till 2:30 p.m. with its peak around 11:00 a.m. – 1:30 p.m. during summers (Table 11). In winters, anthesis occur only during afternoon hours (1230 hrs to 1400 hrs). Size of the flower at the time

of anthesis averages 5 mm. Anthesis of the flower is characterized by the opening of upper two lobes followed by the lower lip whose carinal lobe remains closed. It remains in this condition if undisturbed, carinal lobe expands on disturbance. Disturbance causes the carinal lobe to flip back and release the pollen toward the upper lip in an explosive manner. In the absence of disturbance, carinal lobe remains closed enclosing within it the dehisced anthers and the stigma. Corolla along with this closed carinal lobe in such flowers is shed after 9 – 10 hr of anthesis normally on the day of flower opening itself during summer. In winter this time extends up to 6 days. The percentage of flowers that open their carinal lobe averages 85%. The tubular calyx remains as such on plants even when corolla is shed; it turns brown in color on maturity. By the end of the blooming period, the whole plant dries up and sometimes falls. During the months of April and May, new leaves and flowers are produced on these persistent plants. The time period between pollination and fruit formation in summers is 4 -5 days, during winters (Nov. – Jan.) this time period extends up to 10 -12 days. Fig. 24.

Fig. 24. Stamen and its developmental stages

Anther dehiscence and stigma receptivity

The flowers are weakly protandrous with anther dehiscence taking place approximately 3.00 hrs before anthesis when the size of bud is around 5.00 mm. In winter months (Nov. – Jan.)↑, anther dehiscence is postponed, it occurs on the second day of flower opening when the size of flower has approached 8.00 mm. Also, 1-2 anthers in most of the flowers shrink during the winters. During summer flushes, the stigma attains maximum receptivity around 2.00 p.m. on the day of flower opening, when the flower attains maximum size (app. 8.5 mm), at this time the stigma shows an average pollen load of 102.5± 14.57 (94 – 198). In winter months, the stigma attains maximum receptivity on the third day of flower opening at about 1.00 p.m. when the size of the flower is 8.5 mm. Stigma shows an average pollen load of 48.1± 11.2 (nil – 139) at this time

Pollen output and stain ability

The pollen production per anther averages 301± 8.56 (241 – 350) during summer months. In winter, it decreases and averages 127.53±9.23 (66–189). The number of ovules in all flowers is invariably 4, so the pollen ovule ratio has an average value of 301.1:1 in summers. The pollen stainability in 1% acetocarmine is high in summers with an average of 87.51%, it is low in winters and averages 51.48%. (Fig.25)

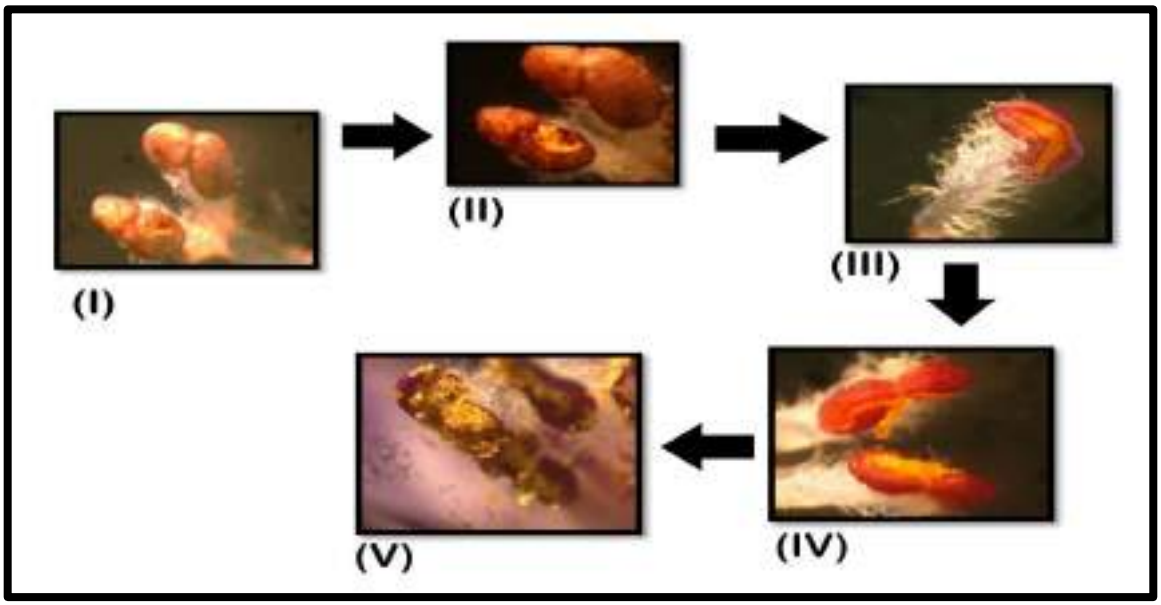


Fig. 25: Different stages of pollen grain development.

Table 11: Phonological events of *Hyptis suaveolens*

S. No.	Event	Month/Time
1.	Appearance of new leaves on old plants	April/May
2.	Seed germination and seedling establishment	April
3.	Initiation of flowering on old plants	April/May
4.	Initiation of flowering on new plants	July
5.	Anther dehiscence a) Summer flowers b) Winter flowers	a) 3:00 hrs before anthesis b) On second day of anthesis
6.	Stigma receptivity a) Summer flowers b) Winter flowers	a) Around 2:00 p.m. after anthesis on 1st day b) Around 1:00 p.m. on the 3rd day of anthesis
7.	Corolla drop a) Summer flowers b) Winter flowers	a) On the same day of flower opening b) On the 4-5th day of flower opening
8.	Fruit maturity a) Summer flowers b) Winter flowers	a) 4-5 days b) 10-15 days

Pollination studies

i) **Insect visitation**

Flowers of *Hyptis suaveolens* are visited by *Apis* sp. and moths mainly during summer bloom. Of these, the frequency of visitation by *Apis* sp. is high. The flies visit the flowers for 5 – 6 sec., while the moth spends around 40 – 70 sec. on each flower. Peak visitation of these insects is directly proportional to peak time of flowering, i.e., 11:30 a.m. to 1: 30 p.m. in summers (August – October). In winters, insect visits become extremely rare and restricted to afternoon hours only. All the collected insects interestingly showed no pollen load on their body irrespective of frequent visits and examinations.

ii) **Open Pollination:**

Mature and unopened flowers were tagged and left undisturbed to record fruit and seed set. The results revealed 100% fruit set in summer months (April – Oct.). In winters (Nov. to Jan.), the average fruit set was 92.69 % (Table 12). Seed set in all fruits was, however; low and on an average it was estimated to be 42.25 % during summers. In winters, it declined further and averaged 33.7%.

iii**)** **Bagging:**

In summers, fruit set on an average was 94.4% while in winters, it was 90.23%. Seed set was low and average seed set was 35.2% during summers, in winters it averaged 32.4%.

Table 12: Fruit and seed set in *Hyptis suaveolens*

S.No.	Treatment (n= 15)	%Fruit Set	
	On open pollination		
(i)	**Summer**	**100**	**42.2**
(ii)	**Winter**	**92.6**	**33.7**
	On Bagging		
(i)	**Summer**	**94.4**	**35.2**
(ii)	**Winter**	**90.2**	**32.4**

Autogamy in flowering plants is considered a derived condition, the evolution of which has been debated time and again by several evolutionary biologists world over. Comparison of related species and genera has led to the enlisting of benefits as well as disadvantages associated with shift from outcrossing to the selfing mode. Present study is an addition to this paradigm and how selfing in *Hyptis suaveolens* promotes its successful invasion and survival in Jammu is of interest. This species is reported to practice a mixed mating system i.e. combination of both autogamy and allogamy. In sub-tropical climates of Jammu, this species behaves as autogamous taxa. Fruit set on open pollination both during summers and winters exceeds 90%. On bagging, the percentage fruit set is again high. The occurrence of high fruit set on bagging in this

species is completely in sync with that observed on open pollination and indicates autoselfing in this species (Fig.26).

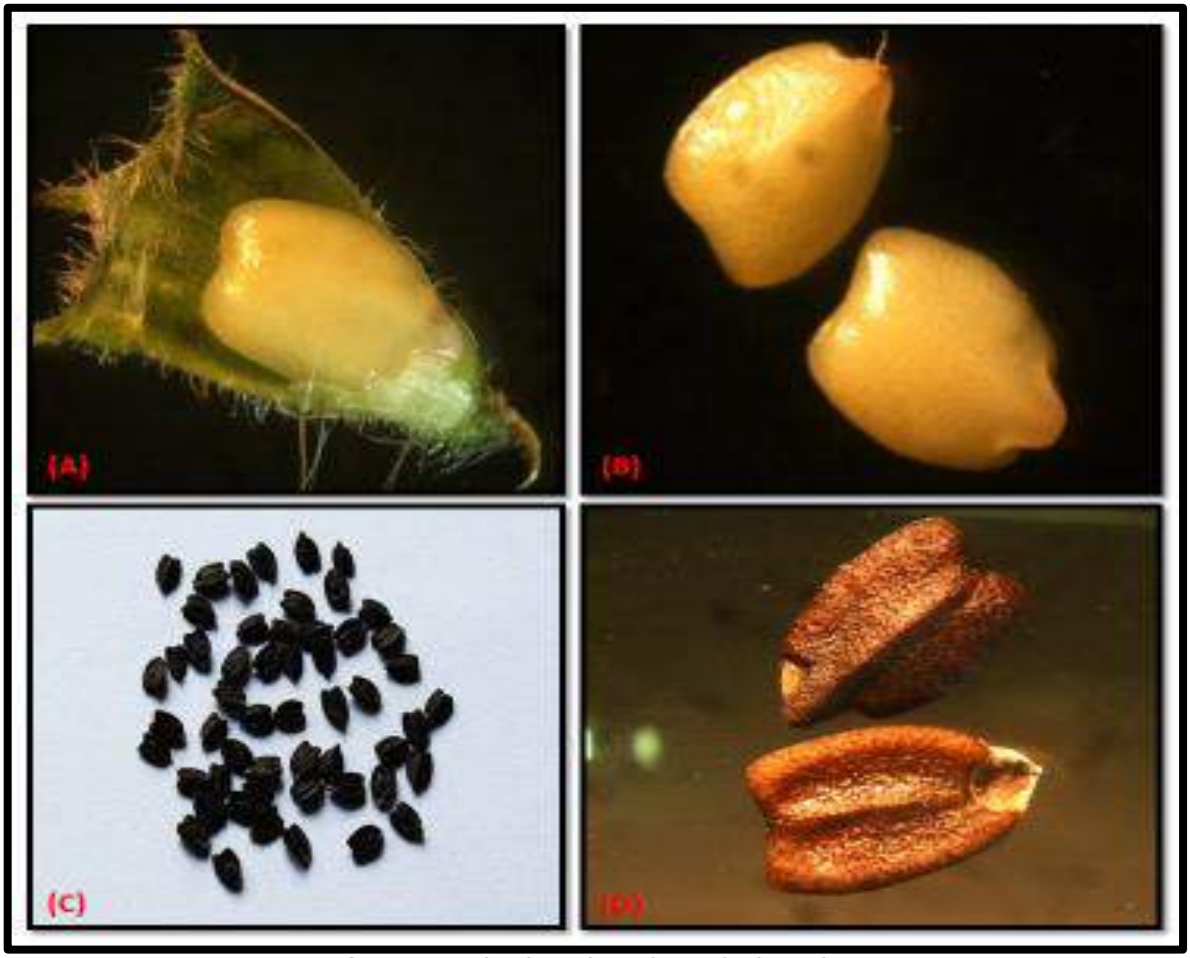


Fig. 26. Fruits (A&B) and seeds (C&D)

Several features noted during the present study make *Hyptis suaveolens* an interesting species from the perspective of reproductive biology in new areas i.e. Jammu:

1. There is significant difference in floral phenology events, pollen ovule ratio, pollen viability as well as frequency of insect visitations during summers and winters, yet the fruit set remains the same.
2. No role of insect visitors in pollination.
3.

Reduced seed set and prevalence of ovule abortion

While character 1 and 2 signify evolution of autogamy in this species, character 3 does not go well with the autogamous nature of the species. Reduced seed set and ovule abortion indicate inbreeding depression (Mahy and Jacqeumark, 1999). Occurrence of the same in this species behaving as an autogamus taxa indicates that autoagamy in *Hyptis suaveolens* growing at Jammu is probably derived, it is an adaptive feature that has helped this species to survive and spread in an area which otherwise could have proved unsuitable for its survival.

4. *Anthemis cotula* L.

The "stinking chamomile, *Anthemis cotula* L., is named for its resemblance to the true chamomile plant, *Anthemis nobilis* both have branching upright stems each topped by a single large flower head, but the "stinking chamomile" is distinguished by its lack of membranous scales beneath the flowers, as well as its characteristic strong odour. Leaves of *Anthemis cotula* resemble those of fennel (*Foeniculum vulgare*), hence the name "Dog's Fennel".

Habitat: The plant species grow widely in almost all types of habitats in Kashmir valley which include rural gardens, arable lands, waste lands, along road side (Fig 33) kitchen gardens, railway tracks, abandoned lands etc. Our studies revealed that it synchronizes its germination with favorable habitat and environmental conditions and recruits individuals both before winter (pre-winter cohort) and also after winter (post-winter cohort). The individuals of the pre-winter cohort survive as rosettes during winter and then flower with the onset of favorable conditions in spring-summer. Their reproductive output is very high and are mainly responsible for the spread of this species in Kashmir Himalaya (Fig. 27).

Fig. 27: A large population of *Anthemis cotula* in a wasteland along a roadside

Despite growing in disturbed ruderal habitats, mycorrhizal association is quite widespread in this species which has been shown to contribute to its spread. The leaf leachate is associated with allelopathic activities and all these traits together with over-compensatory growth in some individuals due to herbivory, contribute to the success of this species in Kashmir. The individuals of the post-winter cohort are small and don’t

produce a large number of reproductive propagules and are meant to give cushion to the species in case pre-winter individuals don't survive because of harsh winter.

Floral morphology: It is an annual, ill-scented herb growing 70-90 cm tall. (Fig. 32). The leaves are 1.6–8.5 cm long and 0.9-1.7 cm in width, bright green, petiolate, alternate, fleshy, hairless to hairy and pinnately compound. Inflorescence 1.7–2.8 cm in diameter with involucre bracts, ray florets white surrounding yellow coloured disc florets. Disc florets 90–250 per capitulum and are hermaphroditic with narrow, yellow corolla tubes. Cypselas subylindrical-turbinate, 1 – 1.5 mm long, light brown, obscurely 8 – 10-ribbed, tuberculate, exauriculate. **(Fig. 28)**

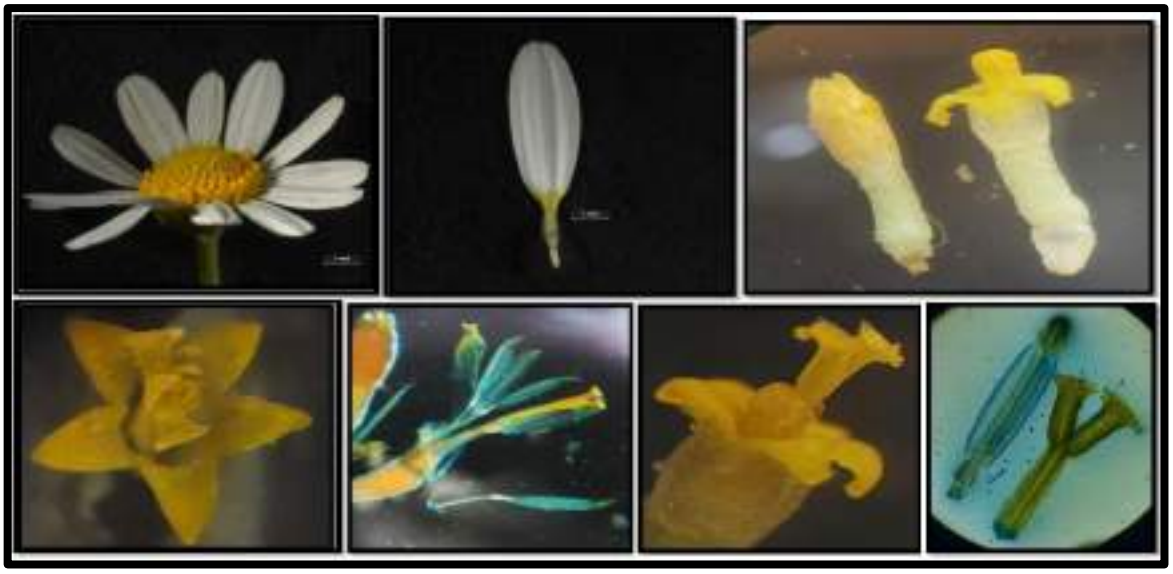


Fig. 28: Different parts of flower

Pollen morphology

The pollen grains are yellow in colour, subprolate or subspheriodal in shape, tricolpate with spiny exine. Polar diameter calculated was 47.6× 35.7).

Pollen count, pollen viability and P/O ratio: The average number of pollen grains produced per capitulum is 195993.6; average number of pollen grains per floret is 1056. The percentage pollen viability calculated is 79.16. The P/O ratio per floret turned out to be 1056.

Stigma receptivity: The flowers of the species have bilobed stigmas with well-developed papillae. The stigma is bifid and the two branches remain close to one another before anthesis and after anthesis, stigma lobes move apart from each other. Flowers are protoandrous, stigma becomes receptive 1-3 days after anthesis. Pollen load on stigmatic surfaces were observed even when the flower tube was closed, however pollen germination was observed on the 2nd or 3rd day after anthesis.

Hereafter, the receptivity of stigmas gradually decreases and is completely lost on the 4th day after anthesis and stigma dries up and loses their turgidity which marks the end of receptivity. The herkogamy and protoandrous nature of the species points towards cross pollinated nature of the species.

Pollination mechanism: The plant produces an average number of 10-21 capitula with average number 185.6 disk florets per capitulum. The florets are mostly pollinated by insects and the anthers and stigmas of the same flower are separated spatially (herkogamy), which facilitate cross pollination. The species has high P/O ratio, protoandrous nature and herkogamy in this species points towards that cross pollinated nature of the species.

Seed output: The seeds are produced in the form of achenes and achene formation starts from September to October. The species on an average produces 98.5 seeds per capitulum the percentage seed set is 53.07%. The data on seed germination revealed that 75% seeds germinate under favorable conditions of light and moisture. All the germinated seeds give rise to new seedlings and each plant gives rise to flowers and seeds. Therefore, a single seed has the potential of producing 500-1000-new plants in one season.

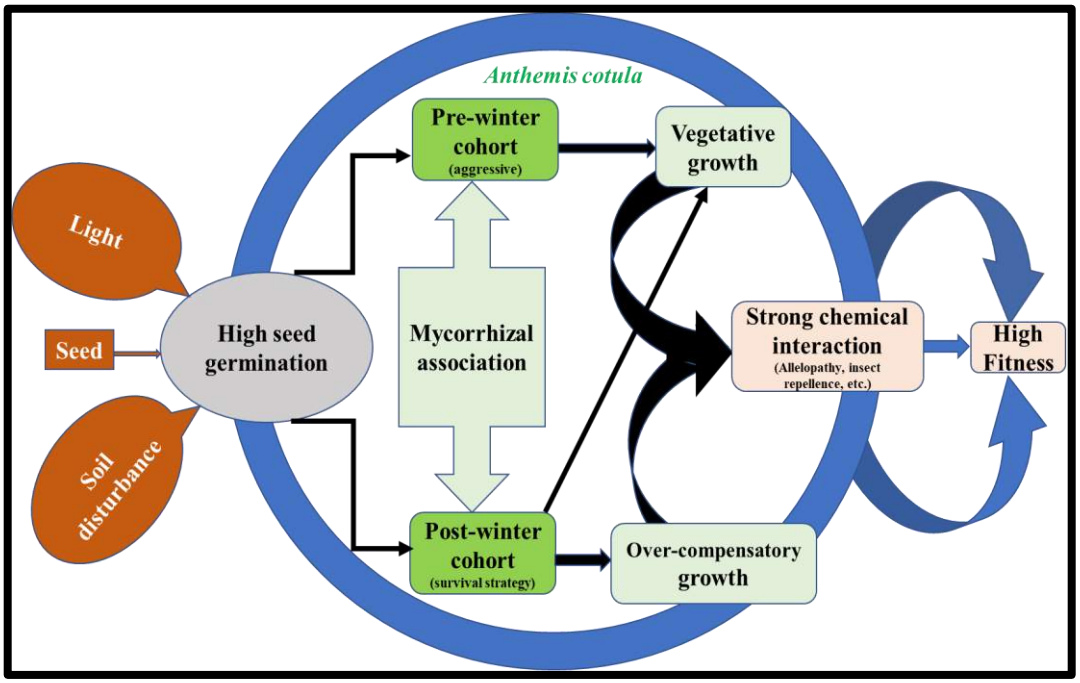


Fig. 29. *Various factors affecting survival of A. cotula*

Species distribution modelling of select alien plant species

I. *Anthemis cotula* L. is distributed in Central and SW Asia and westwards to Algeria. In India the species is one of the serious invasive plants in Kashmir Himalaya and in the

present study the species have been collected from different areas of Trans Himalayan region of Ladakh as well. Theensemble model projected that the geographical distribution and area of suitable habitat for the species in the Himalayan biodiversity hotspot will be influenced by the future climatic scenarios (2050 and 2070). The suitability distributions of *A. cotula* under current and future environmental conditions are shown in Fig. 32 and Tables 12 - 15. The western part of Himalayas even up to central Himalayas includes highly suitable areas for *A. cotula*.

II. *Erigeron canadensis* L. (syn: *Conyza canadensis* (L.) Cronquist) is native of North America and is very widespread there, but has spread to inhabited areas of most of the temperate zone of Asia, Europe, and Australia. This plant species is widespread in Kashmir Himalaya and also Trans Himalayan region of Ladakh as well. The different models projected that the geographical distribution and area of suitable habitat for the species in the Himalayan region will be influenced by the future climatic scenarios (2050 and 2070). The suitability distributions of the target plant species under current and future environmental conditions are shown in Fig. 33 and Tables 16 - 18 The western part of Himalayas include highly suitable areas for *E. canadensis* for present and future as well.

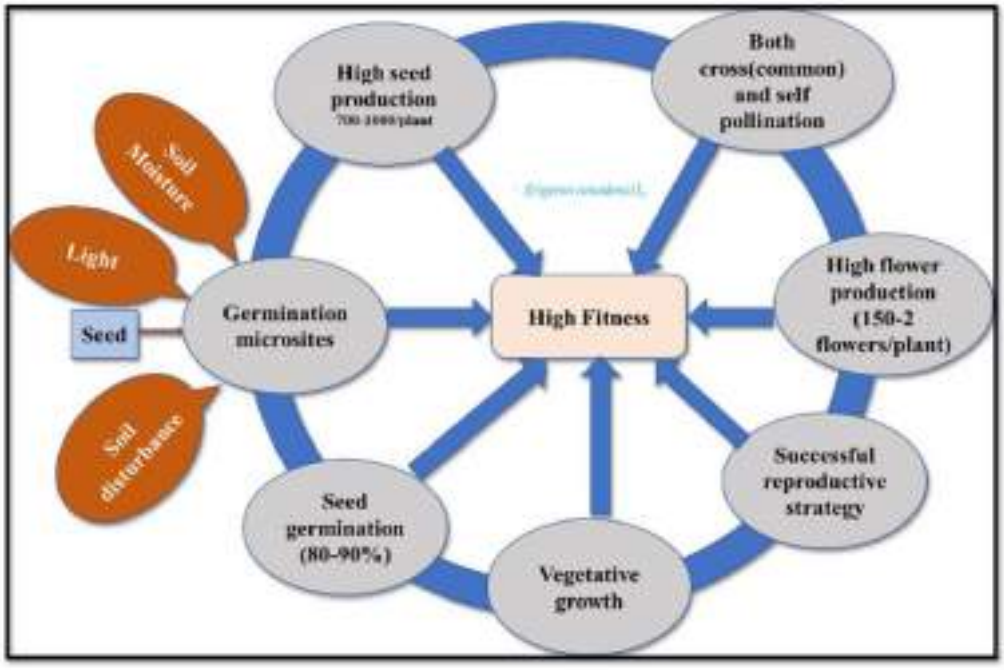


Fig. 30. Different factors affecting survival of *Erigeron canadensis* L

I. ***Hyptis suaveolens*** (L.) Poit. is distributed in America and India. In India the species is widely growing and in J&K species is growing prolifically in the Jammu region. Though the present scenario projected by different models showed that the species is not a serious problem this time in Himalayan, however; it is going

to be problematic invasive plant species in the Himalayan biodiversity hotspot under future climatic scenarios (2050 and 2070). The suitability distributions of *H. suaveolens* under current and future environmental conditions are shown in Fig. 34 and Tables 19 - 21. The western part of Himalayas and some parts of Eastern Himalayas confines highly suitable areas for *H. suaveolens* in future.

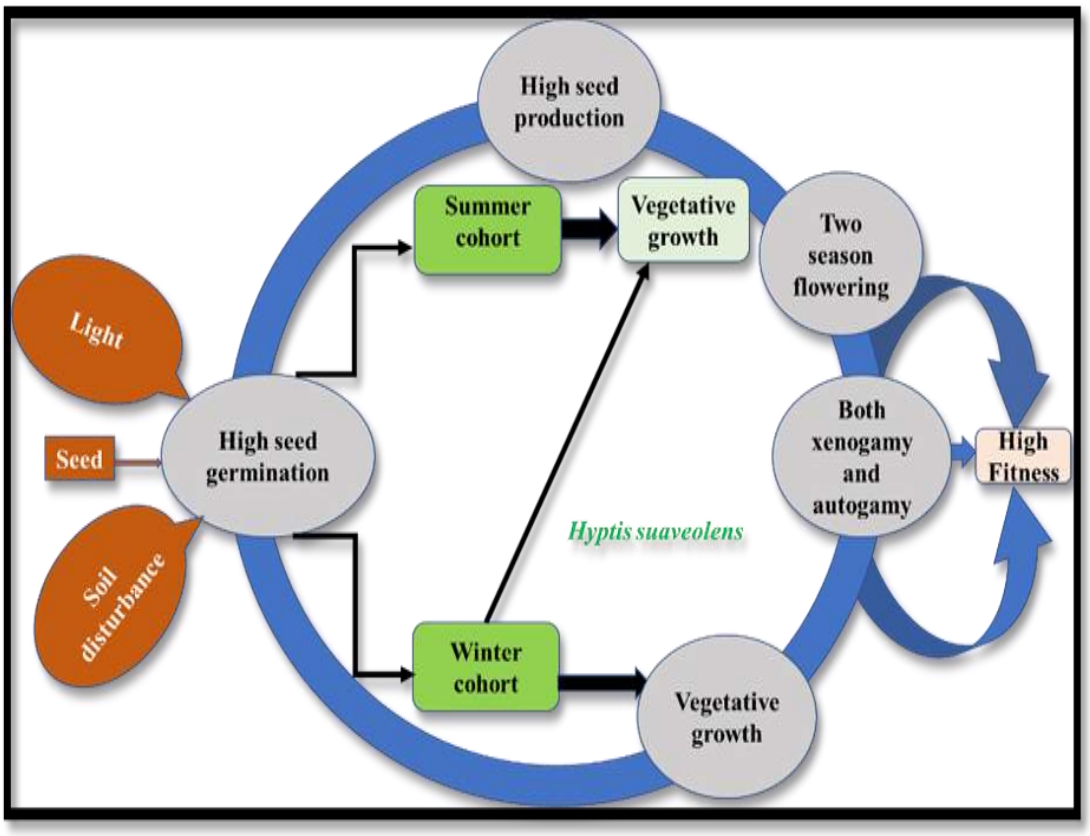


Fig.31 Factors influencing *Hyptis suaveolens* (L.) Poit. During survival

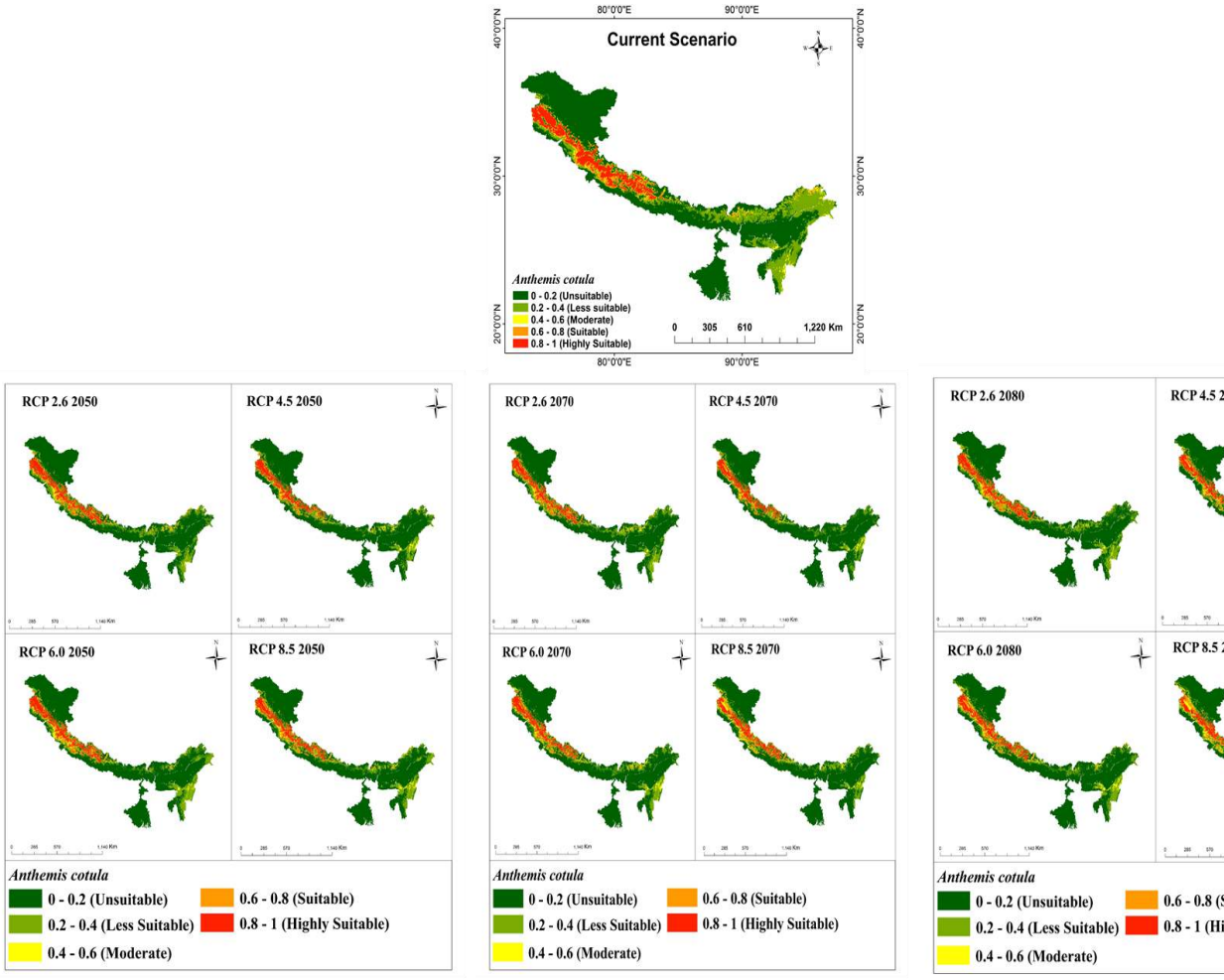


Fig. 32: Present and future distribution of *A. cotula* under different environmental conditions

Table 13: Percent (%) suitable area for occurrence of *Anthemis cotula* at present (current) and in future (2050)

Habitat Suitability	Current	2050			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Moderately suitable (0.4-0.6)	3.22	3.33	3.69	4.75	4.03
Suitable (0.6-0.8)	4.19	4.66	3.17	4.05	4.20
Highly Suitable (0.8 - 1.00)	8.73	8.02	6.96	6.87	7.20

Table 14: Percent (%) suitable area for occurrence of *Anthemis cotula* at present (current) and in future (2070)

Habitat Suitability	Current	2070			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Moderately suitable (0.4-0.6)	3.22	3.46	3.47	4.13	4.57
Suitable (0.6-0.8)	4.19	4.82	3.10	4.30	4.42
Highly Suitable (0.8 - 1.00)	8.73	7.64	6.79	7.13	6.70

Table 15: Percent (%) suitable area for occurrence of *Anthemis cotula* at present (current) and in future (2080)

Habitat Suitability	***Current***	***2080***			
		RCP 2.6	***RCP 4.5***	***RCP 6.0***	***RCP 8.5***
Moderately suitable (0.4-0.6)	***3.22***	***3.23***	***3.41***	***4.15***	***3.78***
Suitable (0.6-0.8)	***4.19***	***4.64***	***3.32***	***4.27***	***4.32***

Highly Suitable (0.8 - 1.00)	***8.73***	***7.80***	***6.49***	***6.87***	***7.88***

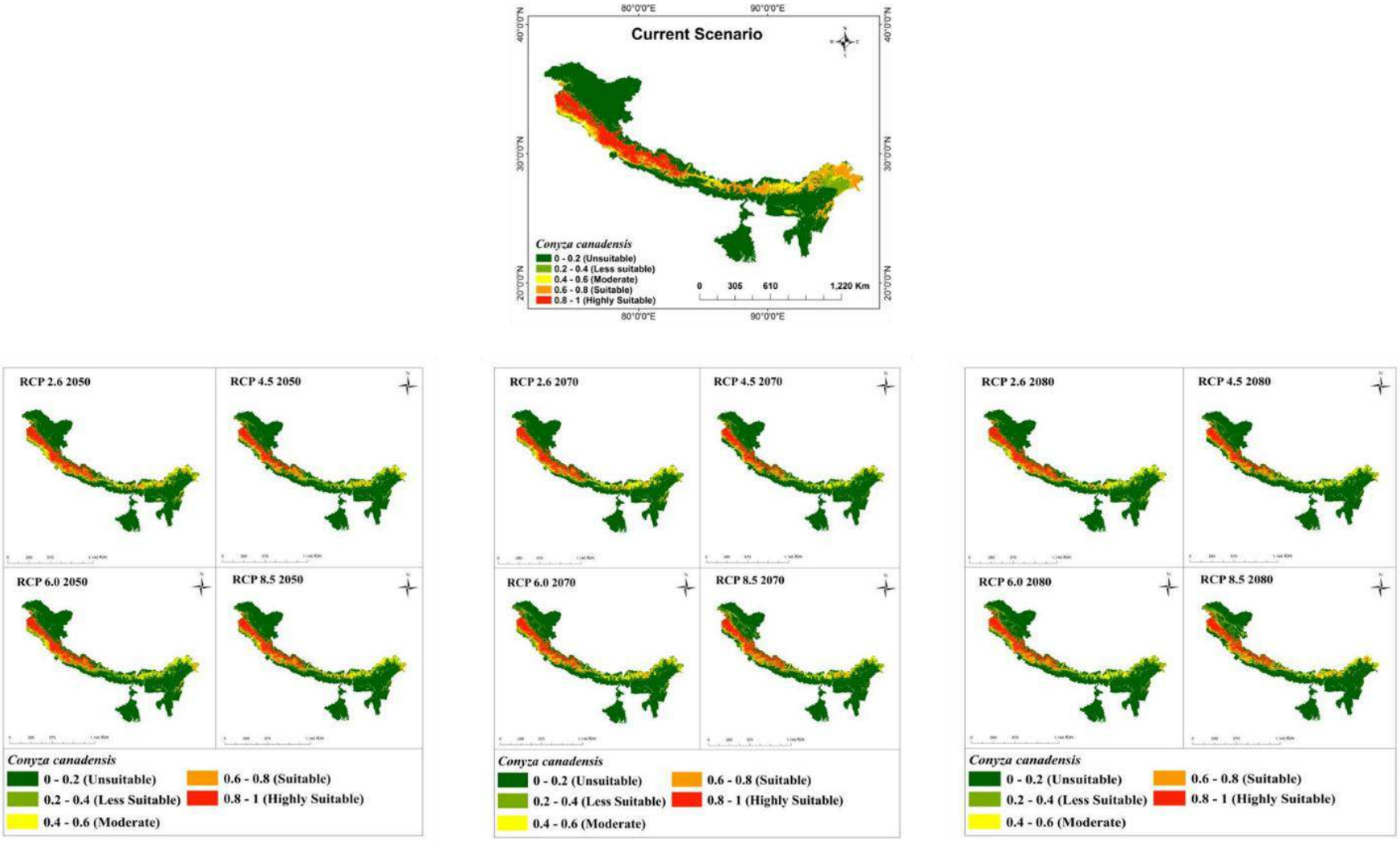


Fig. 33: Present and future distribution of *C. canadensis* under different environmental conditions

Table 16: Percent (%) suitable area for occurrence of *C. canadensis* at present (current) and in future (2050)

Habitat Suitability	Current	2050			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Moderately suitable (0.4-0.6)	6.64	7.85	6.60	7.22	7.45
Suitable (0.6-0.8)	11.69	6.85	5.51	5.30	6.13
Highly Suitable (0.8 - 1.00)	11.43	10.63	8.49	10.45	9.82

Table 17: Percent (%) suitable area for occurrence of *C. canadensis* at present (current) and in future (2070)

Habitat Suitability	Current	2070			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Moderately suitable (0.4-0.6)	**6.64**	**8.36**	**5.99**	**7.34**	**7.49**
Suitable (0.6-0.8)	**11.69**	**6.12**	**4.92**	**5.97**	**6.31**
Highly Suitable (0.8 - 1.00)	**11.43**	**10.66**	**8.40**	**9.49**	**9.61**

Table 18: Percent (%) suitable area for occurrence of *C. canadensis* at present (current) and in future (2080**)**

Habitat Suitability	Current	2080			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Moderately suitable (0.4-0.6)	6.64	7.96	6.57	6.87	8.09
Suitable (0.6-0.8)	11.69	5.33	4.99	5.51	6.84
Highly Suitable (0.8 - 1.00)	11.43	10.74	8.34	9.36	9.25

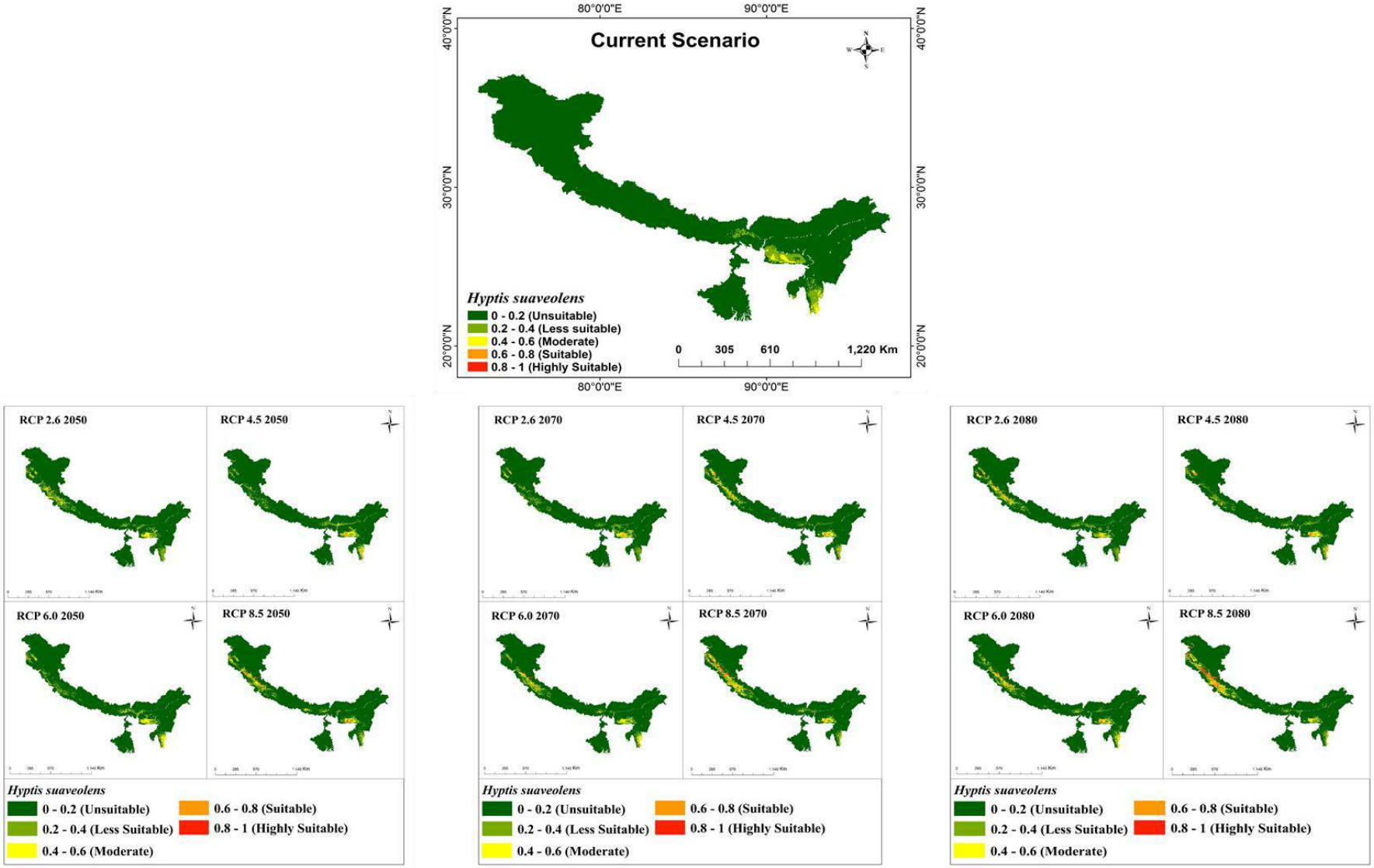


Fig. 34: Present and future distribution of *H.suaveolens* under different environmental conditions

Table19: Percent (%) suitable area for occurrence of *Hyptis suaveolens* at present (current) and in future (2050)

Habitat Suitability	Current	2050			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Moderately suitable (0.4-0.6)	0.71	1.09	1.70	2.15	2.23
Suitable (0.6-0.8)	0	0.25	0.60	0.08	0.91
Highly Suitable (0.8 - 1.00)	0	0.03	0.04	0.02	0.19

Table 20: Percent (%) suitable area for occurrence of *Hyptis suaveolens* at present (current) and in future (2070)

Habitat Suitability	Current	2070			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Moderately suitable (0.4-0.6)	0.71	1.98	1.80	2.38	3.69
Suitable (0.6-0.8)	0	0.39	0.49	0.56	1.89
Highly Suitable (0.8 - 1.00)	0	0.09	0.09	0.10	0.36

Table 21: Percent (%) suitable area for occurrence of *Hyptis suaveolens* at present (current) and in future (2080)

Habitat Suitability	Current	2080			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Moderately suitable (0.4-0.6)	0.71	2.24	2.84	2.43	3.38
Suitable (0.6-0.8)	0	0.72	0.81	0.79	2.14
Highly Suitable (0.8 - 1.00)	0	0.08	0.06	0.21	0.74

Impact assessment

Impact of invasive and spreading species was assessed by comparing the species composition and abundance of plant species in plots invaded and uninvaded by target invasive species. In *Anthemis cotula* invaded plots a total of 20 plant species were recorded, of these 6 plant species were non-native and 14 were native. Likewise, in *A. cotula* un-invaded plots 15 plant species were native and 5 species were non-native (Fig.35).

In *Erigeron canadensis* invaded plots a total of 12 plant species were present, of these 10 plant species were native and 2 were non-native. Similarly, in *E. canadensis* un-invaded plots a total of 11 plant species were recorded, amongst these 9 were native and 2 plant species were non-native (Fig.35).

The present study revealed that in *Sysmbrium orientale* invaded plots a total of 13 plant species were recorded, of these 10 plant species were native and 3 plant species were non-native. Similarly, in *S. orientale* un-invaded plots a total of 13 plant species were recorded, amongst these 10 were native and 3 plant species were non-native (Fig.35).

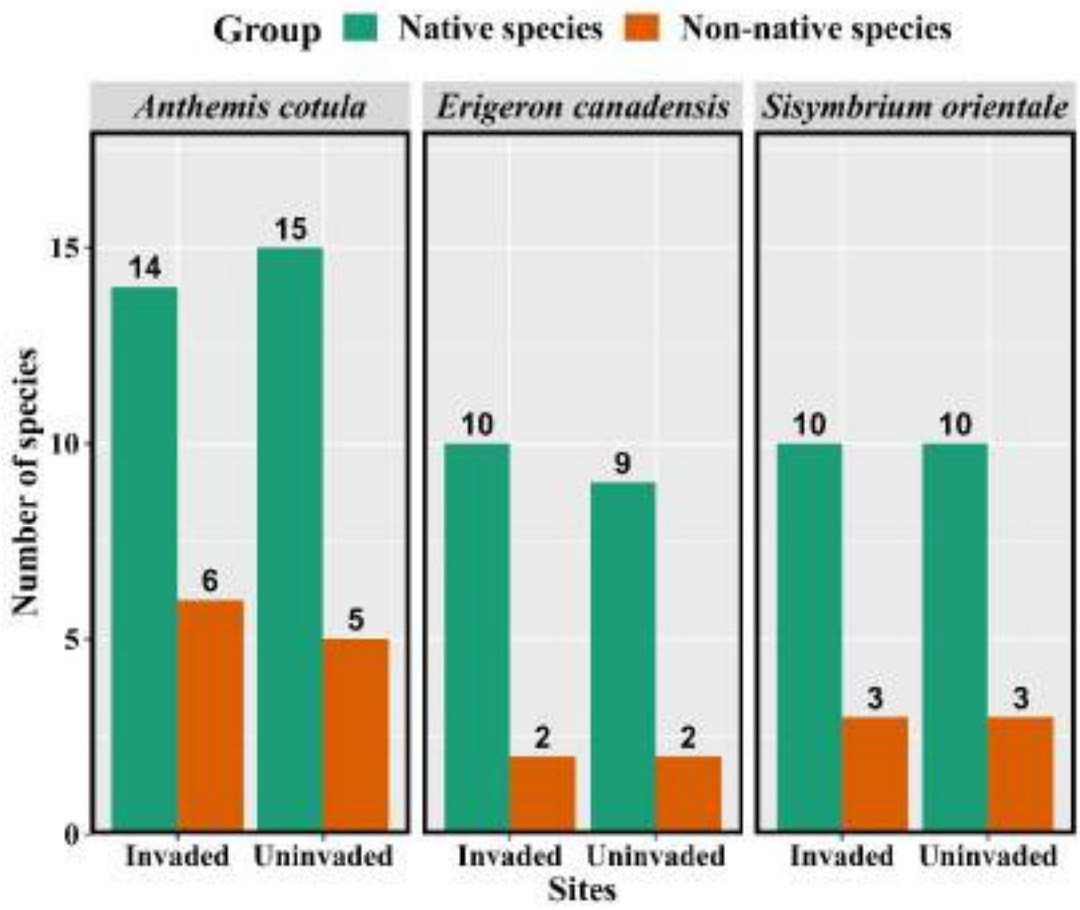


Fig. 35. Impact of invasion by *A. cotula*, *E. canadensis and S. orientale* on number of native and alien plant species in invaded and uninvaded plots

Abundance of species

***Anthemis cotula* L.**

Average abundance of the plant species in both invaded and uninvaded plots was recorded. Amongst the native species, the average abundance of *Cynodon dactylon* was higher in both invaded and uninvaded plots; however, the average abundance of *C. dactylon* was higher in uninvaded plots as compared to invaded plots. While as amongst non-native species, the average abundance *Oenothera rosea* was higher, followed by *Polygonum aviculare* in uninvaded plots and the average abundance of *Veronica agrestis* was noticeably higher invaded plots (Fig.36).

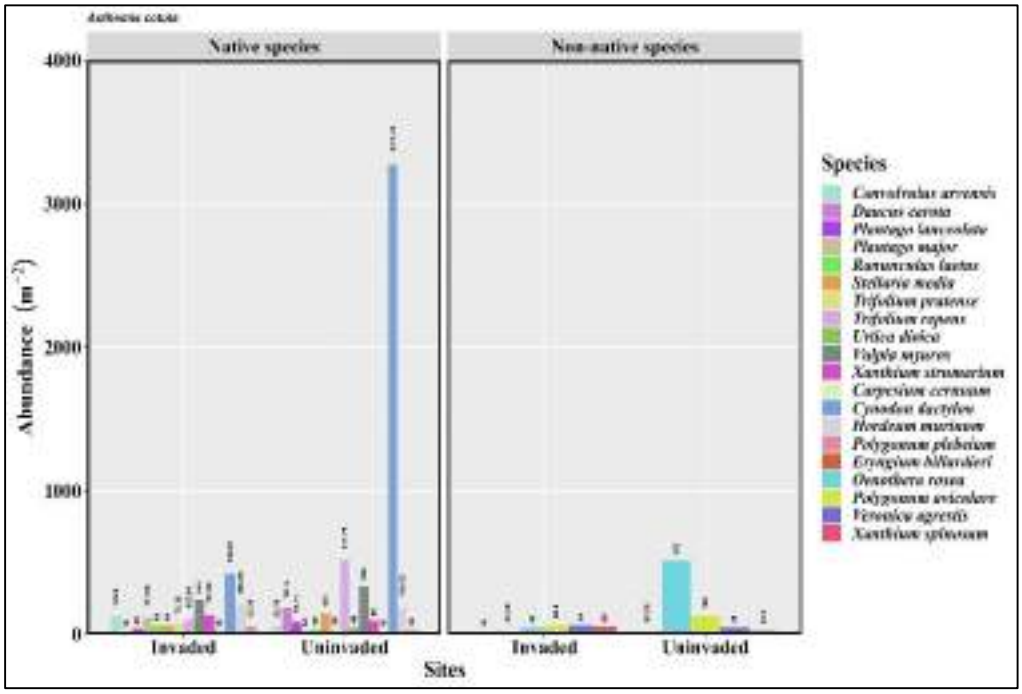


Fig.36. Average abundance of native and non-native plant species in plots invaded and not invaded by *A. cotula*

***Erigeron canadensis* L.**

Perusal of data in Fig. 37 reveals that among the non-native species *Veronica agrestis* was relatively more abundant (428.8 ind. m^{-2}) in invaded plots. Among the native species, *Cynodon dactylon* was most abundant (2116.96 ind. m^{-2}) in uninvaded plots in comparison with *E. canadensis* invaded plots where its abundance was 721.6 ind. m^{-2} (Fig. 37).

The data clearly point towards the fact that invasion of *E. canadensis* brings about significant changes in the abundance of species but not in the species composition.

***Sisymbrium orientale* L.**

In present study it was observed that the average abundance of the native plant species *Cynodon dactylon* was higher in both invaded and uninvaded plots of *S. orientale*; however, the average abundance of *C. dactylon* was noticeably higher in uninvaded plots as compared to invaded plots. While as the average abundance of non-native species in both invaded and uninvaded is concerned it was observed that the abundance of *Vicia lathyroides* was slightly higher in invaded plots (Fig.38).

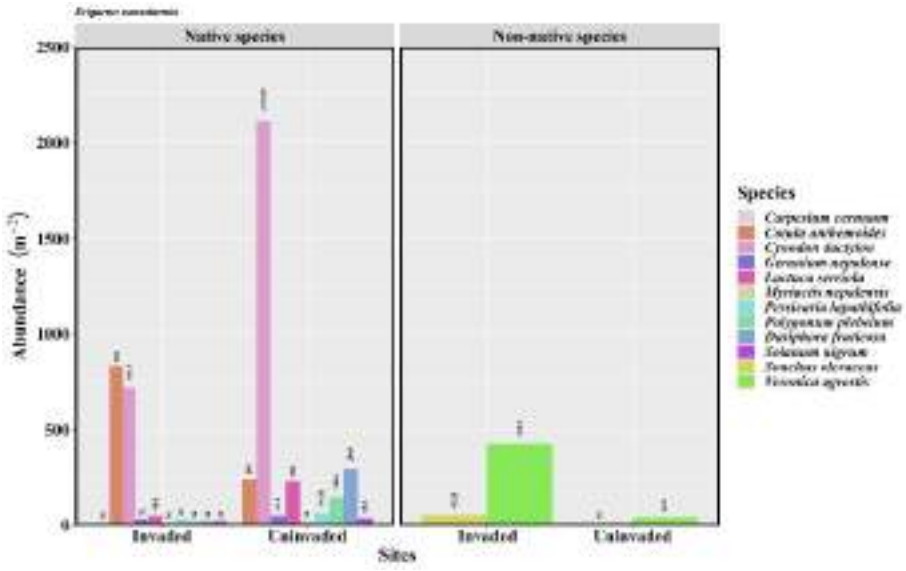


Fig. 37. Average abundance of native and non-native plant species in plots invaded and not invaded by *E. canadensis*

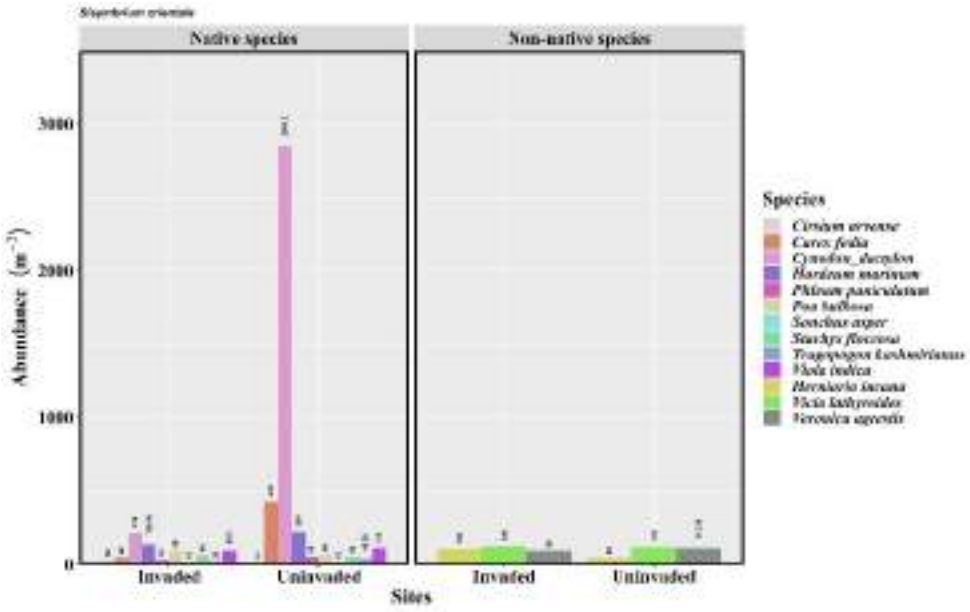


Fig. 38. Average abundance of native and non-native plant species in plots invaded and not invaded by *S. orientale*

Management framework for alien species

Risk analysis/management step		Inputs required
Risk Analysis	RISK ASSESSMENT	● Identification of invasive species and their vectors ● Surveys of current distribution and abundance of invasive species ● Matching species traits to suitable habitats ● Exposure assessment of native biodiversity
Risk Characterization		● Understanding of data completeness ● Estimates of the “potential” distribution and abundance of invasive species ● Estimates of the potential rate of spread of invasive species ● Probable risks, impacts, and costs
Risk Management		● Prediction and prevention ● Early detection and rapid response ● Control ● Policy regulatory framework including legal provision and social considerations together with costs, and benefits ● Information science tools and technology needs for better and timely management and information sharing.

FOR HIMACHAL PRADESH (Prof. Daizy Batish)

- **INTRODUCTION**

Invasive Alien Species (IAS) pose a major threat to the ecology and economy in invaded regions, especially forest and Hill ecosystems (Rai and Singh 2020; Ahmad *et al*. 2021). They cause a major change in vegetation at global level and threaten biodiversity (Tecco *et al.* 2010). Though this phenomenon has been occurring since long, yet the problem of invasion has gained momentum in the last 2 decades because of global economic growth. The magnitude of impact varies depending on the geographical features of the area, population density and type of landscape. The ecological impacts of IAS on forest ecosystems have attracted the attention of researchers, managers and policy makers the world over. As per the reports *of* World Conservation Union (WCU), the Convention on Biological Diversity (CBD), and the Global Invasive Species Programme (GISP), IAS proliferate and spread in new environments and are detrimental to human and national interests. The real challenge before man is to control their spread for meeting the objectives of the CBD and save the local, national and global ecology from destruction. For such reasons, the problem of IAS has been addressed under Article 8(h) of the CBD. This being a priority area demanding urgent policy decisions and alert of all societies, CBD focused year 2009 on the theme of IAS to celebrate International Biodiversity Day. It is well known that the areas invaded by alien plants attract alien dependent fauna. The later could serve as an initial carrier of plant propagule, but primary invaders, by and large, are the plants. Thus, the invasion by plants, the producers, is obviously a basic issue, since all other forms of biota are dependent on them. Therefore, invasion by alien plants assume primary focus of researchers, managers and policy makers. Invasive Alien Plants pose a major threat to the ecology and economy by homogenizing the vegetation and threaten biodiversity (Alexander et al. 2016). Though this phenomenon has been occurring since long, yet the problem of plant invasion did not engage sufficient attention in India and elsewhere. The magnitude of impact varies from place to place depending upon the geographical features, landscape and population density of the area invaded. India, known for its rich biodiversity, supports three biodiversity hotspots. Obviously, here loss of biodiversity on account of alien invasives could have far-reaching consequences. However, like many other countries, India also lacks data on the total area occupied by alien plants and even on total number of such species in each state/UT. Being a signatory to CBD, India is also seriously attempting to control IAS in this era of globalization and economic integration.

(b) Background-Justification:

Background (max. 500 words)

In the past few decades, invasion ecology has gained significant interest with invasion being recognized as an important problem by the ecologists. There have been numerous efforts to understand what actually drive the non-native species to successfully establish themselves. Not many years ago, mountains, islands and oceans offered formidable barriers to invasions, except to the most aggressive ones. But with the changing world, exotic species are breaking down any barrier and thriving in the novel ranges, threatening the native biodiversity and the ecosystem functions. Alien invasion is considered the second most important cause of species extinction (Singh, 2005). Once established, an invasive plant species have the potential to modify native ecosystem, physiochemical and biological qualities of soil, including nutrient cycling regimes (Ehrenfeld 2003; Hawkes et al. 2005), soil microbial and fungal communities (Hawkes et al. 2006). The adverse impact of invasive species on the ecosystem has led to a major interest among ecologists to understand the nature of invasion and to develop methods to control their spread. Baker (1965) proposed that weedy plant species have characteristic traits, such as ability to propagate and spread sexually and vegetatively, phenotypic plasticity and high tolerance to environmental heterogeneity, which promote their weediness. Documenting the invasive species and neo-invasive species, and most vulnerable habitats of an area and assessing the socio-ecological impact is thus an important means to understand how invasive plants establish and persist in diverse habitats of mountain environment.

Overview of the major issues addressed (max. 500 words)

- Identification of most noxious invasive species.
- Characterization of species identified as per their life form, life span, nativity, and invasion status.
- Recoding GPS coordinates of study sites surveyed.
- Assessment of ecological impact of invasive plants on native plant communities.
- Generating awareness in different cross-sectoral groups regarding invasive species.

Baseline Data and Project Scope (max. 500 words)

- Species identified are listed from Himachal Pradesh

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

- Identifying established and new Invasive Alien Vascular Plant Species (IAVPS) in all the 15 Indian Hilly States of Himalaya and estimating the invasion load.
- Characterizing the IAVPS on the basis of their life-forms, lifespan, nativity, status of invasion and purpose of invasion/introduction
- Preparing protocols for prediction, early detection and risk assessment of IAVPS

- Assessment of Ecological & Environmental Impact of invasion and spread with special reference to phytodiversity and soil especially in relation to climate change; This will include the level of disappearance of native
- Selection of at least 10 most noxious established and 10 Neo-invasives and consolidation of all available information including their biology, itemizing at the same
- Identification of a cross- sectoral group to assess the situation in the form of case-studies on these species, and also to formulate workable management strategies aiming to prediction, prevention and control

METHODOLOGIES/STARTEGY/ APPROACH – *supporting documents to be attached.*

3.1 Data collected and Equipments utilized

The methodology involves the survey and collection of invasive alien plants species from Himachal Pradesh (excluding Kinnaur and Lahaul-Spiti district) during vegetation season from different altitudes and habitats. Apart from the collections of specimens, observations were made on the habitat of species, habit and spread of species. All known localities were surveyed to document them and know their status. Herbarium visits were organized for recording reported distribution of major invasive species and comparing with current firld data. Identification of species was carried out with the help of Floras, existing regional monographs/ revisions, protologues, etc. Phytosociological analysis of invasive alien plants species and its associates was carried out by quadrate sampling. The random sampling was done by laying quadrats of 1 m x 1 m for herbs, 5 m x 5 m for shrubs, and 20 m x 20 m for trees. Soil samples were also collected for recording moisture, nitrogen, potassium, phosphorus and organic matter content. Data on elevation, geographical coordinates, understory, habitat type, disturbances, grazers, etc., were noted. Density, Frequency, Abundance, Relative density, Relative frequency and Relative abundance were calculated along with Importance Value Index, for all target species. For recording coordinates and altitude data, Trimble TDC-100 was used. Kjeldahl was used for estimating Nitrogen content in soil and plant samples collected for various purposes. In addition, Infrared gas analyzer was used to record photosynthetic and other physiological parameters of some selected invasive plant species to understand their invasiveness.

3.2 Details of Field Survey conducted

Field surveys were conducted to eight districts of Himachal Pradesh. Surveys were conducted in different habitats like openland, vicinity of agricultural lands, roadsides, forest understory, etc. at different altitudes ranging from 500 m to 4100 m.

3.3 Strategic Planning for each activity with time frame

First year: Recruitment of project staff, visiting national herbaria for recording distribution of invasive plants, surveys to 2 districts during vegetation period.

Second year: conducting field surveys to other districts and collecting and analysing soil samples.

Third year: conducting surveys in other districts, analysing data, publishing results.

KEY FINDINGS AND RESULTS – *supporting documents to be attached.*

4.1 Major Activities

With the initiation of the project, two Junior Research Fellows (JRFs) and one Field Assistant was recruited. They were briefed about their responsibilities and trained. Thorough literature survey was conducted to get an idea of the invasive load present in the study sites. Herbarium visits were also conducted to Botanical Survey of India, Dehradun, herbarium of Panjabi University, Patiala, and herbarium of National Botanical Research Institute, Lucknow. Herbarium sheets of various invasive alien species were studied to know about their presence and the date they were first reported. Field trips were undertaken to different study sites to perform vegetation and phytosociological analysis. During the visits, photographs of invasive plants were taken. Soil samples and specimens of plants were collected and dried to prepare herbarium sheets. Analysis of vegetation and physicochemical analysis of soil samples has been done. During First year of project after joining of project staff (August 2018 to March 2019) sites and plants species were identified in district Solan and Sirmaur. During Second year of project (April 2019 to Feb 2020) sites and plants species were identified in district Chamba, Hamirpur, Shimla, Bilaspur, and Una. During last year of survey (April 2020 to Dec 2020) nationwide lockdown occurred due to which all project actitvities were halted. During extension period of project (Jan 2021 to Sept 2021) the analysis of collected data and soil samples was done, which could not be done before due to closure of university campus and travel restrictions during COVID-19 lockdown.

4.2 Key results

- We have laid a total of 475 quadrats of 1× 1 m to document various herbaceous species.
- We have recorded 10 invasive alien species in study sites so far.
- During the various survey conducted we have recorded 145 plant species (listed in Appendix 1).
- The total species belonged to 42 families. Asteraceae, family had the largest proportion (~62%) of plant species, followed by Polygonaceae (~31%), Ranunculaceae (~19%), Poaceae (~17%), Lamiaceae (~14%), Rubiaceae (~12%), Fabaceae (~12%), and Apiaceae (~12%).
- Out of all the species recorded, ~98% species were angiosperms, ~94% were dicots and ~6% were monocots. ~87% species were herbs, ~10 % shrubs and ~3% were trees.

- 80 alien species were recorded with 10 of them being major invasive species.
- *Parthenium hysterophorus*, *Lantana camara*, *Hyptis suaveolens, Broussonetia papyrifera*, *Biden pilosa*, *Ageratum conyzoides*, *Senna occidentalis* were dominant at <1000 m
- *Parthenium hysterophorus*, *Lantana camara, Cirsium arvense, Bidens pilosa, Ageratina adenophora* at 1000 - 2000 m
- *Ageratina adenophora* was dominant at at 2000-3000 m
- *Taraxacum officinale* and *Achillea millefolium* were found at 3000 m–4100
- Awareness programmes were conducted in District Sirmaur and Nahan with student in different educational institutes before lockdown which reached successful conclusions.
- The awareness programmes included interactive sessions with the project staff for understanding the harmful impacts of invasive plants and successfully identifying some major invasive plants of their region.

4.3 Conclusion of the study

- The project before COVID-19 lockdown was successful in identifying the different alien plants in different altitudes of Himachal Pradesh.
- In addition, awareness was generated in the people for understanding the harmful impacts of invasive plants, and identification of major harmful invasive plant species.
- Major invasive plants identified were *Lantana camara*, *Parthenium hysterophorus*, *Hyptis suaveolens, Ageratum conyzoides, Ageratina adenophora, Bidens pilosa, Broussonetia papyrifera, Sapium sebiferum*

OVERALL ACHIEVEMENTS – *supporting documents to be attached.*

5.1 Achievement on Project Objectives/ Target Deliverables

- Two thousand eight hundred thirty quadrats of 1× 1 m were laid during the study.
- About 145 species have been recorded.
- A list of plant species with their nativity, taxonomic group, habit, habitat is prepared.
- We have recorded ~10 dominant invasive alien species in study sites.

5.2 Interventions (max. 500 words)

- **NA**

5.3 On-field Demonstration and Value-addition of Products, if any (max. 500 words)

- **NA**

5.4 Green Skills developed in in State/ UT (max. 500 words)

- **NA**

5.4 Addressing Cross-cutting Issues (max. 200 words)

- **NA**

PROJECT'S IMPACTS IN IHR – *supporting documents to be attached.*

Socio-Economic impact (max. 500 words)

Species like *Parthenium hysterophorus*, *Ageratum conyzoides*, *Ageratina adenophora*, and *Lantana camara* were responsible for causing major socio-economic harm, especially in agricultural, and cattle and human health sector.

Impact on of Natural Resources/ Environment (max. 500 words)

- Invasive species alter the vegetation composition of the invaded area by causing vegetation homogenization.
- Habitat degradation is evident with alteration of soil properties and lowering of soil health and fertility during altered nutrient cycling.
- Native species with narrow niche width were under extreme threat of extinction.
- Native species displacement was evident with introduction of an invasive species.

Conservation of Biodiversity/ Land Rehabilitation in IHR (max. 500 words)

- NA

Developing Mountain Infrastructures (max. 200 words)

- NA

Strengthening Networking in State/ UT (max. 200 words)

- NA

EXIT STRATEGY AND SUSTAINABILITY – *supporting documents to be attached.*

Utility of project findings (max. 500 words)

Project finding will be useful to governmental organizations and forest department of different districts of Himachal Pradesh. The inventory prepared provide list of alien and native flora encountered that can be further used to study species-specific distribution patterns. The awareness programmes generated curiosity in students to understand the implications and process of plant invasion, that will empower many other associated stake-holders to participate in different management strategies.

Other Gap Areas (max. 200 words)

Modeling of invasive plant distribution with respect to changing environmental factors.

Major Recommendations/ Way Forward (max. 200 words)

Modeling of invasive plant distribution with respect to changing environmental factors

Replication/ Upscaling/ Post-Project Sustainability of Interventions (max. 500 words)

For future monitoring the alien species that are not yet hugely invasive can be focused upon.

FOR UTTARAKHAND (Prof. Harminder Pal Singh)

- **INTRODUCTION**

Nearly one-sixth of the world's land surface is highly vulnerable to invasion by alien species, including key areas of growing economies and global biodiversity hotspots. Invasive plants can displace native species, ruin ecosystems, and harm human health. Invasive plants have been reported to cause severe ecological, environmental, economic, and health issues in the Himalayan region. Many people have benefited socially and economically from globalization, but it has also introduced new concerns, of which are invasive alien species (IAS). A significant portion of the world's terrestrial surface, the mountains, are extremely vulnerable to invasion by alien species, including important hubs of developing economies and global biodiversity hotspots. Invasive plants can displace native species, ruin ecosystems, and harm human health by altering structure and functioning of plant communities. Invasive plants have been reported to cause severe ecological, environmental, economic, and health issues in the Himalayan region. The negative impacts of biological invasion on biodiversity are worldwide known and India is no exception to this. Himalaya is one of megadiversity center and also in the list of biological hotspots is facing number of challenges due to unregulated growth and development. The invasion of plants species such as *Lantana camara*, *Ageratum conyzoides* etc has already created many ecological, economical and health problems in the Himalayan region. Thus, the invasion by plants, the producers, is obviously a basic issue, since all other forms of biota are dependent on them. Several studies reported that IAS causes species extinctions in mountains throughout the world. It is evident that IAS effects the goods and services of ecosystem and can have considerable impacts, directly and/or indirectly on socio-economic as well as human health. Therefore, there is a dire need of controlling the spread and establishment of IAS and also minimizing their impacts on mountains. Here, this study will try to fill the gap focusing the long-term monitoring and assessment of vegetation to measure the impact of climate change.

Background (max. 500 words)

Many people have benefited socially and economically from globalisation, but it has also introduced new challenges, with invasive alien species (IAS) being among the most important. The rate of biological invasion, the variety and quantity of these invaders, and the severity of the effects have never been higher in human history (Reaser et al., 2007). But nowadays the number and the impact of IAS increased and thereby altering nature of the ecosystems. Research over the last decade has increased our understanding of invasion patterns and made significant progress in unravelling the mechanisms underlying invasion (Hejda et al., 2009). Currently, more attention has been given to negative impacts of IAS on functioning and processes of native communities. Liedtke et al. (2020) reported that tourism, roadsides and hiking trails provided conducive environment for invasive species to flourish in mountain ecosystems. In mountains, geographical areas and ecological distances are the major factor which delayed the spread of invasive plants but nowadays these factors have dwindled down, at least

functionally (Alexander et al. 2016). In addition to that climate change and human activities might facilitate the establishment of generalist species (wide ecologyical amplitude) in natural ecosystems (Steyn et al. 2017). Several reseracher reported that encroachment of invasive species in mountain ecosystems might be enhanced by climate change (global warming) (Pauchard et al. 2016; Carboni et al. 2018) and highly infested along the roadsides and tracking trial networks (McDougall et al. 2011; Lembrechts et al. 2017; McDougall et al. 2018). Figueroa et al. (2011) reported that invasive species in the area have been observed to migrate to higher elevations beside highways, and the lowlands of this region are well known to be highly invaded in the Andes of southern Chile.

Overview of the major issues addressed (max. 500 words)

- Identification of species and description of each according to life form, lifespan, place of nativity, and invasion status.
- Ecological evaluation of invasive plant populations' effects on native plant communities as well as recording the GPS coordinates of the study sites visited.
- Raising awareness of invasive species among various industry, nonprofit organizations, and government.

➢ **Baseline Data and Project Scope (max. 500 words)**

- Species identified are listed from Kinnaur district of Himachal Pradesh and Uttarakhand.

➢ **Project Objectives and Target Deliverables (as per the NMHS-Sanction Order)**

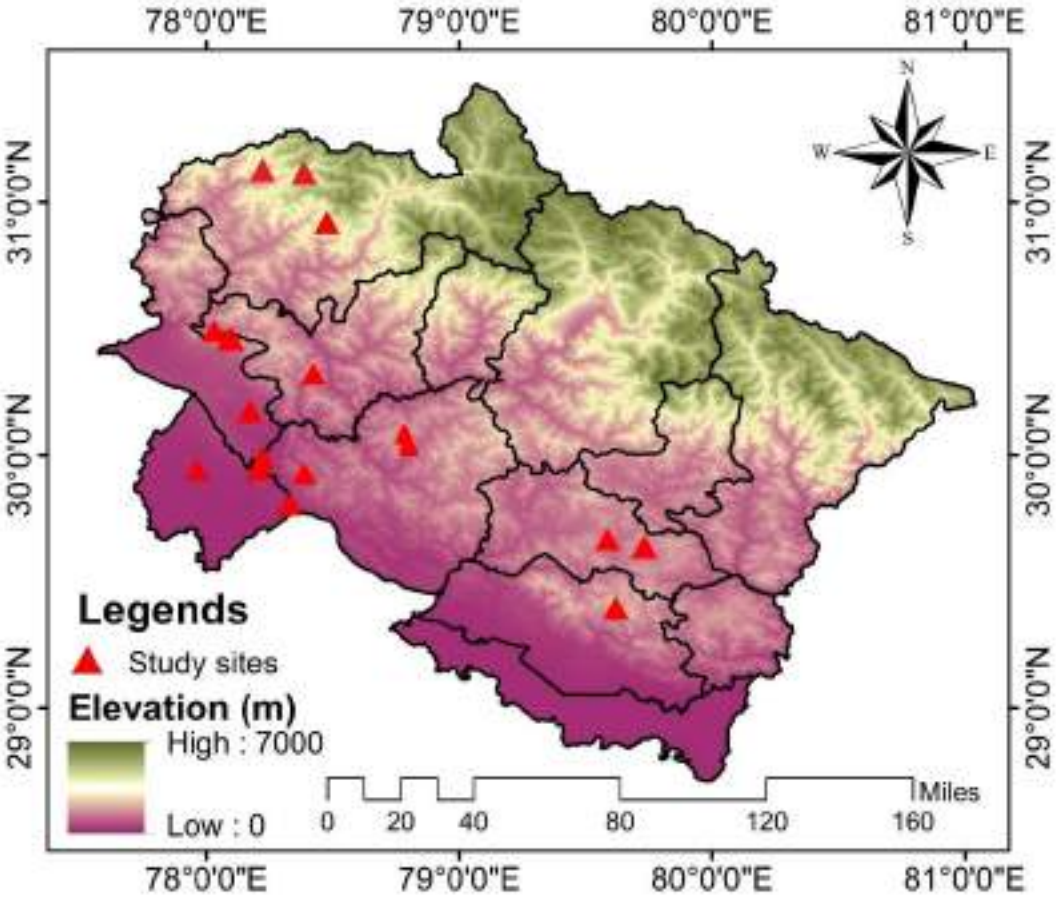
- Identifying established and new Invasive Alien Vascular Plant Species (IAVPS) in all the 15 Indian Hilly States of Himalaya and estimating the invasion load.
- Characterizing the IAVPS on the basis of their life-forms, lifespan, nativity, status of invasion and purpose of invasion/introduction
- Preparing protocols for prediction, early detection and risk assessment of IAVPS
- Assessment of Ecological & Environmental Impact of invasion and spread with special reference to phytodiversity and soil especially in relation to climate change; This will include the level of disappearance of native
- Selection of at least 10 most noxious established and 10 Neo-invasives and consolidation of all available information including their biology, itemizing at the same
- Identification of a cross- sectoral group to assess the situation in the form of case-studies on these species, and also to formulate workable management strategies aiming to prediction, prevention and control

- **METHODOLOGIES/STARTEGY/ APPROACH –** *supporting documents to be attached.*

Methodologies used and Equipments utilized (max. 500 words)

Plots (50×50 m) established in grid-based approach and systematic sampling was done in the study sites including Kinnaur and Uttarakhand. The plot was further categorized into quadrats of 5×5 m for shrubs and 1×1 m for herbs for quantifying spatial pattern of species in randomized manner. Density, abundance, and frequency, and IVI of plant species were analyzed.To characterize the soil conditions, soil samples were collected from all the study sites from the center of each 5 × 5 m quadrat within 5–15 cm depth, and mixed thoroughly to obtain three replicates (n = 3) per site. After air drying and sieving the soil through a mesh (pore size: 2 mm), these were analyzed for pH (soil: water = 1:2, w/v), total nitrogen (TN [%]; Kjeldahl method), total phosphorous (TP [%]; ammonium vanadate molybdate method), total potassium (TK [%]; ammonium acetate extraction method) and organic carbon (OC [%]) in the laboratory as per the methods given by Tandon (1993). Soil samples were also used to determine electrical conductivity (EC; mmhos cm^{-1}) by subjecting the soil suspension (soil: water = 1:2, w/v) to digital conductivity meter (Century CC601 Model; calibrated with 0.01 M KCl solution which gives EC of 1.413 mmhos cm^{-1}). Trimble TDC-600 was used for recording coordinates and altitude information. Portable leaf area meter was used for measuring leaf area in the field during sampling the flora of Kinnaur and Uttarakhand. Kjeldahl was employed to calculate the nitrogen content of soil and plant samples that were obtained for a variety of reasons. Moreover, CNS analyzer was used for estimating protein and organic matter present in some selected invasive species collected during the survey.

- **Details of Field Survey conducted, if any (max 500 words)**
- Surveys were conducted to five districts of Uttarakhand and one district (Kinnaur) of Himachal Pradesh.
- Field surveys were conducted in different habitats like vicinity of agricultural lands, roadsides, forest understory, openland, etc. at different altitudes ranging from 500 m to 4000 m.



- **GPS co-ordinates of field survey**

Site name	Latitude	Longitude	Altitude (m)
Uttarakhand			
1	30°27'33.721"	078°4'42.978"	1857m
2	31°44'5.881"	076°5'50.161"	1721m
3	30°28'6.780"	078°4'50.221"	1316m
4	30°29'36.060"	078°1'37.679"	1726m
5	29°38'21.059"	079°36'42.779"	1249m
6	29°40'10.859"	079°29'24.000"	1729m
7	29°23'530"	079°30'720"	1649 m
8	29°55'984"	078°09'965"	268m

9	29°48'322"	078°16'32"	301m
10	29°55'486"	078°18'992"	364m
11	29°56'3775"	077° 48'1010"	273m
12	29°59'1745"	078°11'1250"	315m
13	30°55'1960"	078°23'5592"	357m
14	30°19'2062"	078°21'1095"	1027m
15	30°10'3464"	078°08'4241"	445.2m
Kinnaur (Himachal Pradesh)			
16	31°21'5.400"	078°26'16.199"	3520m
17	31°32'10.799"	078°15'31.201"	2477m

Strategic Planning for each activity with time frame (max. 200 words)

- First year: Recruitment of two junior research fellow and one field assistant, visiting national herbarias for recording distribution of invasive plants, surveys Kinnaur districts of Himachal Pradesh during vegetation period.
- Second year: Field surveys were conducted in some districts of Uttarakhand and collecting and analysing soil samples.
- Third year: Collected data were analysed and does some paper writing. Moreover, conducting surveys in other districts, analysing data, publishing results.

KEY FINDINGS AND RESULTS – *supporting documents to be attached.*

Major Activities/ Findings (max. 500 words)

- During the study few Invasive or potential invasive alien plant species have been recorded from Uttarakhand.
- A list has been prepared for invasive alien plants; their ecological data have been analysed. Frequency, Abundance, Density, IVI of each plant calculated e.g. *Lantana camara, Parthenium hysterophorus, Hyptis suaveolens, Ageratum conyzoides, Ageratina adenophora*
- An awareness programme has been conducted in District Haridwar

Key Results (max. 500 words in bullets covering all activities)

- During sampling, we have laid 300 quadrats of 1 × 1 identified invasive alien species IAS such as *Prosopis juliflora, Parthenium hysterophorus, Lantana camara, Hyptis suaveolens, Broussonetia papyrifera, Biden pilosa, Ageratum conyzoides, Senna occidentalis, Mirabilis jalapa, Euphorbia hirta* etc.

- Plants collected were identified and list of 108 plant listed in appendix 1

- The total species belonged to 37 families. Asteraceae, family had the largest proportion (~65 %) of plant species, followed by Solanacea (~24 %), Poaceae (~22 %), Fabaceae (~19 %), Ranunculaceae (~14 %), Polygonaceae (~14 %), Euphorbiaceae (11 %) and Brassicaceae (~11 %). Out of all the species recorded, ~99% species were angiosperms, ~93% were dicots and ~7% were monocots. ~84% species were herbs, ~13 % shrubs and ~3% were trees. 100 alien species were recorded with 30 of them being major invasive species.

Conclusion of the study (max. 500 words in bullets)

- The project before COVID-19 lockdown was successful in identifying the different alien plants in different altitudes of Uttarakhand

- Students' curiosity about the effects and causes of plant invasion was sparked by the awareness campaigns, and this eagerness would enable many other related stakeholders to take part in various management techniques. In addition to that this study would help the concerned government authorities and NGOs to devise specific management strategies to conserve the native flora.

OVERALL ACHIEVEMENTS – *supporting documents to be attached.*

Achievement on Project Objectives/ Target Deliverables (max. 500 words)]

- About 145 species have been recorded.
- A list of plant species with their nativity, taxonomic group, habit, habitat is prepared.
- We have recorded ~6 dominant invasive alien species in study sites.

Interventions (max. 500 words)

- NA

On-field Demonstration and Value-addition of Products, if any (max. 500 words)

- NA

Green Skills developed in in State/ UT (max. 500 words)

- NA

Addressing Cross-cutting Issues (max. 200 words)

- NA

PROJECT'S IMPACTS IN IHR – *supporting documents to be attached.*

Socio-Economic impact (max. 500 words)

- Species like, *Ageratina adenophora*, *Parthenium hysterophorus*, *Ageratum conyzoides* and *Lantana camara* were responsible for causing major socio-economic harm, especially in agricultural, and cattle and human health sector.

Impact on of Natural Resources/ Environment (max. 500 words)

- Invasive species alter the vegetation composition of the invaded area by causing vegetation homogenization.
- Habitat degradation is evident with alteration of soil properties and lowering of soil health and fertility during altered nutrient cycling.
- Native species with narrow niche width were under extreme threat of extinction.
- Native species displacement was evident with introduction of an invasive species.

Conservation of Biodiversity/ Land Rehabilitation in IHR (max. 500 words)

- NA

Developing Mountain Infrastructures (max. 200 words)

- NA

Strengthening Networking in State/ UT (max. 200 words)

- NA

EXIT STRATEGY AND SUSTAINABILITY – *supporting documents to be attached.*

Utility of project findings (max. 500 words)

- This study would help the concerned government authorities and NGOs to devise specific management strategies to conserve the native flora.
- List of species prepared would help researchers for further study carried out in this direction

Other Gap Areas (max. 200 words)

- Modeling of invasive plant distribution with respect to changing environmental factors.

Major Recommendations/ Way Forward (max. 200 words)

- Modeling of invasive plant distribution with respect to changing environmental factors.

Replication/ Upscaling/ Post-Project Sustainability of Interventions (max. 500 words)

- NA

FOR SIKKIM & WEST BENGAL (DARJEELING HIMALAYAS) (Prof. Harminder Pal Singh)

Introduction

Invasive Alien species (IAS) are species which cross over their natural distribution and get introduced to the new ecosystem which has ability to spread in the new location, displacing the local biota and threatens native biological diversity (Saxena,1991; Keane and Crawley ,2002). Invasive Alien plants distributed in all type of ecosystem throughout the world. According to International Union for Conservation of Nature and Natural Resources (IUCN., 2000) defines, “alien as an invasive species or exotic, which establishes itself in natural or semi-natural ecosystems, habitats and invariably threatens the native biological diversity.” Hence, any species non-native to any considered ecosystem and causing economic and environmental harm can essentially be categorized as an invasive to that particular ecosystem. The rapid spread of invasive alien species posing serious threats to global biodiversity has become a major concern among ecologists, naturalists, biologists and land managers worldwide. Moreover, evidence indicates that as international trade and economic industrialization increase, the magnitude of the threat posed by invasive Alien species increases globally. Invasive alien species alter ecosystem processes, decrease native species abundance and richness via competition, predation, hybridization and indirect effects, change community structure and alter genetic diversity. Thus, the effect of invasive alien species on local plant communities and biodiversity has become a major research focus worldwide. invasive alien plants represent a recurrent and ubiquitous threat to both agricultural and natural ecosystems. Invasion may be accidental or deliberate, as a result of introduction of some species on purpose. The success of these species in the alien and new environment may be attributed to several reasons. The impacts are often immense, insidious and frequently irreversible. Although both indigenous and alien (exotic) species are capable of attaining weedy status, the latter types are more likely to become problems because they often are released from their natural enemies, and also have not co-evolved with the indigenous species. Thus, alien species can interfere strongly with indigenous types and as a result they tend to dominate or even displace the less adaptive native species. It is widely accepted that alien invader plants constitute a major threat to biodiversity, directly by displacement of flora and fauna, or indirectly through placing natural resources under strain.

Invasive alien species menace has not been felt so far, though species like *Lantana camara*, *Rumex nepalensis*, *Eupatorium* spp., *Mikenia micrantha*, *Polygonum* spp. and aquatic weeds have caused severe problems at many places inhibiting the regeneration and growth of indigenous species and/or choking the water bodies. It is necessary to have scientifically guided surveys and quantification of the damages caused by invasive species and prevent introduction of any new invasive species in the state.

Objective(s):

- Survey, documentation and characterisation of invasive vascular alien plants on the basis of their life-forms, lifespan, nativity, status of invasion in Sikkim and Darjeeling Himalaya.
- Selection of major noxious invasive species in the study area.

- Monitoring the distribution patterns and population dynamics of different invasive species (*Lantana camara*; *Eupatorium riparium*; *E. adenophorum; E. odoratum and Mikania micrantha*) in various ecosystems across the altitudes.
- Assessment of ecological impacts of alien plant invasion on native plant community.

Study Site

The Himalayan state Sikkim is one of the smallest states in India that comprises only 4 districts, namely North, East, South and West (Fig. 1) with an area of 7096 km square. It lies between 27º 04' to 28º 07' N latitudes and 88º00' to 88º 55' E longitudes at the altitudes ranging from 300 m to 8864 m above sea level with steep terrains which are drained by river Teesta and many brooks. It is a reservoir of many types of forest vegetations including temperate, alpine and small patches of cold desert. The state has great geographical importance as it is surrounded by Tibet (China) in north and north-east, Bhutan in south-east, Indian state West Bengal in south and Nepal in west. The annual rainfall ranges between 2000 mm to 4000 mm. The region may be smaller in area, but due to its 47% forest cover, it is well known for its rich biological diversity with good amount of rare, endemic and endangered flora and fauna and scenic beauty. The annual rainfall ranges from less than 5 mm to nearly 4000 mm. The state has about 80% of its geographical area under forest cover and has over 5500 species of flowering plants. Besides 39% area occupied by alpine pastures and snow, the state supports an immensely rich reservoir of biological diversity as tremendously useful genetic resource pool. The vegetation ranges from sal (*Shorea rubusta*) and its associates in the low elevations and gradually transitions to oaks, low attitude pines, firs, and finally the high-altitude alpine grasslands and meadows. The state is very rich in orchids and pteridophytes. Sikkim jointly with Darjeeling hills has been blessed with rich diversity of medicinal plants (over 700 species). The Rhododendrons are a great indicator of forest health and ecological stability and out of nearly 72 *Rhododendron* species in North-East India, Sikkim is known to have 36 species. The proposed region (Sikkim Himalaya and Darjeeling) has great potential of ecotourism and attract thousands of people every year.

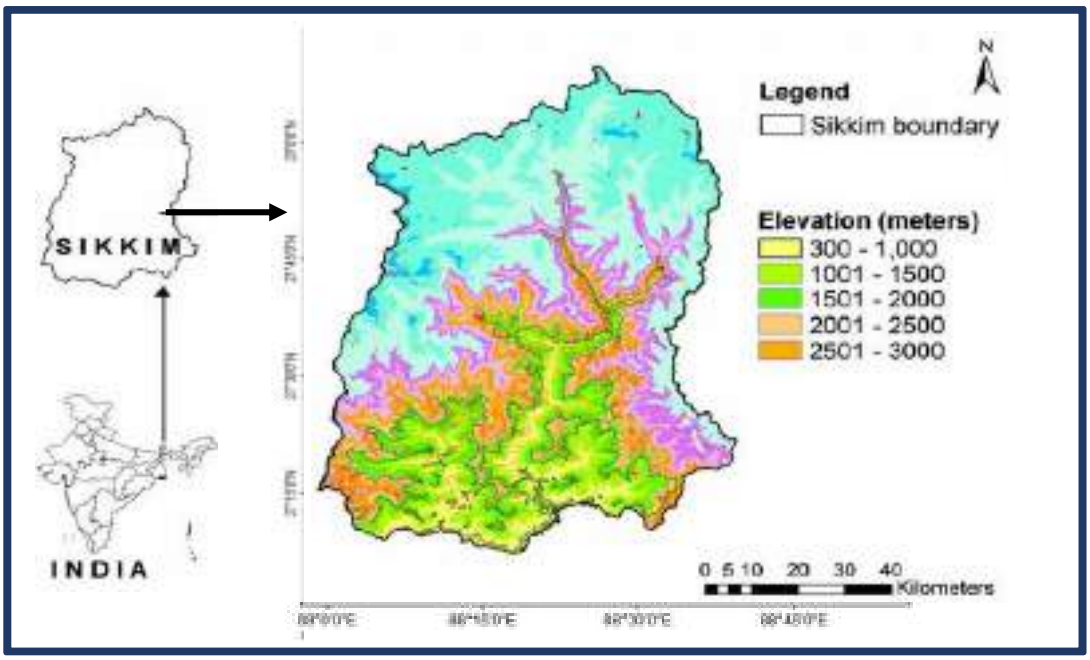

SIKKIM
INDIA
N
Legend
Sikkim boundary
Elevation (meters)
300 - 1,000
1001 - 1500
1501 - 2000
2001 - 2500
2501 - 3000
0 5 10 20 30 40
Kilometers

Fig. 1 Study site depicting the sampling points in Sikkim Himalaya during 2018 and 2021.

Methodology:

Population and phytosociological studies

We conducted an extensive field survey in Sikkim Himalaya, mostly in the forest fringes, fallow lands, meadows, and an understory of disturbed forests during 2018 and 2021, and phytosociological analysis of the invaded ecosystems was done across all vegetation types. rveying the same area after 3 years duration during 2021. Vegetation was surveyed systematically using random quadrats (Misra, 1968). A total of 304 quadrates of 5 m×5 m size, covering a total area of 7600 m2, were laid along seven elevational gradients for plant community analysis. Shrub and herbaceous vegetation in the invaded area were included in the plant community analysis, and the population of targeted species along with its associates were calculated. Data on vegetation type, altitudes, geographical coordinates, and the presence of human-induced or natural disturbances were recorded. Basal cover of all herbs and shrubs was measured at a collar height of 5 cm above the ground using a vernier caliper. The voucher specimens have been deposited at the herbarium of the National Botanical Research Institute, Lucknow, India (LWG). Herbarium specimens of all the associated species were preserved and identified with the help of published literature (Grieson & Long, 1983–2001; Kumar & Singh, 2001; Ghosh & Mallick, 2014)

and consulting the specimens at the herbarium of Botanical Survey of India, Sikkim Circle, Gangtok, India (BSHC) and LWG. Seven different elevational gradients were surveyed between 600 and 2700 m (600–900 m (Alt. 1), 900–1200 m (Alt. 2), 1200–1500 m (Alt. 3), 1500–1800 m (Alt. 4), 1800–2100 m (Alt. 5), 2100–2400 m (Alt. 6), and 2400–2700 m (Alt.7). Different parameters like density, frequency and dominance of the vegetation were calculated of each altitudinal gradients in MS Excel using various formulae as per Kent and Coker (1992). Importance value indices (IVIs) were calculated for each plant species using the formula:

Importance value index (IVI) = R.Den. + R.F. + R.D. (Philips, 1959).

where, R.Den.= Relative density,

R.F. = Relative Frequency, and R.D. = Relative Dominance.

Dominance = Basal area × density where,

Basal area = πr2 (π = 3.14 is constant and r = basal radius of plant stem).

Ecological Indices were calculated as per the formulae given by Ludwig and Reynold (1988).

Shannon Index (H); Shannon and Weaver, 1963). $H' = -\sum_{i=1}^{s} Pi\ lnpPi$

Simpson's Index (λ) calculated as per formula given by Simpson (1949).

$\lambda = = \sum_{i=1}^{s} (ni/N)2$

Evenness Index (E) was calculated as per Hill (1973).

E = H' /lnS

pi = the proportion of individuals belonging to i^{th} species, and **ln** = the natural log, **S** = the number of species, **ni** = number of individuals of i^{th} species, and **N** = total number of species.

Taxonomic Study

Four field tours were conducted in various regions of Sikkim Himalaya at different altitudinal gradients ranging between 600 m to 2700 m to collect and document alien plant species during 2018–2019 in pre and post monsoon seasons. The plants were collected to prepare voucher specimens following standard taxonomic procedure (Lawrence, 1951,1967, Jain & Rao, 1977). All voucher specimens have been deposited at LWG after their proper identification made with the help of regional and local floras (Grieson & Long, 1983, 1984, 1987, 1991, 1994, 1999, 2001; Kumar & Singh, 2001; Ghosh & Mallick, 2014) and by the study of specimens housed at LWG and BSHC. An updated nomenclature has been provided for each species after consulting different websites like Plants of the World Online (POWO), The Plant List, Tropicos and International Plant Names Index (IPNI). All recorded alien species have been provided in

table 1 in alphabetical order along with their families, taxonomic group, growth form, habitat, flowering period, invasion status, native range and mode of introduction.

Major Research Achievements

Floristic Study:

This study provides a first-hand information towards the knowledge of the alien plant species present in Sikkim. During the course of study, a total of 336 alien plant species were enumerated from the flora of Sikkim that comprises 298 dicot species and 38 monocot species under 224 genera and 69 families (Table 1 & Fig. 2). Of which, the top 10 families [Fabaceae (58 species), Asteraceae (47 species), Solanaceae (30 species), Poaceae (21 species), Amaranthaceae (14 species), Malvaceae (13 species), Convolvulaceae (12 species) Euphorbiaceae (12 species), Brassicaceae (09 species) and Rosaceae (06 species)] account for 66.07% of the total alien flora (Fig. 3). About 30 families are represented by only a single alien species (Table 1). Amongst genera Solanum (12 species), Ipomoea (10 species), Senna (09 species), Euphorbia (07 species), Acacia, Alternanthera, Cestrum, Hibuscus and Opuntia (05 species each), Amaranthus, Erigeron and Lathyrus (04 species each) account for majority of the alien species (Fig. 4). Herbs (191 species) constitute the majority of the species (56.84 %) of alien flora, followed by Shrubs (78 species, 23.21%), Trees (29 species, 8.63%), climbers (20 species, 5.95 %), grasses (17 species, 5.05 %) and subshrub (01 species, 0.29 %) (Fig. 5). It was recorded that 192 species have been intentionally (deliberately) introduced while the remaining species as unintentionally (Fig. 6). The maximum alien species have been introduced from American continent. Out of the total alien species found in the study area, 5.95 % are casual, 12.80 % are naturalized, 20.83 % are casual or naturalized, 26.19% are cultivated and 34.23% are of invasive nature (Fig. 7). Of the total alien species, the maximum invasive alien species were noticed in the family Asteraceae (23 species), followed by Fabaceae (16 species), Amaranthaceae, Convolvulaceae and Solanaceae (09 species each) (Fig. 8 & 9), however the family Fabaceae consists of more cultivated and naturalised species (Fig. 9). The alien plant species prefer to grow along roadsides, urban landscape, forest clearings, riparian and scrub habitat in open areas chiefly near human settlements. They mainly reproduce during summer and rainy seasons.

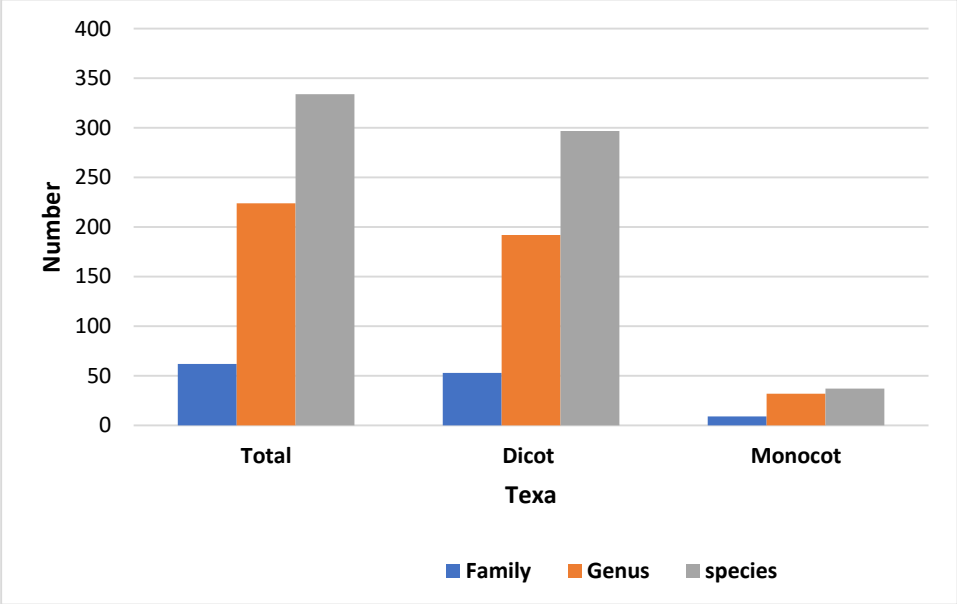


Fig. 2 Distribution of alien plant species among family, genera and species in dicots and monocots.

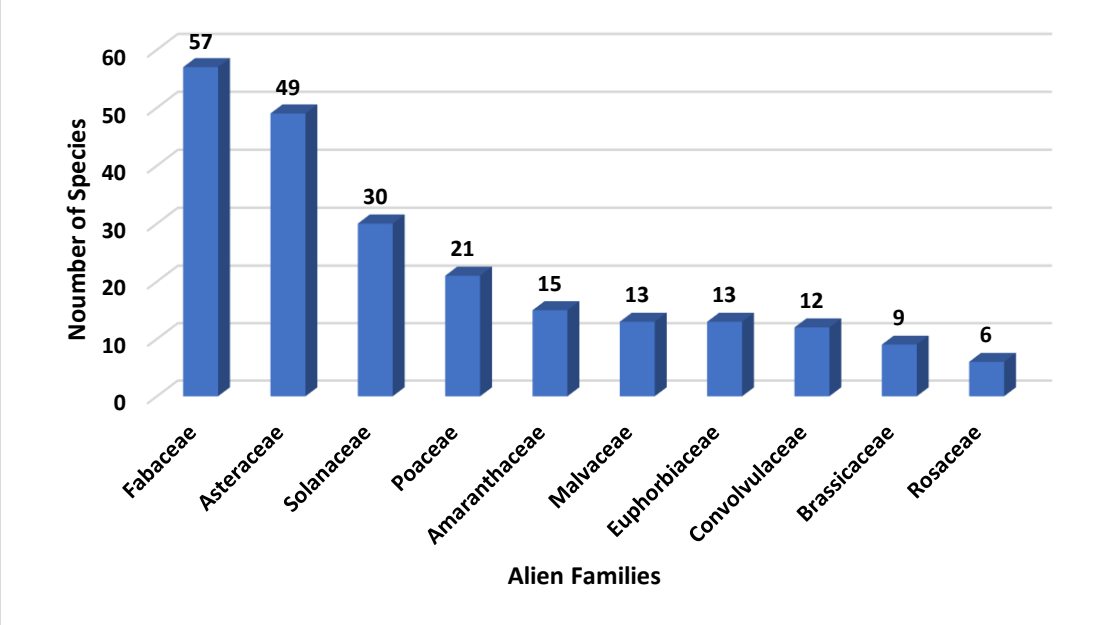


Fig. 3 Dominant families with alien plant species.

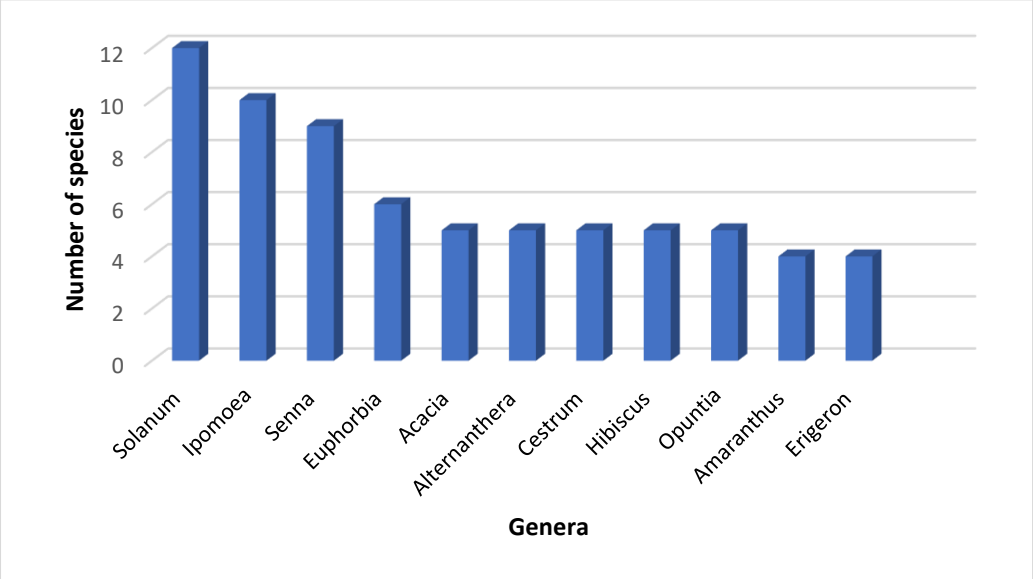


Fig. 4 Genera with highest number of alien plant species.

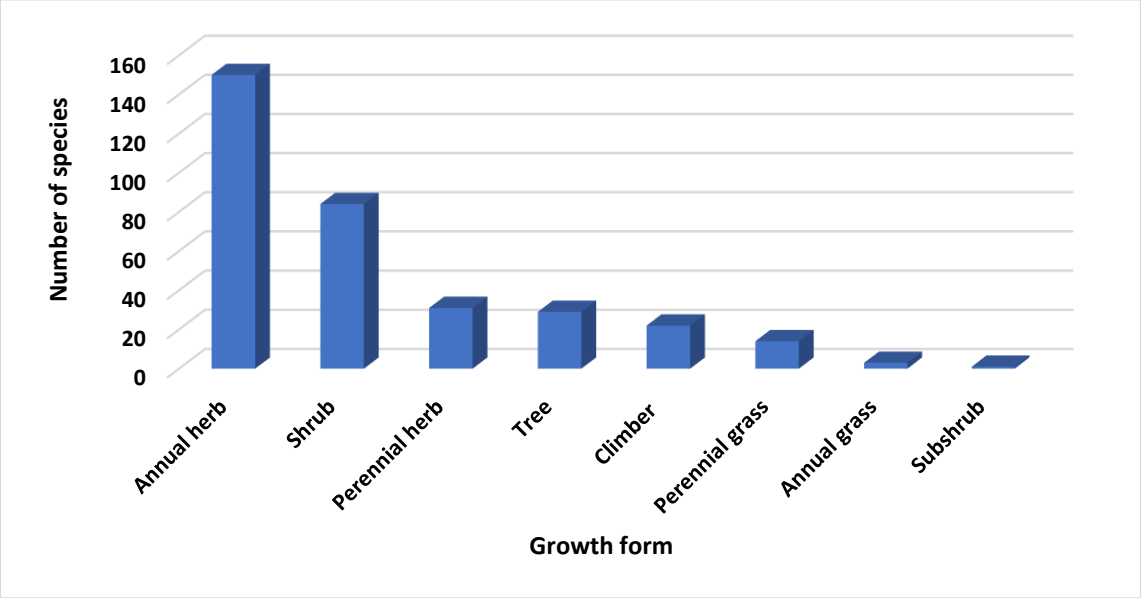


Fig. 5 Different growth forms of plants.

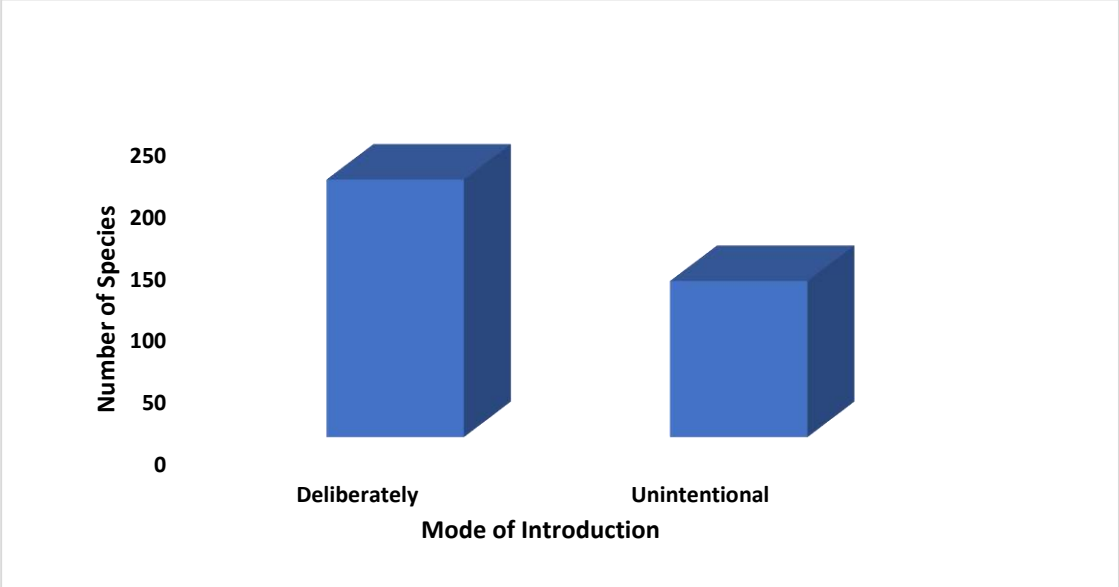


Fig. 6 Mode of introduction of alien plants.

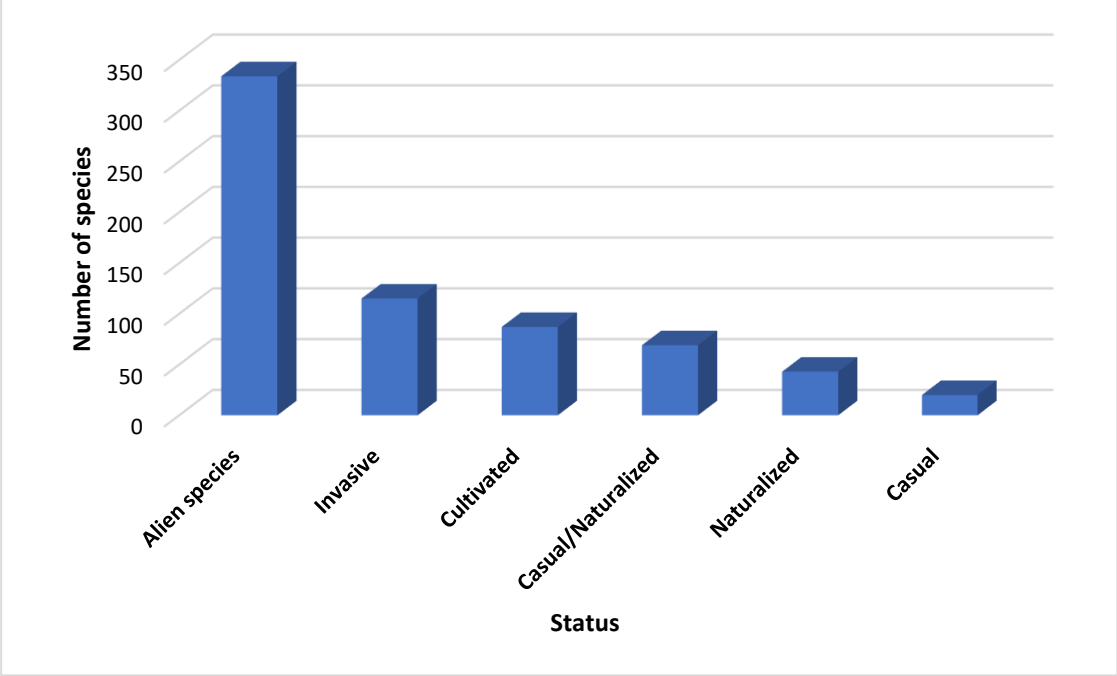


Fig. 7 Invasion status of alien plant species.

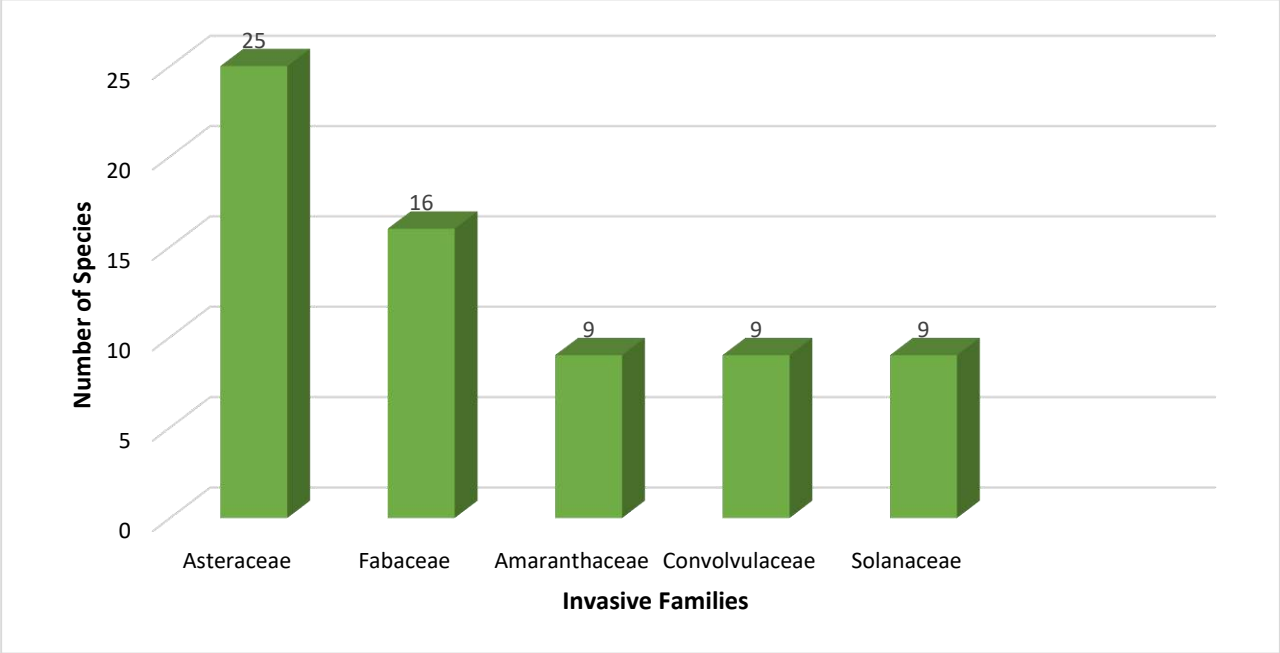


Fig. 8 Families with maximum number of invasive alien plant species.

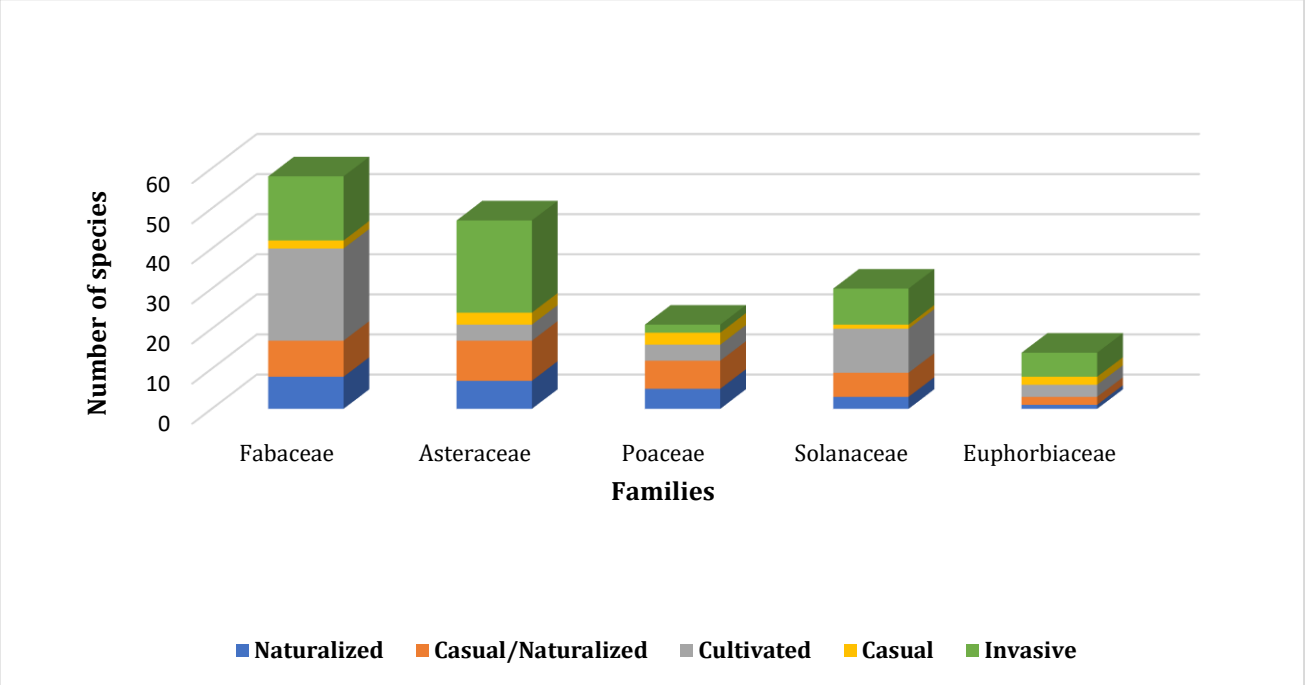


Fig. 9 Dominant families with different categories of alien plant species.

Table 1. List of alien plant species found in Sikkim Himalaya.

Sl. No	Family/Species name	Growth Form	Habitat	Introduction/ Invasion status	Native range
1	**Acanthaceae**				
2	*Justicia brandegeeana* Wassh. &L.B.Sm.	Shrub	Roadside	Delib./Cultivated	N.America
3	*Ruellia tuberosa* L.	P.herb	Wastelands	Delib./Invasive	Mexico to N. South America and Peru, Caribbean
4	*Thunbergia alata* Bojer ex Sims	Climber	Riverbanks, Roadside	Delib./Casual/Naturalized	Trop.& S. Africa, Madagascar
	Amaranthaceae				
5	*Alternanthera bettzickiana* (Regel) G.Nicholson	P.herb	Wastelands	Delib./Casual/Naturalized	W. South America to Brazil
6	*Alternanthera ficoidea* (L.) P.Beauv.	P.herb	Wasteplaces	Uninten./Invasive	Trop. America
7	*Alternanthera paronychioides* A.St.-Hil.	P.herb	River beds	Uninten./Invasive	Trop & Subtrop. America
8	*Alternanthera philoxeroides* (Mart.) Griseb.	A.herb	River beds	Uninten./ Invasive	Trinidad to N. Argentina
9	*Alternanthera pungens* Kunth	A.herb	Wastelands	Uninten./Invasive	Mexico to Trop.America
10	*Amaranthus blitum* L.	A.herb	Roadside	Delib./Casual/Naturalized	Peru to Brazil and N. Argentina
11	*Amaranthus caudatus* L.	A.herb	Agric. Lands	Delib./ Invasive	Ecuador to NW. Argentina
12	*Amaranthus spinosus* L.	A.herb	Roadside	Uninten./Invasive	Mexico to Trop. America
13	*Amaranthus viridis* L.	A.herb	Wastelands, Roadside	Delib./Casual/Naturalized	SE. Mexico to Trop.America
14	*Celosia argentea* L.	A.herb	Crop fields	Uninten./Invasive	Trop. Africa
15	*Dysphania*	A.herb	Disturbed	Uninten./Invasive	America, Subantarctic

	ambrosioides (L.) Mosyakin & Clemants		areas, Roadside		Islands
16	*Gomphrena celosioides* Mart.	A.herb	Cultivated fields	Uninten./Casual/Naturalized	Ecuador to N. Argentina
17	*Gomphrena globosa* L.	A.herb	Agric. Lands	Delib./Casual/Naturalized	Mexico to Brazil
18	*Gomphrena serrata* L.	A.herb	Cultivated fields	Uninten./Invasive	SE. & S. Cent. U.S.A. to Cent. America
19	*Iresine diffusa f. herbstii* (Hook.) Pedersen	P.herb	Roadside	Uninten./Cultivated	N. Peru
	Amaryllidaceae				
20	*Allium cepa* L.	P.herb	Disturbed areas, Roadside	Delib./Cultivated	Cent. Asia
21	*Zephyranthes candida* (Lindl.) Herb.	A.herb	Cultivated areas	Delib./Cultivated	SE. & S. Brazil to NE. Argentina
	Annonaceae				
22	*Annona reticulata* L.	Tree	Agric. Lands	Delib./Cultivated	Mexico to NE. Venezuela
23	*Annona squamosa* L.	Shrub	Roadside	Delib./Cultivated	Mexico to Colombia
	Apiaceae				
24	*Anethum graveolens* L.	A.herb	Agric. Lands	Delib./Naturalized	N. Africa to Chad, Iran to Arabian Peninsula
25	*Coriandrum sativum* L.	A.herb	Agric. Lands ,	Delib./Casual/Naturalized	E. Medit. to Pakistan
26	*Cuminum cyminum* L.	A.herb	Disturbed areas	Delib./Cultivated	Iraq to Afghanistan
27	*Cyclospermum leptophyllum* (Pers.) Sprague ex Britton & P.Wilson	A.herb	Roadside, Wasteareas	Uninten./Invasive	Mexico to S. Trop. America
28	*Eryngium foetidum* L.	P.herb	Forest edges, Roadside	Delib./Casual/Naturalized	Mexico to Trop. America

	Apocynaceae				
29	*Allamanda cathartica* L.	Climber	Roadside	Delib./Casual/Naturalized	South and Cent.America
30	*Asclepias curassavica* L.	A.herb	Roadside	Uninten./Invasive	Mexico to Trop.America
31	*Catharanthus roseus* (L.) G. Don	Shrub	Riverbanks	Delib./Casual/Naturalized	Madagascar
32	*Cryptostegia grandiflora* Roxb. ex R.Br.	Shrub	Cultivated fields	Uninten./Invasive	S. & SW. Madagascar
	Araceae				
33	*Caladium bicolor* (Aiton) Vent.	P.herb	Waste areas	Delib./Cultivated	Cent. America to Argentina
	Arecaceae				
34	*Cocos nucifera* L.	Tree	Roadside	Delib./Naturalized	Cent. Malesia to SW. Pacific
	Aristolochiaceae				
35	*Aristolochia littoralis* Parodi	Climber	Roadside	Delib./Cultivated	Colombia to N. Argentina
	Asparagaceae				
36	*Agave angustifolia* Haw.	Shrub	Roadside	Delib./Naturalized	Mexico to Cent. America
37	*Agave vera-cruz* Mill.	Shrub	Roadside	Delib./Naturalized	Mexico (Veracruz, Oaxaca)
38	*Asparagus officinalis* L.	Subshrub	Abandoned fields, Roadside	Delib./Naturalized	Europe, northern Africa & West Asia
39	*Dracaena trifasciata* (Prain) Mabb.	P.herb	Abandoned fields, Roadside	Delib./Cultivated	S. Nigeria to W. Cent.Trop. Africa
	Asteraceae				
40	*Acanthospermum hispidum* DC.	A.herb	Wastelands	Uninten./Invasive	Trop. America
41	*Acmella radicans* (Jacq.) R.K.Jansen	A.herb	Roadside	Uninten./Invasive	Mexico to NW Venezuela and Bolivia, Caribbean
42	*Acmella uliginosa*	A.herb	Agric.	Delib./Naturalized	Trop. America

	(Sw.) Cass.		Lands , Roadside		
43	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob..	Shrub	Open forest, Agric. Lands	Delib./Invasive	Mexico
44	*Ageratina ligustrina* (DC.) R.M.King & H.Rob.	Shrub	Roadside	Uninten./Casual/Naturalized	Mexico to Cent. America
45	*Ageratum conyzoides* L.	A.herb	Wastelands	Delib./Invasive	Mexico
46	*Ageratum houstonianum* Mill.	A.herb	Wastelands	Delib./Invasive	Mexico to Cent.America
47	*Bidens pilosa* L.	A.herb	Roadside	Uninten./Invasive	Trop. & Subtrop. America
48	*Calendula officinalis* L.	A.herb	Roadside	Delib./Casual	W. Medit.
49	*Callistephus chinensis* (L.) Nees	A.herb	Open forests, Roadside	Delib./Cultivated	S. Russian far East to China
50	*Carthamus tinctorius* L.	A.herb	Disturbed areas, Roadside	Delib./Cultivated	Cent. & E. Turkey to Iran
51	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Shrub	Roadside	Delib./Invasive	Trop. & Subtrop.America
52	*Coreopsis tinctoria* Nutt.	A.herb	Meadows, Roadside	Delib./Cultivated	Canada to E. Mexico
53	*Cosmos bipinnatus* Cav.	A.herb	Abandoned fields, Roadside	Delib./Casual/Naturalized	Mexico
54	*Cosmos sulphureus* Cav.	A.herb	Disturbed areas, Roadside	Delib./Casual/Naturalized	Mexico to Cent. America
55	*Crassocephalum crepidioides* (Benth.) S.Moore	A.herb	Forests	Uninten./Invasive	Trop. & S. Africa, Madagascar

56	*Dahlia pinnata* Cav.	A.herb	Disturbed areas, Roadside	Delib./Casual	Mexico
57	*Eclipta prostrata* (L.) L.	A.herb	Roadside	Uninten./Invasive	Temp. & Subtrop.America
58	*Eleutheranthera ruderalis* (Sw.) Sch.Bip.	A.herb	Roadside	Uninten./Casual/Naturalized	Trop. America
59	*Erigeron annuus* (L.) Pers.	A.herb	Abandoned fields, Roadside	Uninten./Naturalized	Canada to U.S.A., Nicaragua to Panama
60	*Erigeron bonariensis* L.	A.herb	Roadside, Wastelands	Uninten./Invasive	Mexico to Trop. America
61	*Erigeron canadensis* L.	A.herb	Railway, Roadside	Uninten./ Invasive	New World
62	*Erigeron karvinskianus* DC.	P.herb	Agric. Lands	Uninten./Invasive	Mexico to Venezuela
63	*Flaveria trinervia* (Spreng.) C.Mohr	A.herb	Waste grounds, disturbed areas	Uninten./ Invasive	Trop. & Subtrop.America
64	*Gaillardia pulchella* Foug.	A.herb	Distrubed places, grasslands	Delib./Cultivated	Central & S. U.S.A. to N. Mexico
65	*Galinsoga parviflora* Cav.	A.herb	Roadside	Uninten./Invasive	Mexico to Trop. America
66	*Galinsoga quadriradiata* Ruiz & Pav.	A.herb	Wastelands	Uninten./Invasive	Mexico to S. Trop.America
67	*Gamochaeta pensylvanica* (Willd.) Cabrera	A.herb	Disturbed areas, Roadside	Uninten./Invasive	Trop. & Subtrop.America
68	*Guizotia abyssinica* (L.f.) Cass.	A.herb	Roadside, Waste areas	Delib./Naturalized	NE. Trop. Africa
69	*Helianthus annuus* L.	A.herb	Roadside	Delib./Casual	North America

70	*Hypochaeris radicata* L.	P.herb	Disturbed areas, Grasslands	Delib./Casual/Naturalized	Europe to Caucasus
71	*Lagascea mollis* Cav.	A.herb	Waste lands, Roadside	Uninten./Invasive	Mexico to Trop.America
72	*Mikania micrantha* Kunth	Climber	Agric. Lands	Delib./Invasive	Trop. & Subtrop.America
73	*Montanoa bipinnatifida (*Kunth) K.Koch	Shrub	Roadside	Uninten./Naturalized	Mexico
74	*Parthenium hysterophorus* L.	A.herb	Roadside	Uninten./ Invasive	Trop. & Subtrop.America
75	*Soliva anthemifolia* (Juss.) R.Br.	A.herb	Fields & Lawns	Uninten./Casual/Naturalized	S. Trop.America
76	*Sonchus asper* (L.) Hill	A.herb	Roadside	Uninten./Invasive	Temp. Eurasia, N. Africa to Sahel and Somalia
77	*Sonchus oleraceus* L.	A.herb	Roadside	Uninten./Invasive	Macaronesia, Europe to Medit., Sahara to Arabian Peninsula
78	*Synedrella nodiflora* (L.) Gaertn.	A.herb	Wastelands, Roadside	Uninten./Invasive	Trop. & Subtrop.America
79	*Tagetes erecta* L.	A.herb	Roadside	Delib./Casual/Naturalized	Mexico to Guatemala
80	*Tagetes minuta* L.	A.herb	Roadside, Riverbanks	Uninten./Casual/Naturalized	Brazil to S. South America
81	*Taraxacum sect. Taraxacum* F.H.Wigg.	Shrub	Agric. Lands	Uninten./Naturalized	N. Sweden
82	*Tithonia diversifolia* (Hemsl.) A. Gray	Shrub	Agric. Lands	Delib./Invasive	Mexico to Cent.America
83	*Tithonia rotundifolia* (Mill.) S.F.Blake	A.herb	Agric. Lands, Roadsides	Delib./Naturalized	Mexico to Cent. America
84	*Tridax procumbens*	P.herb	Agric.	Uninten./Invasive	Mexico to Trop. America

	L.		Lands, Roadside		
85	*Xanthium strumarium* L.	A.herb	Roadsides	Uninten./Invasive	N. America, Peru to Brazil and S. South America
86	*Xerochrysum bracteatum* (Vent.) Tzvelev	Shrub	Roadside	Delib./Casual/Naturalized	Papua New Guinea, Australia
87	*Zinnia elegans* Jacq.	A.herb	Disturbed areas, Roadside	Delib./Casual/Naturalized	Mexico to Cent. America
88	*Zinnia peruviana* (L.) L.	A.herb	Roadside	Delib./Naturalized	S. U.S.A. to Venezuela and N. Argentina
	Boraginaceae				
89	*Heliotropium curassavicum* L.	A.herb	Meadows, Riverbanks	Uninten./Naturalized	Tropi. & Subtrop. America
90	*Heliotropium indicum* L.	A.herb	Waste areas, Roadside	Delib./Invasive	Peru to Brazil and N. Argentina
	Brassicaceae				
91	*Brassica juncea* (L.) Czern.	A.herb	Wastelands, Roadside	Delib./Casual	China
92	*Brassica napus* L.	A.herb	Disturbed areas	Delib./Cultivated	S. Europe
93	*Brassica rapa* L.	A.herb	Roadside, Riverbanks	Delib./Casual	Cent. & E. Medit. to Iran and Arabian Peninsula, NE. Trop. Africa
94	*Iberis amara* L.	A.herb	Wastelands, Roadside	Delib./Casual	W. Europe to NW. Italy
95	*Lepidium didymum* L.	A.herb	Roadside, Wastelands	Uninten./Invasive	Peru to Brazil and S. South America
96	*Lepidium virginicum* L.	A.herb	Roadside	Uninten./Casual/Naturalized	Canada to Centr.America, Caribbean
97	*Nasturtium officinale* W.T.Aiton	P.herb	Marshy ground	Uninten./Naturalized	Europe to Cent. Asia and Arabian Peninsula, Macaronesia, N. & NE. Trop. Africa

98	*Raphanus raphanistrum* L.	A.herb	Wetland	Uninten./Naturalized	Europe to Medit. and Cent.Asia
99	*Raphanus raphanistrum* subsp. *sativus* (L.) Domin	A.herb	Waste areas, Roadside	Uninten./Casual	Greece, Italy, Sicilia, Yugoslavia
	Cactaceae				
100	*Opuntia cochenillifera* (L.) Mill.	Shrub	Dry forests	Delib./Naturalized	Mexico
101	*Opuntia dillenii* (Ker Gawl.) Haw.	Shrub	Dry forests	Uninten./Invasive	Mexico, S. Jamaica
102	*Opuntia elatior* Mill.	Shrub	Agric. Lands	Uninten./Casual/Naturalized	S. Caribbean, Costa Rica to Venezuela
103	*Opuntia humifusa* (Raf.) Raf.	Shrub	Dry rocky, streams	Uninten./Casual/Naturalized	E. U.S.A., Mexico
104	*Opuntia stricta* (Haw.) Haw.	Shrub	Wastelands	Uninten./Invasive	SE. U.S.A. to E. & S. Mexico
	Calceolariaceae				
105	*Calceolaria mexicana* Benth.	A.herb	Roadside	Delib./Invasive	Mexico to Bolivia
106	*Calceolaria tripartita* Ruiz & Pav.	A.herb	Roadside	Delib./Invasive	Mexico to Peru
	Cannabaceae				
107	*Cannabis sativa* L.	A.herb	Irrigated lands	Uninten./Invasive	SE. European Russia to NW. China and Pakistan
	Cannaceae				
108	*Canna indica* L.	P.herb	Roadside	Delib./Cultivated	Trop. & Subtrop.America
	Caricaceae				
109	*Carica papaya* L.	Shrub	Disturbed areas, Roadside	Delib./Cultivated	S. Mexico to Venezuela
	Caryophyllaceae				
110	*Atocion armeria* (L.) Raf.	A.herb	Open forest	Delib./Casual	Europe to NW. Turkey
111	*Dianthus barbatus* L.	A.herb	Disturbed areas	Delib./Casual	European Mountains
112	*Drymaria cordata* (L.)	A. herb	Disturbed	Delib./Casual/Natur	Mexico to S.

	Willd. ex Schult.		areas	alized	Trop.America, Trop. & S. Africa
	Cleomaceae				
113	*Cleome rutidosperma* DC.	A.herb	Roadside	Uninten./Invasive	Cape Verde, Trop. Africa
	Convolvulaceae				
114	*Distimake aegyptius* (L.) A.R.Simões & Staples	Climber	Forest edges, Roadside	Uninten./Invasive	Trop. & Subtrop.America, Trop. Africa
115	*Evolvulus nummularius* (L.) L.	P.herb	Wastelands	Uninten./Invasive	Trop. & Subtrop. America
116	*Ipomoea alba* L.	Climber	Disturbed areas	Delib./Cultivated	Trop. & Subtrop.America
117	*Ipomoea batatas* (L.) Lam.	Climber	Disturbed areas, Roadside	Uninten./Cultivated	Mexico
118	*Ipomoea carnea* Jacq.	Shrub	Wastelands	Uninten./Invasive	Mexico to S. Trop. America
119	*Ipomoea carnea* subsp. *fistulosa* (Mart. ex Choisy) D.F.Austin	Shrub	Wastelands	Uninten./Invasive	Mexico to S. Trop.America
120	*Ipomoea hederifolia* L.	A. herb	Disturbed areas, Roadside	Uninten./Invasive	Trop. & Subtrop. America
121	*Ipomoea indica* (Burm.) Merr.	Climber	Roadside, Riverbanks	Delib./Invasive	Trop.& Subtropical America
122	*Ipomoea muricata* (L.) Jacq.	A.herb	Roadside	Uninten./Invasive	Mexico to Trop.America.
123	*Ipomoea nil* (L.) Roth	A.herb	Disturbed areas, Roadside	Uninten./Casual/Naturalized	Trop. & Subtrop. America
124	*Ipomoea purpurea* (L.) Roth	A.herb	Disturbed areas, Roadside	Delib./Invasive	Trop. & Subtrop. America
125	*Ipomoea quamoclit* L.	A.herb	Disturbed	Uninten./Invasive	Mexico to Cent. America

			areas, Roadside		
	Crassulaceae				
126	*Kalanchoe pinnata* (Lam.) Pers.	Shrub	Disturbed areas, Wasteplaces	Delib./Casual/Naturalized	Madagascar
	Cucurbitaceae				
127	*Cucurbita maxima* Duchesne	Climber	Wastelands, Cultivated area	Delib./Cultivated	Bolivia to N. Argentina
128	*Cucurbita moschata* Duchesne	Climber	Wasteland, Roadside	Delib. /Cultivated	Mexico to Guatemala
129	*Cucurbita pepo* L.	Climber	Disturbed areas, Roadside	Delib./Cultivated	Mexico
130	*Cyclanthera pedata* (L.) Schrad.	A.herb	Wastelands	Delib./Cultivated	S. Mexico to NW. Argentina
131	*Lagenaria siceraria* (Molina) Standl.	Climber	Riverside, Disturbed sites	Delib./Naturalized	W. Trop. Africa to Ethiopia and Tanzania
132	*Sicyos edulis* Jacq.	Climber	Roadside	Delib./Cultivated	Mexico to Belize
	Cyperaceae				
133	*Cyperus alternifolius* subsp. *flabelliformis* Kük.	P.grass	Roadside	Delib./Casual/Naturalized	Trop.Africa to KwaZulu-Natal, Madagascar, Arabian Peninsula
	Euphorbiaceae				
134	*Croton bonplandianus* Baill.	A.herb	Roadside, Wastelands	Uninten./Invasive	S. Bolivia to Uruguay
135	*Euphorbia heterophylla* L.	A.herb	Gardens, Roadside	Uninten./Invasive	Cent. & S. U.S.A. to Trop & Subtrop.America
136	*Euphorbia heterophylla* var. *cyathophora* (Murray) Griseb.	A.herb	Roadside, wasteareas	Delib./Invasive	Cent. U.S.A. to N. Central Argentina
137	*Euphorbia hirta* L.	A.herb	Crop fields	Uninten./Invasive	Trop. & Subtrop.America

138	*Euphorbia prostrata* Aiton	A.herb	Disturbed places, Gardens, Roadside	Uninten./Casual/Naturalized	Cent. & S. U.S.A. to Trop. & Subtrop. America
139	*Euphorbia pulcherrima* Willd. ex Klotzsch	Shrub	Gardens, roadside	Delib./Casual/Naturalized	Mexico
140	*Euphorbia thymifolia* L.	A.herb	Wastelands, roadside	Uninten./Invasive	Trop. & Subtrop. America
141	*Jatropha curcas* L.	Shrub	Wasteareas , Roadside	Delib./Naturalized	Mexico to Trop. America
142	*Jatropha multifida* L.	Shrub	Abandoned gardens, Roadside	Delib./Cultivated	Mexico, Caribbean
143	*Manihot esculenta* Crantz	Shrub	Disturbed areas	Delib./Cultivated	W. South America to Brazil
144	*Ricinus communis* L.	Shrub	Roadside, Riverbanks	Delib./Invasive	NE. Trop. Africa
145	*Triadica sebifera* (L.) Small	Tree	Agric. Lands, Roadside	Delib./Invasive	Cent. & S. China to Vietnam and Temp. E. Asia
146	*Vernicia fordii* (Hemsl.) Airy Shaw	Tree	Open areas	Delib./Cultivated	Cent. & S. China to N. Indo-China
	Fabaceae				
147	*Acacia auriculiformis* A. Cunn. ex Benth.	Tree	River banks	Delib./Planted/Naturalized	Maluku to New Guinea and N. Australia
148	*Acacia dealbata* Link	Tree	Roadside	Uninten./Naturalized	Australia
	Acacia decurrens (J.C.Wendl.) Willd.	Tree	Roadside	Delib./Cultivated	Australia (E. Central & New South Wales)
149	*Acacia mearnsii* De Willd.	Tree	Roadside	Delib./Invasive	Australia
150	*Acacia melanoxylon* R. Br.	Tree	Agric. Lands	Delib./Naturalized	Australia
151	*Aeschynomene*	Shrub	Roadside	Uninten./Invasive	Trop. & Subtrop. America

	americana L.				
152	*Arachis hypogaea* L.	A.herb	Roadside	Delib./Cultivated	Cent. Brazil
153	*Caesalpinia pulcherrima* (L.) Sw.	Shrub	Roadside	Delib./Cultivated	SE. Mexico to Cent.America
154	*Calliandra haematocephala* Hassk.	Shrub	Open areas, Roadside	Delib./Cultivated	Bolivia
155	*Canavalia ensiformis* (L.) DC.	Climber	Disturbed areas	Delib./Cultivated	Trop. & Subtrop.America
156	*Cassia javanica* L.	Tree	Roadside	Delib./Casual/Naturalized	Malesia to Papuasia
157	*Christia vespertilionis* (L.f.) Bakh. f.	A.herb	Open areas	Delib./Cultivated	S. China to Trop. Asia
158	*Cicer arietinum* L.	A.herb	Disturbed areas, Roadside	Delib./Cultivated	Iran, Iraq
159	*Clitoria ternatea* L.	Climber	Grasslands, Disturbed forests	Delib./Naturalized	Cape Verde, Trop. & S. Africa, Arabian Peninsula
160	*Crotalaria micans* Link	Shrub	Roadside	Delib./Naturalized	S. Mexico to Trop.America
161	*Cytisus scoparius* (L.) Link	A.herb	Disturbed areas, Roadside	Uninten./Invasive	Europe
162	*Delonix regia* (Bojer ex Hook.) Raf.	Tree	Waste areas, Roadside	Delib./Casual/Naturalized	Madagascar
163	*Desmanthus virgatus* (L.) Willd.	Shrub	Roadside	Delib./Invasive	Texas to S. America
164	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Shrub	Abandoned fields, Roadside	Delib./Naturalized	Mexico to Colombia
165	*Glycine max* (L.) Merr.	A.herb	Cultivated areas, Roadside	Delib./Cultivated	China to Temp. E. Asia
166	*Laburnum*	Shrub	Disturbed	Delib./Cultivated	Cent. & SE. Europe

	anagyroides Medik.		areas, Meadows		
167	*Lathyrus odoratus* L.	A.herb	Disturbed areas, Roadside	Delib./Naturalized	S. Italy, Sicilia
168	*Lathyrus oleraceus* Lam.	A.herb	Forests margins, Meadows	Delib./Casual	Medit. to Afghanistan
169	*Lathyrus sativus* L.	A.herb	Crop fields, Roadside	Uninten./Casual/Naturalized	Bulgaria, Yugoslavia
170	*Leucaena leucocephala* subsp. *leucocephala*	Shrub	Roadside	Uninten./Cultivated	Mexico to Belize
171	*Lysiloma latisiliquum* (L.) Benth.	Tree	Wastelands, Roadside	Uninten./Invasive	S. Mexico, Florida to Cuba
172	*Macroptilium atropurpureum* (DC.) Urb.	A. herb	Roadsides, Wastelands	Uninten./Invasive	Mexico to W. South America and Tobago
173	*Macroptilium lathyroides* (L.) Urb.	A.herb	Pastures, Roadside	Uninten./Invasive	Trop. & Subtrop.America
174	*Mimosa pudica* L.	Shrub	Forests	Uninten./Invasive	Brazil
175	*Pachyrhizus erosus* (L.) Urb.	Shrub	Roadside	Delib./Casual/Naturalized	Mexico to Cent. America
176	*Parkia biglandulosa* Wight &Arn.	Tree	Roadside	Delib./Cultivated	Bangladesh to Myanmar
177	*Peltophorum pterocarpum* (DC.) Backer ex K.Heyne	Tree	Disturbed Forest	Delib./Cultivated	Indo-China to N. Australia
178	*Phaseolus lunatus* L.	Climber	Disturbed sites, Grasslands	Delib./Cultivated	Mexico
179	*Phaseolus vulgaris* L.	A.herb	Wetland	Delib./Cultivated	Mexico
180	*Pithecellobium dulce* (Roxb.) Benth.	Shrub	Roadside	Delib./Invasive	Mexico to Guyana and Peru
181	*Prosopis juliflora*	Shrub	Roadside	Uninten./Invasive	Mexico to Venezuela,

	(Sw.) DC.				Peru, Caribbean
182	*Psophocarpus tetragonolobus* (L.) DC.	A.herb	Roadside	Delib./Cultivated	Cultigen from E. Trop. Africa
183	*Samanea saman* (Jacq.) Merr.	Tree	Roadside	Delib./Casual/Naturalized	Cent. America to Venezuela and Ecuador
184	*Senna alata* (L.) Roxb.	Shrub	Roadside	Delib./Invasive	SW. Mexico to Trop.America
185	*Senna bicapsularis* (L.) Roxb.	Shrub	Roadside	Delib./Casual/Naturalized	Trop.America
186	*Senna hirsuta* (L.) H.S.Irwin & Barneby	A.herb	Degraded land ,Roadside	Uninten./Invasive	Trop. & Subtrop. America
187	*Senna occidentalis* (L.) Link	Shrub	Wastelands	Uninten./Invasive	Trop. & Subtrop.America
188	*Senna spectabilis (*DC.) H.S. Irwin & Barneby	Shrub	Forest areas	Delib./Cultivated	SW. Mexico to S. Trop. America
189	*Senna septemtrionalis* (Viv.) H.S.Irwin & Barneby	Shrub	Disturbed areas, Roadside	Delib./Naturalized	Mexico to Cent.America
190	*Senna siamea* (Lam.) H.S.Irwin & Barneby	Tree	Roadside	Delib./Cultivated	Sri Lanka, Indo-China
191	*Senna sophera* (L.) Roxb.	Shrub	Wastelands	Uninten./Casual/Naturalized	Trop. America
192	*Senna tora* (L.) Roxb*.*	A.herb	Wastelands	Uninten./Invasive	Cent. America
193	*Sesbania grandiflora* (L.) Poir*.*	Shrub	Forest edges	Delib./Cultivated	Malesia to New Guinea
194	*Spartium junceum* L.	Shrub	Grasslands	Delib./Cultivated	Azores, S. Europe to E. Medit.
195	*Tamarindus indica* L.	Tree	Open area	Delib./Casual/Naturalized	Madagascar
196	*Trifolium dubium* Sibth.	A.herb	Cultivated areas	Delib./Naturalized	Macaronesia, Europe to Medit. and Caucasus
197	*Trigonella foenum-graecum* L.	A.herb	Agric. Lands,	Delib./Cultivated	Iraq to Afghanistan

			Roadside		
198	*Ulex europaeus* L.	Shrub	Roadside	Uninten./Invasive	W. & Cent. Europe, Algeria
199	*Vachellia farnesiana* (L.) Wight &Arn.	Tree	Roadside	Uninten./Invasive	Trop. & Subtrop.America
200	*Vicia lens* (L.) Coss. & Germ.	A.herb	Agric. Lands	Delib./Cultivated	Medit. to Pakistan
201	*Vigna unguiculata* (L.) Walp.	A.herb	Cultivated areas	Delib./Cultivated	Cent. America
202	*Wisteria sinensis* (Sims) DC.	Climber	Roadside	Delib./Casual	Cent. & S. China
	Fagaceae				
203	*Castanea sativa* Mill.	Tree	Roadside	Delib./Cultivated	Southern Europe
	Francoaceae				
204	*Melianthus major* L.	Shrub	Open areas	Delib./Naturalized	Cape Prov.
	Hydrangeaceae				
205	*Hydrangea macrophylla* (Thunb.) Ser.	Shrub	Forest margins, Stream banks	Delib./Casual	S. Central Japan to Izu-shima, Kazan-retto
	Iridaceae				
206	*Cipura paludosa* Aubl.	A.herb	Dry areas in pastures	Delib./Naturalized	Mexico to Trop. America
207	*Eleutherine bulbosa* (Mill.) Urb.	P.herb	Grown in gardens	Delib./Casual/Naturalized	Caribbean to S. Trop. America
208	*Gladiolus undulatus* L.	A.herb	Disturbed areas	Delib./Casual/Naturalized	SW. Cape Prov
209	*Iris japonica* Thunb.	P.herb	Hillsides, Meadows	Delib./Naturalized	China & Japan
210	*Iris tectorum* Maxim.	P.herb	Wetland	Delib./Naturalized	China
	Lamiaceae				
211	*Coleus scutellarioides* (L.) Benth.	A.herb	Disturbed areas	Delib./Casual/Naturalized	Indo-China to Nansei-shoto and N. Australia
212	*Mesosphaerum*	A.herb	Roadside	Uninten./Invasive	Mexico to Trop. America

	suaveolens (L.) Kuntze				
	Lauraceae				
213	*Cinnamomum camphora* (L.) J. Presl	Tree	Roadside	Delib./Cultivated	Korea, W. Cent.& S. Japan to E. & S. Taiwan
214	*Persea americana* Mill.	Tree	Roadside	Delib./Cultivated	Mexico
	Linaceae				
215	*Linum usitatissimum* L.	A.herb	Gardens, Roadsides	Delib./Casual	Turkey to Iran
	Malvaceae				
216	*Alcea rosea* L.	A.herb	Roadsides, Waste areas	Delib./Casual	Turkey
217	*Gossypium barbadense* L.	Shrub	Agric. Lands	Delib./Cultivated	Colombia to Peru
218	*Gossypium hirsutum* L.	Shrub	Agric. Lands	Delib./ Cultivated	Mexico to Ecuador and NE. Brazil
219	*Hibiscus cannabinus* L.	A.herb	Pastures, Roadside	Delib./Cultivated	Trop.& S. Africa, SW. Arabian Peninsula
220	*Hibiscus mutabilis* L.	Shrub	Disturbed sites , Waste areas	Uninten./Cultivated	S. China, Taiwan
221	*Hibiscus sabdariffa* L.	Shrub	Disturbed ground	Delib./Casual/Naturalized	W. Trop. Africa to Sudan
222	*Hibiscus schizopetalus (*Mast.) Hook.f.	Shrub	Gardens, Roadside	Delib./Cultivated	SE. Kenya to E. Tanzania
223	*Hibiscus syriacus* L.	Shrub	Hillsides, Roadside	Delib./Cultivated	S. China, Taiwan
224	*Malachra capitata* (L.) L.	A.herb	Wastelands	Uninten./Invasive	Trop. & Subtrop. America
225	*Malva parviflora* L.	A.herb	Waste places	Delib./Casual/Naturalized	Macaronesia, Medit. to Pakistan and Sahara

226	*Malvastrum coromandelianum* (L.) Garcke	A.herb	Roadside	Uninten./Invasive	New World
227	*Malvaviscus arboreus* Dill. ex Cav.	Shrub	Disturbed areas, Riversides	Delib./Cultivated	Mexico to Trinidad and Peru
228	*Waltheria indica* L.	P.herb	Roadside	Uninten./Invasive	Tropical & Subtropical America
	Martyniaceae				
229	*Martynia annua* L.	A.herb	Roadside	Delib./Invasive	Mexico to Cent. America, Caribbean
	Melastomataceae				
230	*Miconia crenata* (Vahl) Michelang.	A.herb	Roadside	Uninten./Invasive	Mexico to Trop.America
	Meliaceae				
231	*Swietenia mahagoni* (L.) Jacq.	Tree	Forests	Delib./Naturalized	S. Florida to Caribbean
	Myrtaceae				
232	*Melaleuca citrina* (Curtis) Dum.Cours.	Shrub	Roadside	Delib./Casual/Naturalized	Australia
233	*Psidium guajava* L.	Shrub	Forests edges	Delib./Naturalized	Trop. & Subtrop. America
	Nyctaginaceae				
234	*Boerhavia erecta* L.	P.herb	Roadside, wasteareas	Uninten./Casual/Naturalized	Trop. & Subtrop.America
235	*Bougainvillea glabra* Choisy	Climber	Roadside	Delib./Casual/Naturalized	E. & S. Brazil
236	*Bougainvillea spectabilis* Willd.	Shrub	Disturbed areas, Roadside	Delib./Casual/Naturalized	E. & S. Brazil
237	*Mirabilis jalapa* L.	A.herb	Wastelands	Delib./Invasive	Mexico to Cent. America
	Onagraceae				
238	*Ludwigia hyssopifolia* (G.Don) Exell	A.herb	Roadside	Delib./Casual/Naturalized	S. Mexico to Trop. America
239	*Oenothera rosea* L'Hér. ex Aiton	A.herb	Open areas	Uninten./Casual/Naturalized	S. U.S.A. to W. & S. South America, Cuba,

					Jamaica
	Oxalidaceae				
240	*Averrhoa carambola* L.	Tree	Roadside	Delib./Cultivated	Central & E. Jawa to Maluku
241	*Oxalis corniculata* L.	P.herb	Crop fields	Uninten./Invasive	Mexico to Venezuela and Peru, Caribbean
242	*Oxalis debilis* Kunth	P.herb	Roadside	Delib./Invasive	Cent. America to Guyana and Paraguay
243	*Oxalis latifolia* Kunth	P.herb	Roadside	Delib./Invasive	Trop. & Subtrop.America
	Papaveraceae				
244	*Argemone mexicana* L.	A.herb	Wastelands	Uninten./Invasive	Cent.Mexico to Honduras
245	*Argemone ochroleuca* Sweet	A.herb	Roadside, Wastelands	Uninten./Invasive	Mexico
246	*Papaver somniferum* L.	A.herb	Agric. Lands, roadside	Delib./Casual/Naturalized	W. Medit.
	Passifloraceae				
247	*Passiflora edulis* Sims	Climber	Forests edges	Delib./Casual/Naturalized	Brazil to NE. Argentina
248	*Passiflora foetida* L.	A.herb	Wastelands	Uninten./Invasive	Trop.& Subtrop. America
249	*Turnera subulata* Sm.	P.herb	Agric. Lands	Delib./Invasive	Windward Islands to S. Trop. America
	Phyllanthaceae				
250	*Phyllanthus acidus* (L.) Skeels	Tree	Roadside	Delib./Planted	Brazil (Pará)
251	*Phyllanthus tenellus* Roxb.	A.herb	Roadside	Uninten./Invasive	Tanzania to Mozambique, SW. Arabian Peninsula, W. Indian Ocean
	Piperaceae				
252	*Peperomia pellucida* (L.) Kunth	A.herb	Roadside	Uninten./Invasive	Trop. & Subtrop. America, Trop. Africa, Madagascar
253	*Piper betle* L.	Climber	Roadside	Delib./Naturalized	Indo-China to Malesia
	Plantaginaceae				
254	*Antirrhinum majus* L.	A.herb	Roadside, Waste	Delib./Casual	Baleares, E. Pyrenees, NE. Spain, S. Central

			areas		France
255	*Cymbalaria muralis* G.Gaertn., B.Mey. &Scherb.	A.herb	Disturbed areas, Wasteplaces	Delib./Casual/Naturalized	S. Alps
256	*Mecardonia procumbens* (Mill.) Small	A.herb	Roadside	Uninten./Invasive	Trop. & Subtrop.America
	Poaceae				
257	*Anthoxanthum odoratum* L.	P.grass	Roadside	Delib./Naturalized	Macaronesia, Europe to Mongolia, NW. Africa
258	*Avena sativa* L.	A.herb	Abandoned fields, Roadside	Delib./Casual	Europe
259	*Axonopus compressus* (Sw.) P.Beauv.	Pgrass	Roadside	Delib./Casual/Naturalized	Trop. & Subtrop. America
260	*Bromus catharticus* Vahl	A.grass	Cultivated fields	Uninten./Casual/Naturalized	Venezuela to S. South America
261	*Cenchrus americanus* (L.) Morrone	A.grass	Wastelands	Delib./Casual/Naturalized	Trop. Africa
262	*Cenchrus clandestinus* (Hochst. ex Chiov.) Morrone	P.grass	Grasslands, Disturbed areas	Delib./Naturalized	Eritrea to S. Trop.Africa
263	*Cenchrus purpureus* (Schumach.) Morrone	A.grass	Forests	Delib./Invasive	Sahara to Trop. Africa, Aldabra, Arabian Peninsula
264	*Chloris gayana* Kunth	P.grass	Grasslands, Disturbed areas	Delib./Casual/Naturalized	Macaronesia, Tropical & S. Africa, Arabian Peninsula
265	*Eleusine coracana* (L.) Gaertn.	A.herb	Roadside	Delib./Cultivated	Africa and Asia
266	*Hordeum vulgare* L.	A.herb	Grassland areas, Meadows	Delib./Casual	Cultigen from Israel

267	*Imperata cylindrica* (L.) P.Beauv.	P.grass	Wastelands	Uninten./Invasive	Trop. America
268	*Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs	P.grass	Agric. Lands	Delib./Naturalized	Trop. & S. Africa, W. Indian Ocean, Arabian Peninsula
269	*Melinis minutiflora* P. Beauv.	P.grass	Forest edges	Uninten./Casual	Trop. & S. Africa, Madagascar
270	*Paspalum dilatatum* Poir.	P.grass	Roadside, Agric. Lands	Uninten./Naturalized	SE. & S. Brazil to S. South America
271	*Paspalum notatum* Flugge	P.grass	Forests edges, roadside	Uninten./Naturalized	Peru to Brazil and N. Argentina
272	*Saccharum officinarum* L.	P.grass	Waste areas, Roadside	Uninten./Cultivated	New Guinea
273	*Setaria italica* (L.) P. Beauv.	A.herb	Roadside	Delib./Cultivated	China
274	*Setaria sphacelata* (Schumach.) Stapf &C.E.Hubb. ex Moss	P.grass	Roadside	Uninten./Casual/Naturalized	Trop. & S. Africa, Madagascar
275	*Sorghum bicolor* (L.) Moench	P.grass	Open pastures	Delib./Casual/Naturalized	West Asia
276	*Urochloa brizantha* (A.Rich.) R.D.Webster	P.grass	Roadside	Delib./Casual/Naturalized	Trop. & S. Africa, W. Indian Ocean, SW. Arabian Peninsula
277	*Zea mays* L.	A.herb	Roadside	Delib./Cultivated	Cent. & SW. Mexico to W. Guatemala
	Polygonaceae				
278	*Antigonon leptopus* Hook. &Arn.	Shrub	Disturbed areas	Uninten./Invasive	Mexico to Cent.America
279	*Fagopyrum esculentum* Moench	A.herb	Wasteareas, Roadside	Uninten./Casual	E. Tibet to China
280	*Rumex acetosella* L.	P.herb	Roadside	Delib./Naturalized	Temp. Eurasia

	Pontederiaceae				
281	*Pontederia crassipes* Mart.	P.herb	Aquatic	Delib./Invasive	S. Trop.America
	Portulacaceae				
282	*Portulaca oleracea* L.	A.herb	Roadside	Uninten./Invasive	Macaronesia, Trop. Africa, Medit. to Pakistan and Arabian Peninsula
	Ranunculaceae				
283	*Delphinium ambiguum* L.	A.herb	Garden, Roadside	Delib./Cultivated	S. Iberian Peninsula, NW. Africa
	Rosaceae				
284	*Chaenomeles lagenaria* (Loisel.) Koidz.	Shrub	Wastelands	Delib./Cultivated	China
285	*Eriobotrya japonica* (Thunb.) Lindl.	Tree	Roadside	Delib./Cultivated	China (Chongqing, Hubei)
286	*Malus domestica* (Suckow) Borkh.	Shrub	Roadside	Delib./Cultivated	Afghanistan to Cent.Asia and NW. China
287	*Prunus domestica* L.	Tree	Roadside	Delib./ Cultivated	Turkey
288	*Prunus persica* (L.) Batsch	Tree	Forest edges, Roadside	Delib./Cultivated	N. Cent. China
289	*Pyrus communis* L.	Tree	Agric. Lands	Delib./Cultivated	Europe to N. Iraq
	Rubiaceae				
290	*Mitracarpus hirtus* (L.) DC.	A.herb	Roadside	Uninten./Casual/Naturalized	Mexico to Trop. America
291	*Spermacoce latifolia* Aubl.	A.herb	Roadside	Uninten./Invasive	Mexico to Trop. America
	Rutaceae				
292	*Citrus* × *aurantiifolia* (Christm.) Swingle	Shrub	Roadside	Delib./Cultivated	Artificial hybrid
293	*Citrus* × *aurantium* L.	Shrub	Roadside	Delib./Cultivated	Artificial hybrid

	Salicaceae				
294	*Salix babylonica* L.	Tree	Wastelands, Roadside	Delib./Naturalized	N. & E. China to Korea
	Scrophulariaceae				
295	*Scoparia dulcis* L.	A.herb	Wasteareas	Uninten./Invasive	Trop.& Subtrop.America
	Solanaceae				
296	*Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Sweet	Shrub	Forest edges	Uninten./Naturalized	Brazil (S. Bahia to N. Rio Grande do Sul)
297	*Brunfelsia pauciflora* (Cham. & Schltdl.) Benth.	Shrub	Roadside	Delib./Cultivated	Brazil (Rio de Janeiro to Santa Catarina)
298	*Capsicum annuum* L.	P.herb	Roadside	Uninten./Cultivated	South and Cent.America
299	*Capsicum frutescens* L.	P.herb	Forests edges, Roadside	Delib./Cultivated	Bolivia to Brazil
300	*Cestrum aurantiacum* Lindl.	Shrub	Roadside	Delib./Cultivated	Mexico to Venezuela
301	*Cestrum elegans* (Brongn. ex Neumann) Schltdl.	Shrub	Roadside	Delib./Cultivated	Mexico
302	*Cestrum fasciculatum* (Schltdl.) Miers	Shrub	Wasteareas	Delib./Naturalized	Mexico
303	*Cestrum nocturnum* L.	Shrub	Disturbed areas	Delib./Casual/Naturalized	Mexico to Venezuela
304	*Cestrum parqui* (Lam.) L'Hér.	Shrub	Roadside	Delib./Cultivated	Bolivia to Brazil and S. South America.
305	*Datura metel* L.	Shrub	Wastelands	Uninten./Invasive	Texas to Colombia
306	*Datura stramonium* L.	Shrub	Roadside	Uninten./Invasive	Texas to Cent. America, Caribbean
307	*Nicandra physalodes* (L.) Gaertn.	A.herb	Waste areas, Roadside	Delib./Invasive	Peru to NW. Argentina
308	*Nicotiana*	A.herb	Wastelands	Uninten./Invasive	Mexico to Guatemala

	plumbaginifolia Viv.				
309	*Nicotiana rustica* L.	A.herb	Wetland	Uninten./Cultivated	Peru
310	*Nicotiana tabacum* L.	A.herb	Forests, wetlands	Delib./Casual/Naturalized	Bolivia
311	*Physalis angulata* L.	A.herb	Disturbed areas, Roadside	Uninten./Invasive	Trop.& Subtrop.America
312	*Physalis heterophylla* Nees	A.herb	Disturbed areas, Roadside	Uninten./Cultivated	N. America
313	*Physalis peruviana* L.	A.herb	Forests edges	Uninten./Casual/Naturalized	Bolivia to W. Brazil
314	*Solanum americanum* Mill.	A.herb	Cultivated & Disturbed areas	Delib./Invasive	New World
315	*Solanum anguivi* Lam.	Shrub	Disturbed areas	Uninten./Casual/Naturalized	Trop. & S. Africa, Comoros, Madagascar
316	*Solanum asperolanatum* Ruiz & Pav.	Shrub	Forest edges	Uninten./Naturalized	Mexico to Guatemala, W. South America
317	*Solanum betaceum* Cav.	Shrub	Forests	Delib./Cultivated	S. Trop. America
318	*Solanum lycopersicum* L.	A.herb	Cultivated lands	Delib./Cultivated	Peru
319	*Solanum melongena* L.	Shrub	Cultivated lands	Delib./Cultivated	Trop. Africa
320	*Solanum myriacanthum* Dunal	Shrub	Open area	Uninten./Casual/Naturalized	Mexico to Cent. America
321	*Solanum seaforthianum* Andrews	Climber	Wastelands	Delib./Invasive	Florida to Caribbean, Mexico to Venezuela, Brazil
322	*Solanum sisymbriifolium* Lam.	Shrub	Roadside	Uninten./Casual/Naturalized	S. Trop. America
323	*Solanum torvum* Sw.	Shrub	Forests	Uninten./Invasive	Mexico to N. South America, Caribbean, E. Brazil

324	*Solanum tuberosum* L.	A.herb	Agric. Lands	Delib./Casual	S. America
325	*Solanum viarum* Dunal	A.herb	Forests	Uninten./Invasive	Colombia, Bolivia to Brazil and N. Argentina
	Theaceae				
326	*Camellia sinensis* (L.) Kuntze	Shrub	Abandoned plantations	Delib./Casual/Naturalized	China
	Tropaeolaceae				
327	*Tropaeolum majus* L.	A.herb	Roadside	Delib./Cultivated	Peru
	Urticaceae				
328	*Pilea microphylla* (L.) Liebm.	A.herb	Forest edges & riparian areas	Uninten./Invasive	Mexico to N. South America and Peru, SE. U.S.A. to Caribbean
	Verbenaceae				
329	*Lantana camara* L.	Shrub	Roadside, Waste lands	Delib./Invasive	Mexico to Trop.America
330	*Lippia alba* (Mill.) N.E.Br. ex Britton & P.Wilson	Shrub	Roadsides, Wastelands	Delib./Casual/Naturalized	Trop.& Subtrop.America
331	*Stachytarpheta cayennensis* (Rich.) Vahl	P.herb	Open field like pastures	Delib./Invasive	S. Mexico to Trop.America
332	*Stachytarpheta jamaicensis* (L.) Vahl	P.herb	Roadside	Uninten./Invasive	SE. U.S.A. to Trop.America
333	*Verbena rigida* Spreng.	P.herb	Agric. Lands	Delib./Casual/Naturalized	Bolivia to Uruguay
	Vitaceae				
334	*Vitis vinifera* L.	Climber	Agric. Lands	Delib./Casual/Naturalized	S. Cent. & SE. Europe to Cent. Asia and N. Iran

Phytosociological Study

In **Sikkim** at the lower gradient between **600m-900m**, it was observed that ***Ageratina adenophora*** exhibited highest frequency (100%) while lowest frequency was observed in ***Lantana camara*** (25%) along with other associates. The density (34.66 ind./100m^2), basal cover (6.61 cm^2/100m^2) and IVI (104.91) values of ***Ageratina adenophora*** observed highest. while Lowest density was observed in

Lantana camara (10.6 ind./100m^2), but Highest basal cover and highest Importance value index (IVI) was observed in *Lantana camara (*0.222 cm^2/m^2) and (68.26) respectively, however the lowest basal cover and IVI was exhibited in ***Mikania micrantha*** (0.006cm^2/m^2) ***Chromolaena odorata*** that is 36.***Ageratina adenophorum*** showed highest frequency (90.9%), highest density (35.45 ind./100m2), highest IVI (63.33) and basal cover (3.68 cm^2/100m^2) along with other associate at **900m-1200m** altitude, while ***Mikania micrantha,*** *was* exhibited minimum values.

At the gradient **1200m-1500m** ***Ageratina adenophora*** exhibited highest frequency (90%) with highest density (33.60 ind./100m^2) and highest IVI value (76.57), while ***Lantana camara*** showed highest basal cover (15.70 cm^2/m^2) along with other associates. In this altitude the lowest values were observed in ***Mikania micrantha****.*

At the higher altitudes between **1500m-1800m**, ***Ageratina adenophora*** represented highest frequency (100%), highest density (40.52 ind./100m^2), basal cover (9.86cm^2/m^2) and highest IVI (87.69) along with other prominent associates, while ***Chromolena odorata*** showed minimum values. At **1800m- 2100m**, ***Ageratina adenophora*** represented highest frequency (100%), highest density (31.48 ind./100m^2), highest basal cover (8.45 cm^2/m^2) and highest IVI (71.19) value respectively, however other three targeted species were not found during study at this gradient.

Ageratina adenophora exhibited highest frequency (83.33%) with highest density (21.33 ind./100m^2), highest basal cover (10.18cm2/m2) and highest IVI value (92.04) along with other associates, ***Lantana camara***, ***Mikania micrantha*** and ***Chromolena odorata*** were not found during survey at this high altitudinal gradient in between **2100m-2400m**.

At **2400m-2700m** gradient, ***Ageratina adenophora*** showed higest values fallowed by ***Chromolena odorata.***

In **Darjeeling** very few number of plots was laid in between **1500m to 2100m** altitudinal gradient. there were ***Ageratina adenophora*** noticed with highest values followed by other associates there were no other targeted species found during field survey***.***

Table 2. Phytosociological attributes of different plant species at 600 m-900 m altitudinal gradient.

Sl NO.	**Name of Species**	**frequency (%)**	**Density (ind./100m^2)**	**Basal cover(cm2/100m2)**	**IVI**
1	***Ageratina adenophora***	**100.00**	**34.67**	**6.62**	**104.92**
2	*Ageratum*	83.33	26.33	1.24	50.49
12	*Polygonum sp.*	41.67	8.00	0.22	17.53
7	*Oxyspora peniculata*	25.00	4.33	0.99	17.07
4	*Bidens*	33.33	4.67	0.60	15.92
5	***Lantana camara***	**8.33**	**1.33**	**1.25**	**13.02**

3	***Mikania micrantha***	**25.00**	**5.00**	**0.17**	**10.96**
6	*Polygonum sp.*	16.67	3.00	0.04	6.41
13	*Crassocephalum crepidiodes*	16.67	2.00	0.13	6.34
8	*Thysanolaena maxima*	8.33	0.67	0.40	5.60

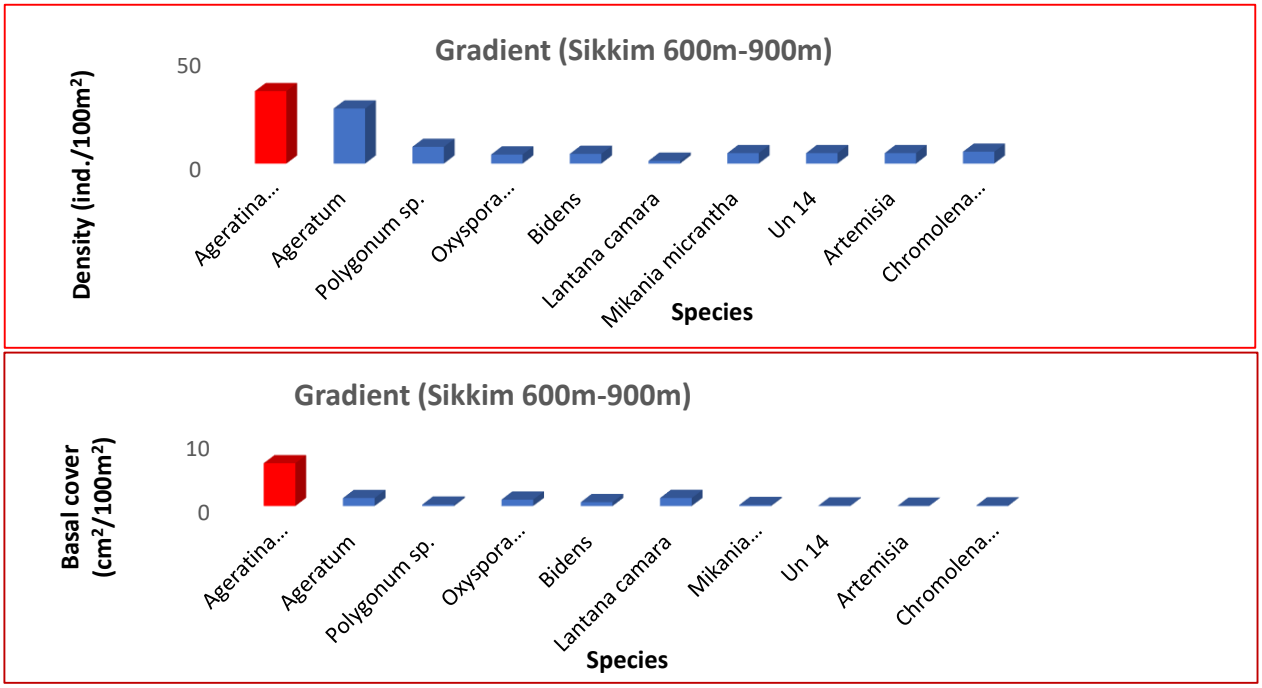


Fig. 8. Phytosociological attributes of different plant species at 600 m-900 m altitudinal gradient.

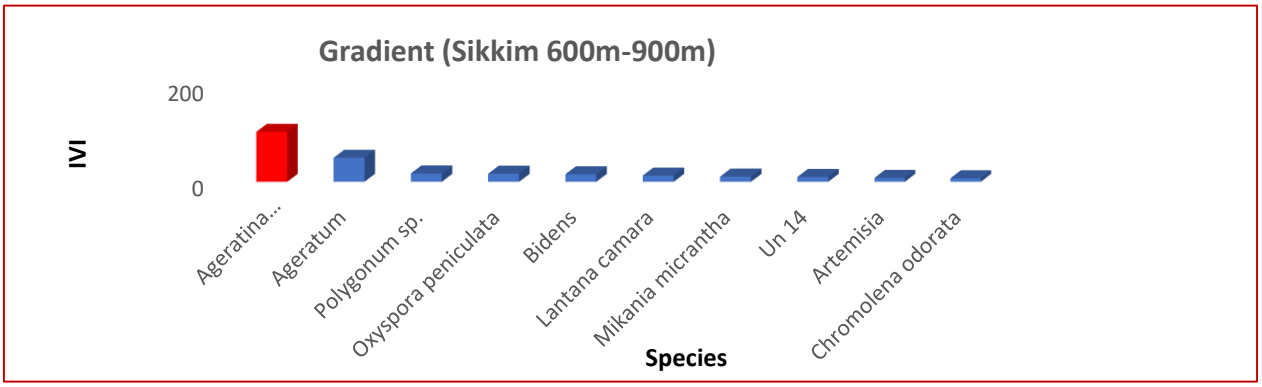


Table 3 . Phytosociological attributes of different plant species at 900 m-1200 m altitudinal gradient.

Sl NO.	**Name of Species**	**frequency (%)**	**Density (ind./100m²)**	**Basal cover(cm²/100m²)**	**IVI**
1	***Ageretina adenophora***	**90.90**	**35.45**	**3.68**	**63.33**
10	*Justicia adhathoda*	13.63	1.45	15.97	56.43
8	*Pilea scripta (Small)*	59.09	14.54	1.30	29.88

2	*Ageratum*	54.54	15.09	0.42	26.52
	Chromlaena odorata	**31.81**	**9.27**	**1.32**	**19.43**
9	*Artemisia vulgaris*	13.63	2.36	3.47	16.38
3	*Bidens*	40.90	6.18	0.61	16.20
16	*Polygonum sp.*	31.81	5.45	0.15	12.12
7	***Lantana camara***	**4.54**	**0.72**	**2.35**	**9.32**
6	***Mikania micrantha***	**4.54**	**1.09**	**0.01**	**1.99**

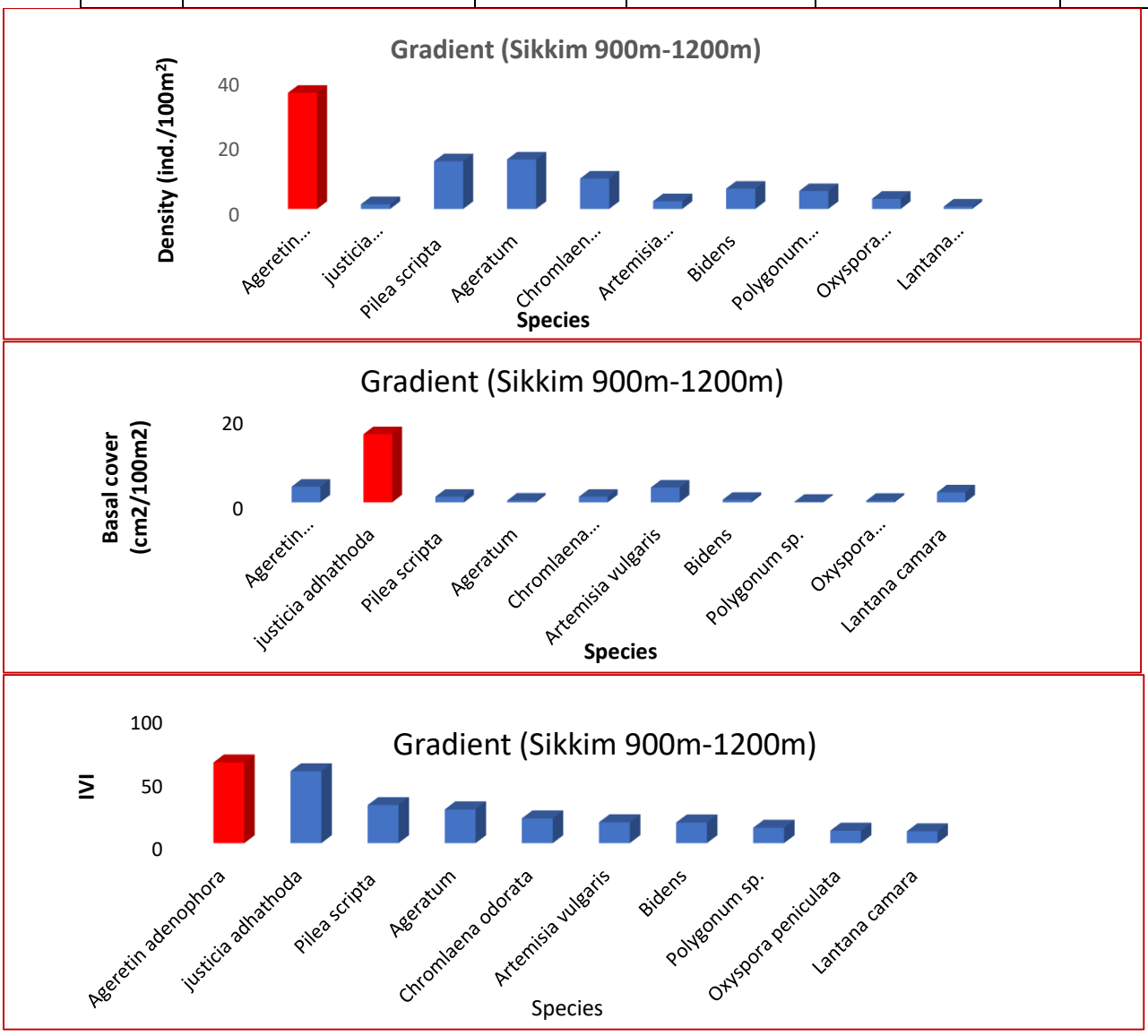


Fig. 9. Phytosociological attributes of different plant species at 900 m-1200 m altitudinal gradient.

Table-4. Phytosociological attributes of different plant species at 1200 m-1500 m altitudinal gradient.

SI NO.	Name of Species	frequency	Density	Basal	IVI

		(%)	(ind./100m^2)	cover(cm^2/100m^2)	
1	***Ageretina adenophora***	**90**	**33.6**	**11.25**	**76.57**
7	***Lantana camara***	**15**	**2.6**	**15.70**	**32.53**
3	*Bidens*	40	10.2	4.82	28.712
9	*Artemisia vulgaris*	20	2	11.11	25.51
2	*Ageratum*	25	6	2.24	16.26
18	*Oxyspora peniculata*	20	2.8	3.69	14.04
5	***Chromlaena odorata***	**20**	**5.6**	**1.83**	**13.93**
4	*Artemesia nilagirca*	10	2.4	1.03	6.73
6	***Mikania micrantha***	**5**	**1.4**	**0.05**	**2.80**
8	*Pilea scripta*	10	2.6	1.03	6.94

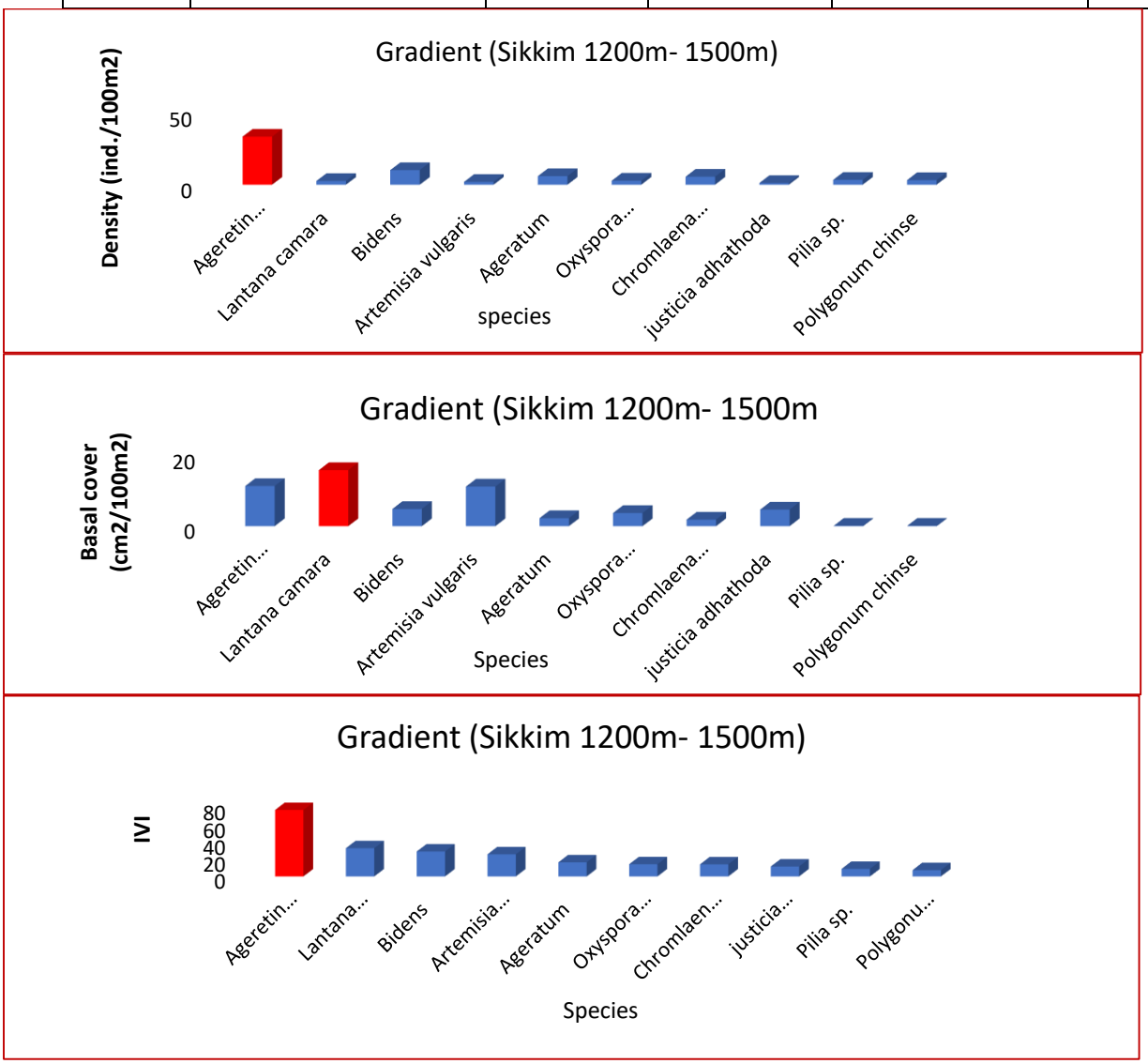


Fig. 10. Phytosociological attributes of different plant species at 1200 m –1500 m altitudinal gradient.

Table 5. Phytosociological attributes of different plant species at 1500 m–1800 m altitudinal gradient.

Sl NO.	**Name of Species**	**frequency (%)**	**Density (ind./100m^2)**	**Basal cover(cm^2/100m^2)**	**IVI**
1	***Ageratina adenophora***	**100**	**40.52**	**9.86**	**87.69**
7	*Oxyspora peniculata*	31.15	4.72	3.34	18.89
12	*Artemisia vulgaris*	32.79	6.1	1.36	17.46
4	*Bidens*	31.15	5.77	1.34	16.65
15	*Giardinia diversifolia*	8.2	1.64	6.69	15.36
13	*Pilia scripta*	26.23	4.59	0.56	12.74
21	*Rubus ellipticus*	14.75	1.77	3.69	12.02
2	*Ageratum*	16.39	2.95	1.17	9.46
6	***Chromolena odorata***	**6.56**	**1.44**	**0.97**	**4.93**
3	*Melissa axillaris*	6.56	1.31	0.63	4.21

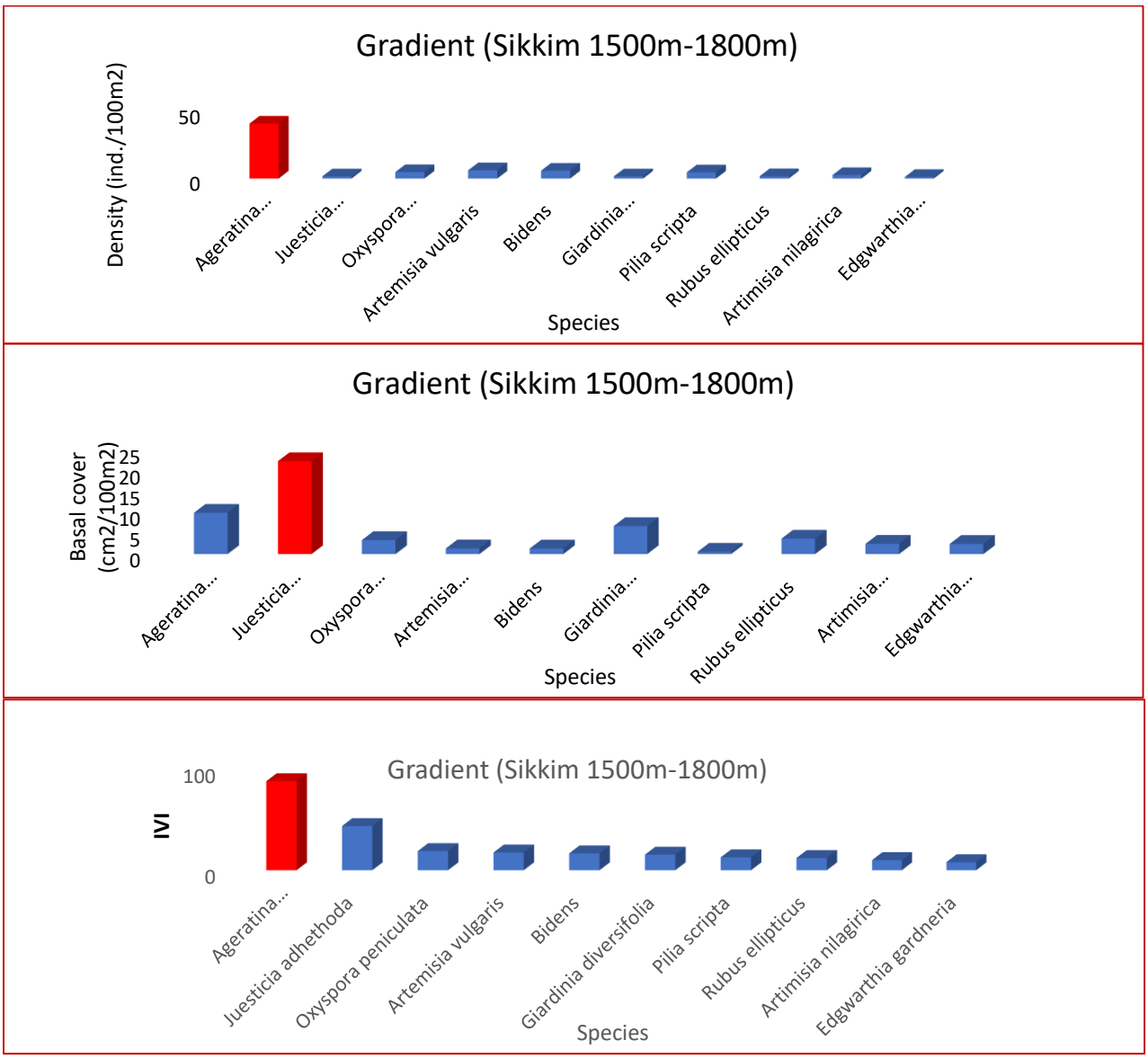


Fig.11 Phytosociological attributes of different plant species at 1500 m–1800 m altitudinal gradient.

Table 6. Phytosociological attributes of different plant species at 1800 m–2100 m altitudinal gradient.

SI NO.	Name of Species	frequency (%)	Density (ind./100m^2)	Basal cover(cm^2/100m^2)	IVI
1	***Ageretina aadenophora***	**100**	**31.467**	**8.453**	**71.192**
5	*Melissa axillaris*	33.33	9.06	0.11	19.60
6	*Pillia small*	20	12	0.13	19.23
3	*Bidens*	20	6.66	1.44	14.42
17	*Oxyspora peniculata*	26.66	2.93	2.53	13.08
9	*Artemisia vulgaris*	26.66	3.2	1.74	12.64

8	*Giardinia diversifolia*	6.66	0.8	8.99	11.13
2	*Ageratum*	13.33	3.2	1.37	8.60
10	*Laportea interupta*	13.33	3.46	1.78	9.27
4	*Artemesia nilagirca*	13.33	1.6	1.75	7.14

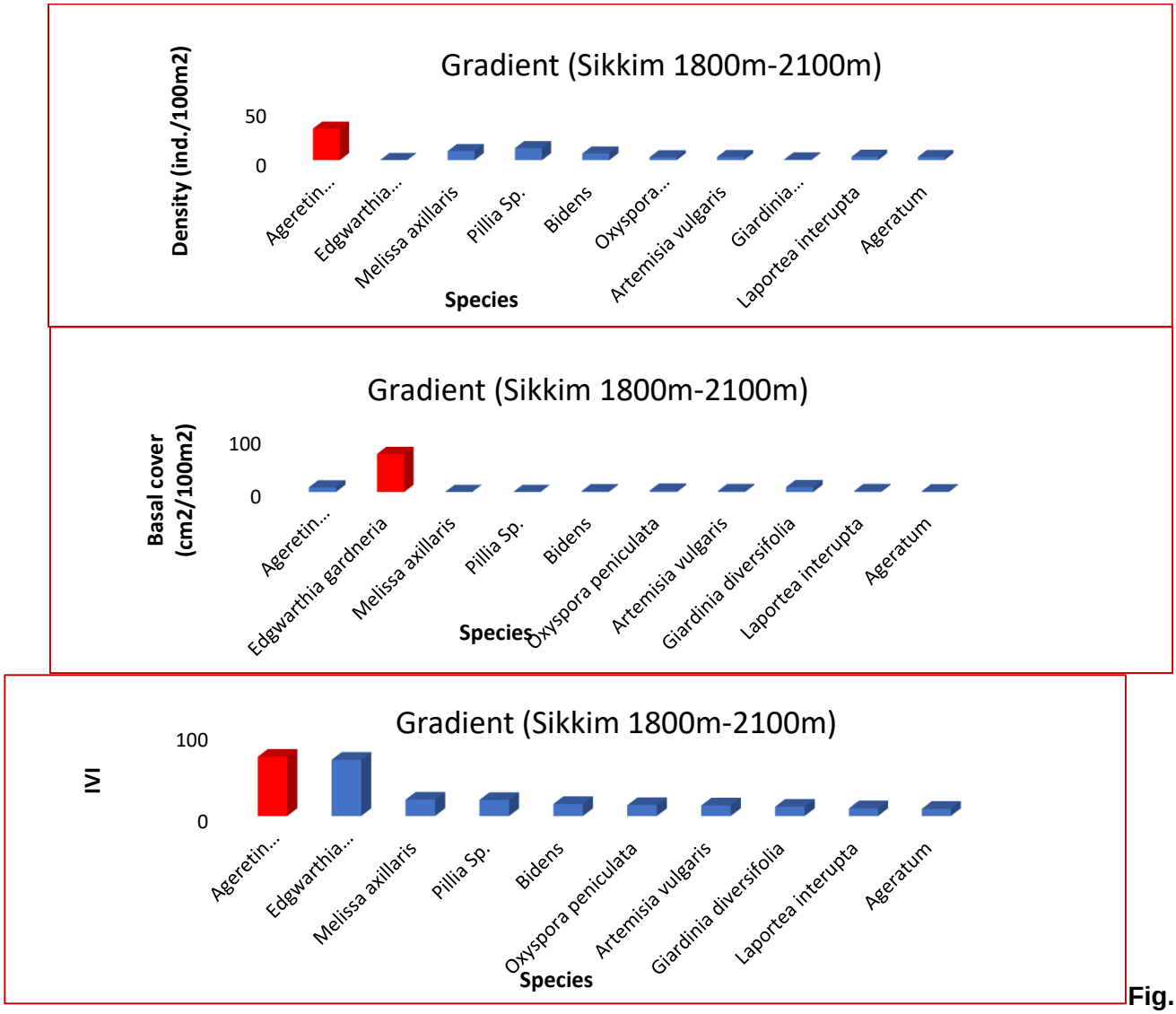


Fig. 12. Phytosociological attributes of different plant species at 1800 m–2100 m altitudinal gradient.

Table 7. Phytosociological attributes of different plant species at 2100 m–2400 m altitudinal gradient.

Sl NO.	**Name of species**	**Frequency (%)**	**Density (ind./100m^2)**	**Basal cover(cm2/100m2)**	**IVI**
1	***Ageratina adenophora***	**83.33**	**21.33**	**10.18**	**92.04**
2	*Anaphilis sp.*	66.66	10.66	1.45	46.76
3	*Rubus lineatus*	33.33	6.66	6.76	39.28

4	*Artemesia vulgaris*	50	6	2.70	34.90
5	*Artemesia nilagirca*	16.66	2	2.91	16.10
6	*Calciolaria*	16.66	1.33	0.04	8.49
7	*Giardinia diversifolia*	16.66	5.33	20.95	62.42

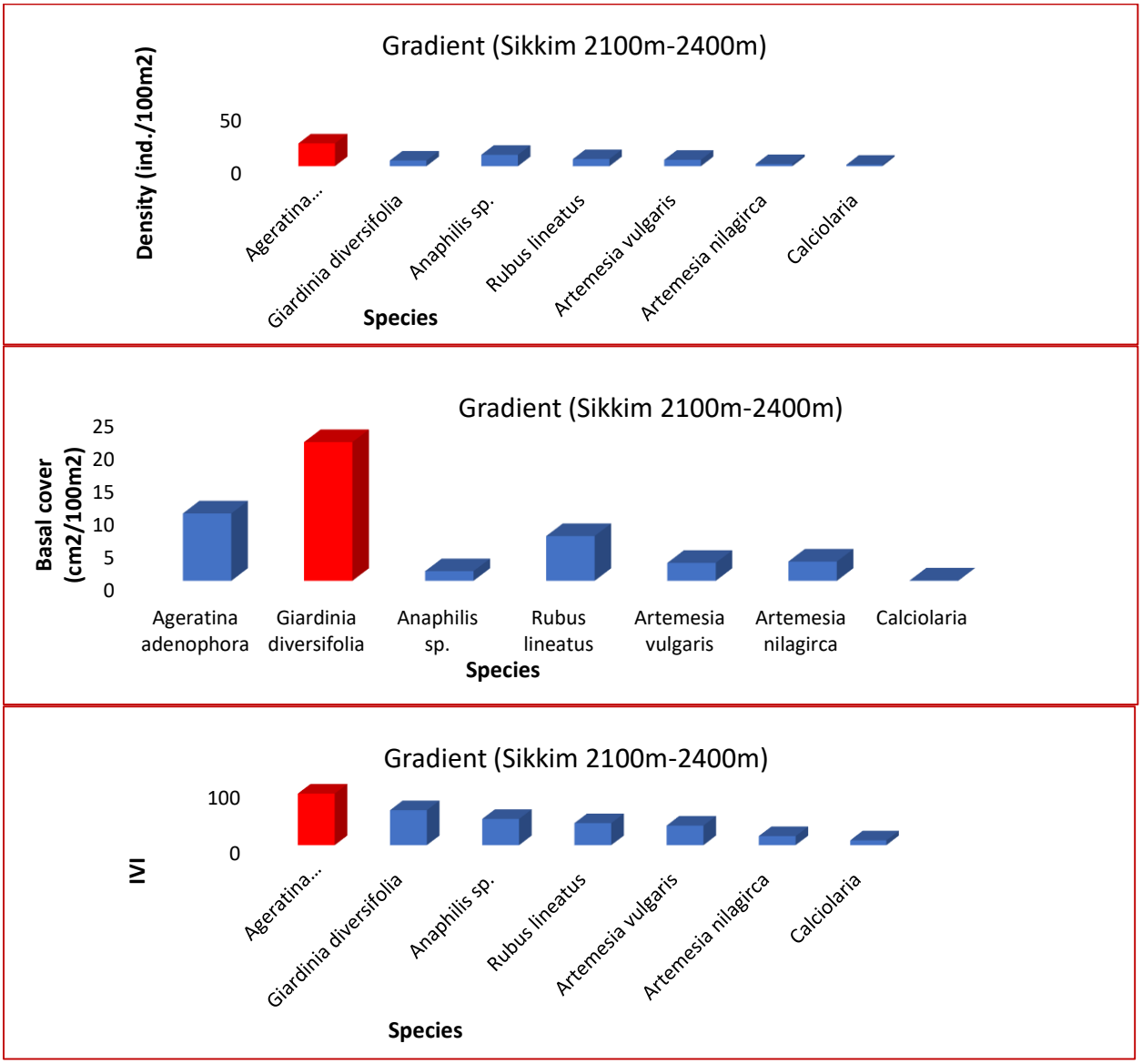


Fig. 13. Phytosociological attributes of different plant species at 2100 m–2400 m altitudinal gradient

Table 8. Phytosociological attributes of different plant species at 2400 m–2700 m altitudinal gradient.

SI NO.	Name os Species	frequency (%)	Density (ind./100m^2)	Basal cover(cm2/100m2)	IVI
1	*Artemisia vulgaris*	42.857	8.571	8.039	64.43
2	*Anaphilis sp.*	71.429	10.857	1.498	60.808
3	***Ageratina adenophora***	**71.429**	**19.429**	**10.32**	**109.04**
4	***Chromolena odorata***	**14.286**	**0.571**	**0.065**	**7.76**
5	*Giardinia diversifolia*	14.286	2.286	10.709	46.349
6	*Calciolaria*	14.286	2.286	0.052	11.614

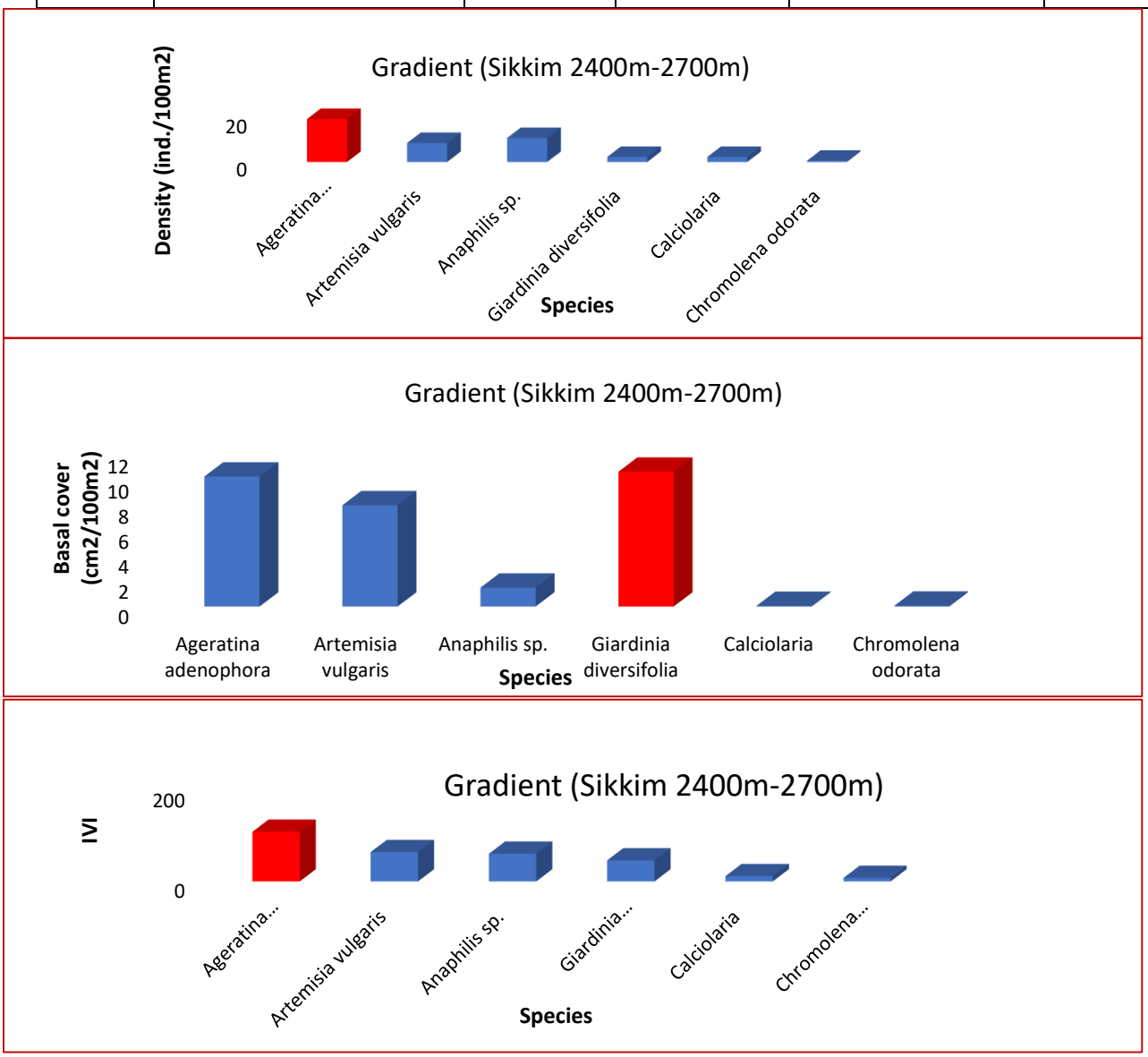
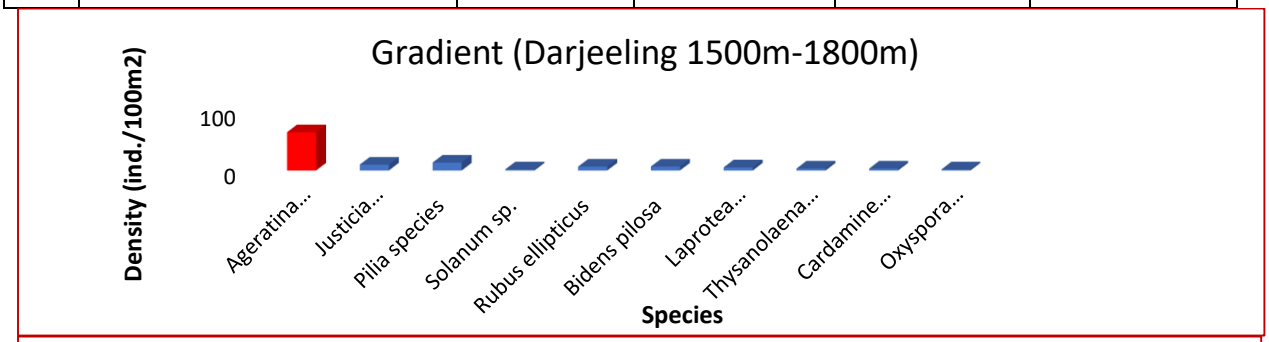


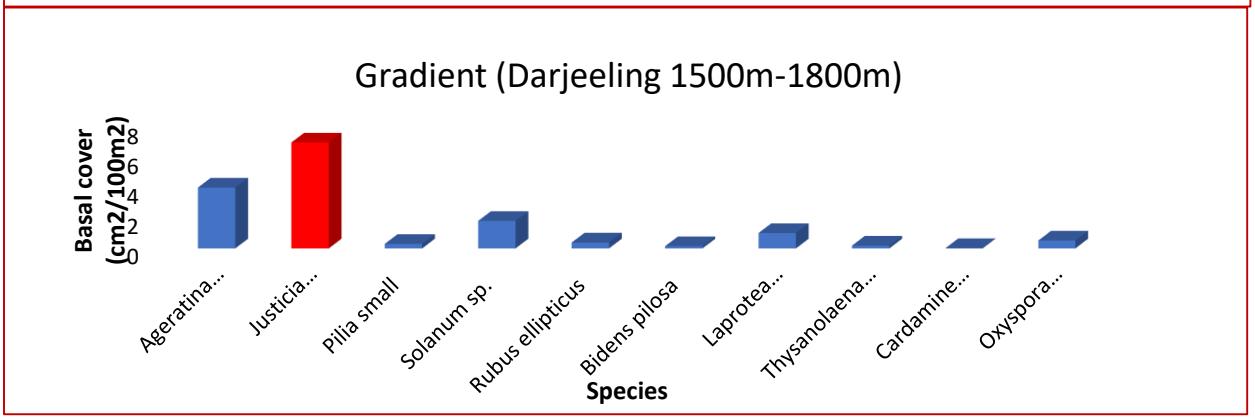
Fig. 14. Phytosociological attributes of different plant species at 2400 m–2700 m altitudinal gradient**.**

Table 9. Phytosociological attributes of different plant species at 1500 m–1800 m altitudinal gradient in Darjeeling.

Sl	Name of Species	**Frequency**	**Density**	**Basal cover**	**IVI**

No		(%)	(ind./100m^2)	(cm^2/100m^2)	
1	***Ageratina adenophora***	**100.00**	**64.667**	**4.034**	**100.84**
2	*Un 2*	16.67	3.333	0.028	6.70
3	*Pelia sp.*	66.67	13.333	0.299	28.00
4	*Rubus ellipticus*	33.33	6.667	0.390	15.55
5	*Bidens pilosa*	33.33	6.667	0.147	13.99
6	*Cardamine flexuosa*	16.67	3.333	0.017	6.63
7	*Thysanolaena maxima*	16.67	3.333	0.182	7.69
8	*Justicia adhathoda*	50.00	10.000	7.023	64.64
9	*Un 6*	33.33	5.333	1.018	18.50
10	*Solanum sp.*	33.33	2.000	1.826	21.02
11	*Oxyspora peniculata*	16.67	2.000	0.523	8.81
12	*Laprotea interupta*	16.67	4.000	0.092	7.65





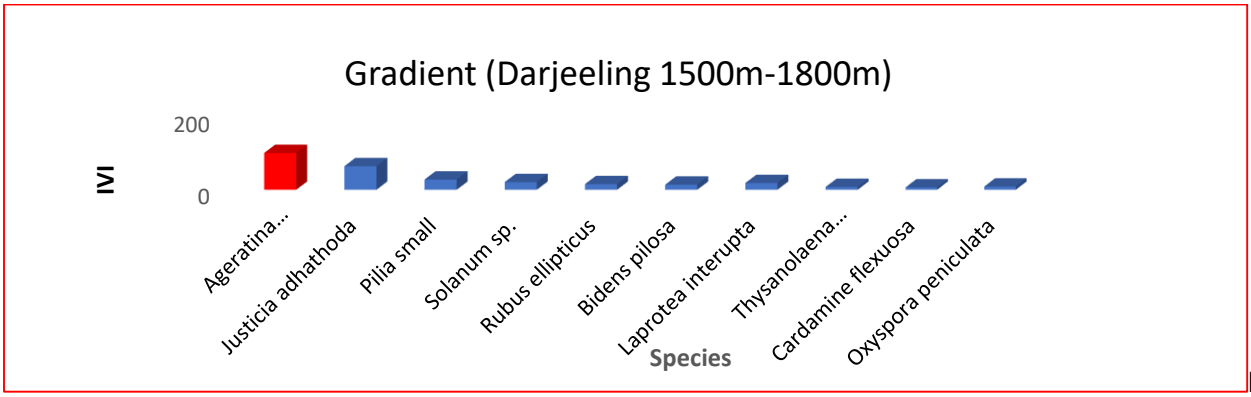


Fig. 15. Phytosociological attributes of different plant species at 1500 m-1800 m altitudinal gradient**.**

Table. 10. Phytosociological attributes of different plant species at 1800 m-2100 m altitudinal gradient in Darjeeling.

Sl No	Name of Species	**Frequency (%)**	**Density (ind./100m^2)**	**Basal cover (cm^2/100m^2)**	**IVI**
1	***Ageratina adenophora***	**100**	**42.5**	**26.46466575**	**146.9334**
2	*oxyspora peniculata*	37.5	7	6.708767	36.68288
3	*Solanum sp.*	12.5	1	0.040192	4.751672
4	*Melissa axillaris*	12.5	5	0.489425694	10.26734
5	*Justicia adhathoda*	25	7.5	2.080790778	20.89661
6	*Eregron sp.*	37.5	9	0.058561	20.50128
7	*Artemisia sp.*	12.5	2	0.090432	5.959597
8	*Melissa axillaris*	37.5	7.5	0.061858	18.90609
9	*Calceolaria*	12.5	1	0.0157	4.684199
10	*Pseudonehalium affine*	12.5	1.5	0.05969925	5.340172
11	*Bidens*	12.5	2.5	0.098125	6.51555
12	*Pilia small*	37.5	7	0.13129125	18.56261

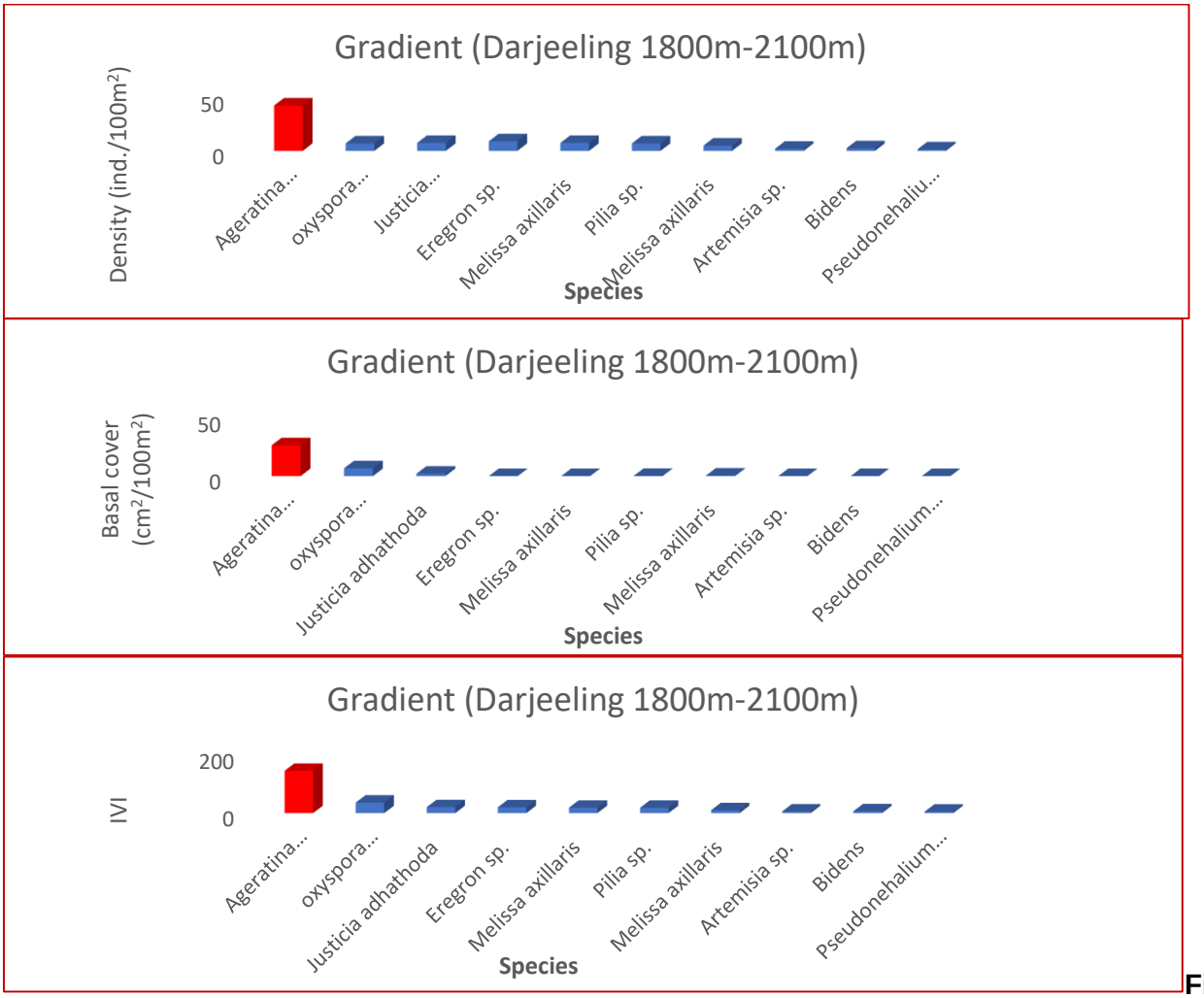


Fig. 16. Phytosociological attributes of different plant species at 1800 m-2100 m altitudinal gradient**.**

Discussion:

Out of 4,920 angiospermic species found in Sikkim Himalaya (Singh & Das, 2019), about 336 species are alien which constitutes 6.8 % of total flora that is quite lower than the country average of alien species (18%) estimated by Nayar (1977) and Sharma *et al*. (2005). However, Khuroo *et al*. (2011) have observed only 8.5 % of alien plants in the flora of India. A comprehensive list of all alien species found in Sikkim has been provided here with information on their families, taxonomic group, growth form, habitat, flowering period, invasion status, native range and mode of introduction. In Sikkim, the highest number of alien species is found in the family Fabaceae, however, the invasive alien species are more dominant in the family Asteraceae. Many of the invasive alien species such as *Lantana camara*, *Parthenium hysterophorus*, *Ageratum conyzoides, Ageratina adenophora* etc. are quite dominant and cover substantial area in Sikkim region. These species have also been found more dominate in different parts of India as well (Kohli *et al*. 2006). It has also been observed that these species with time, naturalization and changing climatic conditions fastly migrate to the less disturbed deep forest areas (Kleinbauer *et al*. 2010). The gradual spread of invasive alien plant species in any area is becoming threat to the various indigenous plants species by causing harmful effect to the indigenous species in an ecosystem, which

also leads to climate change and influence the global environmental diversity (Wilcove *et al*. 1998; Thuiller *et al*., 2007; Kushwaha, 2012). Grêt-Regamey *et al*. (2012) have also noticed that increasing alien plant invasion into mountain is alarming because these species consist of some special traits like tolerant of wide range of soil, weather, generalistic distribution behavior, aggressive root system, short generation time and long flowering and fruiting period that help them in colonizing the Himalayan regions easily. Like Kosaka *et al*. (2010), we also noticed that the naturalized alien species are mostly proliferating along human disturbed areas, construction areas, open canopy and forest edges. Environmental attributes and species competition structures the overall community and distribution of species at a given place (Zhang & Tielbörger, 2020), and these changes may be occurred steadily or swiftly, depending upon the exposure of the habitat and climatic changes at the targeted landscape (Dormann et al., 2018). In order to preserve the ecosystem integrity, it is crucial to understand the response of species to the changing environmental conditions, and it becomes more important in light of the ever-increasing disturbances to ecosystems, particularly by invasive plant species as they tend to alter ecosystem community structure and processes rapidly (Soliveres et al;2015). The invasiveness success of these invasive species at every altitudinal gradient can attribute with its highest germination success, wilder acclimatization to diverse habitats, and maximum adaptative traits making the species a successful invader to diverse landscapes. It is well established that invasive species by virtue of their morphological and reproductive traits succeed in the vicinity and get more supplements than their other native associate in the recipient community, thus infesting the region at a higher pace, leading to a decrease in the number of native and local species (Sharma et al., 2005; Witkowski & Wilson, 2001). With consideration of the factors mentioned above, we conclude that the invasion, presence, and further spread of this species are detrimental to Sikkim Himalaya, as its steady invasiveness is diminishing the available natural habitats for the growth of native plants and therefore depleting the plant. Till the date the forest of Sikkim Himalaya which contains lesser amount of alien flora in comparison to the other Himalayan regions, is well preserved and protected, however, the number of invasive plant species are increasing gradually by various anthropogenic activities such as construction work and also due to visitors who travel the area throughout the year. Though till now the undisturbed natural forests are resistant to such invasion, but the degraded and secondary forest areas are aggressively invaded by the invasive species and it could be predicted that it would not take much time for these species to invade the core areas. Following steps may be taken at local level to control and manage the invasive alien plant species. The first solution may be to mechanically eradicate the species along a gradient in the habitats and follow the re-establishment of the ecosystem resulting from the removal of the target species. Secondly, the population size could be reduced by using biocides along with regular monitoring of the habitat. The third solution could be identifying a native species which shows potential to challenge the invasive species. Planting of such species along with the invasive could check their spread. We also suggest ‘participatory management system’ by local people and stakeholders who could work as a group and eradicate these species and monitor the habitat from time to time. Decision-makers and planners can

educate these groups and distribute a knowhow to spread the awareness. In tourist place like Sikkim, the visitors should also be guided regarding rules and regulation of the forest and about its management and protection. For any management strategy to work the first step should be the identification of the invasive species, their rate of invasiveness and their impact on native populations, species and ecosystems. An inventory like this may provide insights for fundamental understanding of eco-region-specific invasion status by these species which will be useful in future to improve the managing strategy for the invaded ecosystem. There is an urgent need to execute detailed biological studies on each species.

Conclusion

Invasive plant species spread extensively throughout India in the last 10 decades, after being introduced. The present study concludes that targeted invasive plant species have successfully invaded and spread throughout the almost all possible habitat of Sikkim Himalaya, reducing the habitat suitability for native plant species. Based on the phytosociological data, we observed that *A. adenophora* is present at all seven elevational gradients (600 m to 2700 m), which reflects stage III of species invasion, which indicates that the species has already started reproducing and establishing their populations in the non-native range. However, it was observed that the other invasive plant species like *Ageratum conyzoides, Chromolaena odorata*, *Lantana camara, Bidens sp.*, and *Mikania micrantha* are successfully invading the habitats in the presence of A. Adenophora, which is posing a serious threat to the native plant community and will result in the depletion of plant diversity. Immediate interventions are needed to slow down the invasion process and reduce its existing population size and reverse the process with suitable biological control measures. Otherwise, these alien plant species being noxious invasive alien plant species is going to invade gregariously, putting serious threats to native plants in diverse habitats. To stop and ultimately reverse the spread and impact of invasive alien plant species in Sikkim Himalayas, a mass drive for control and executive action at the local and state levels is expected.

FOR MIZORAM & TRIPURA (Dr. S.S. Dash)

➢ INTRODUCTION

The global biodiversity crisis has given rise to a growing concern at the prospect of a rapidly accelerating loss of species, populations, domesticated varieties and natural habitats. Biological invasion gained much attention as one of the foremost global ecological and environmental issues and recognized as a key problem for biodiversity. They have been studied extensively in temperate areas but far less in tropical and subtropical areas The assumption that tropical and subtropical forests are resistant to biological invasion dates back at least to Elton (1958) and is based on the hypothesis that the high diversity of native species in these regions leads to “biotic resistance” due to stronger biotic interactions with the resident species (e.g. Levine et al., 2004; Freestone et al., 2013). But due to many fold interferences, this hypothesis proved wrong and tropical and subtropical regions of world, particularly in the developing countries, forests are highly vulnerable to invasion of biological threat. With varied habitat and environmental condition, India is especially vulnerable to Invasion by alien species. Till now 197 species of invasive alien species have been reported from India. It is worth to explore whether many important groups of invasive plants, has any common ecological impact or invasive strategies. Even distribution of these species has undergone through a period of rapid spread and has nearly reached a balance in competition with the native flora and its dispersal ability is constantly increasing. In the present proposal, three important invasive species, *Mikania micrantha* and *Ageratina adenophora* are typical of the alien Asteraceae that invades the forests of Northeast including the farmlands, forests, wastelands causing a significant damage to the local flora has been proposed to study.

Invasive alien plants are a critical component of global environmental change because, after establishment, they randomly proliferate in all direction; mainly when the environment is conducive as in a rough and sloppy mountain terrains (Rumlerová, Vilà, Pergl, Nentwig, & Pyšek, 2016). The recent global climate change has also catalysed the rate of introduction and spread of alien species into areas where they were previously absent, or increased their performance as compared to native species.

Sporadic information is available on alien species, particularly on Indian Himalayan regions. Ecological studies on invasive plants, mainly on *Ageratum conyzoides*, *Parthenium hysterophorus* and *Lantana camara* were reported from the north-western Himalayan region (Kohli, Batish, Singh, & Dogra, 2006); 571 alien species enumerated from the Kashmir Himalayas (Khuroo, Reshi, Rashid, & Dar, 2011); 190 alien species identified from Indian Himalayan region (Sekar, Manikandan, & Srivastava, 2012); 497 alien species enumerated. However, accurate estimation on the spread of invasive species and its potential threats is not available from North-eastern states of India, particularly from Mizoram and Tripura. A proper estimation of floristic elements or landscapes infested with invasive alien plants is the need of the hour to build appropriate strategies for conservation and management of natural flora.

Currently there is no true estimate on the spread of invasive species, loss of natural habitat and potential threat of *Mikania micrantha* and *Ageratina adenophora* in Mizoram and Tripura or any permanent strategy to conserve the indigenous flora. Therefore, not only, there is a need to know the floristic elements of different landscapes infested with high invasion for estimating the information on change in abundance of the species, but also brings into question the appropriate strategies for management. The state of Mizoram and Tripura, are two of the smallest states of North-eastern India, are ecologically heterogeneous, thus can be used as natural experimental sites for determining the ecological characteristics and habitat preferences of two selected invasive alien species. The study, proposes two invasive species *Mikania micrantha* and *Ageratina* as two suitable subjects for reconstruct a model for predicting its potential invasion of further spread within the State of Mizoram and Tripura and also their impact on the natural flora.

- **Overview of the major issues**

Mizoram, one of the seven sister states of the North-eastern India, forms tongue shaped rugged mountainous region, in the extreme southern fringe of North east India. It was called Lushai hills district during the British period and formed part of undivided Assam. Geographically, the state is located between 21°57' 24 °30' N latitude and 92° 15'- 93° 29' E longitude, covering 21,081 sq. km of land area. The length of the state from North to South is about 277 km, while East- West width extends over 121 km. The varied physiographic and eco-climatic conditions, met within the state, have adequately expressed itself by supporting a rich vegetation both in luxuriance and diversity. Located between Cachar district of Assam, Kuki hills of Manipur, Chin and Arakan hills of Myanmar and Chittagong hills of Bangladesh, the state displays a close floristic affinity with not only these regions but with other neighbouring and distant part of the world as well. The forest cover of the state at present is 18,338 sq.km which constitute 86.99 per cent of the total geographical area and is the second largest amongst the North-eastern states of the country. Besides, the socio-economic- ecological significance, the forests of the regions are directly related to its geography, climate, and biological diversity. The food security, survival and economic activity of the inhabitants are directly dependent on the forest ecosystem health and continued availability of its services.

Recent studies are indicating that the biodiversity of the state has been increasingly threatened due to various anthropogenic activities, unsustainable practices, waste generation and climate change. Besides, the localized biodiversity degradation, recent changes in climate possesses great challenge for the diversity of the state. This paves the way for invasion by alien plants. Most of mountainous forests are susceptible to the adverse effects of alien plant invasion due to continuing anthropogenic disturbances such as agricultural expansion, over grazing, habitat degradation, deforestation, forest fires and infrastructure development. These dramatic declines in vegetation in the biodiversity of the state will definitely have a negative impact on the livelihood and survival of local people all along state. Hence an

integrated scientific approach is need of the hour to understand the vegetation of the state, their conservation and management.

- **Baseline Data and Project Scope**

The proposed project “Ecological investigations to understand causes and consequences of invasion in Tripura, Mizoram and adjoining parts of Assam and Manipur” aims to evaluate the rate of spread of *Ageratina* and *Mikania* by analyzing their abundance, rate of aboveground growth during different seasons in different ecological habitats; to determine the reproductive potential by analyzing their seed production and seedling recruitment and characteristic; to study the similarities and differences in spread pattern and invasive load on early recovery successional landscapes, and its impact on the natural flora and also to undertake awareness programmes among all the stalk holders including local people through an interactive local level capacity building programme regarding the consequences of invasive species, if not managed. This is in spite of increasing requirements from the Convention on Biological Diversity to do so, in recognition of the benefit that such information can have for effective policymaking and implementation. For example, Invasive load assessment can help to monitor the state of biodiversity and identify geographic priority areas and actions to address urgent conservation needs across. The BSI has collected voluminous data on inventory and species distribution over a period of time. This will act as baseline data to compare with any additional data to be collected again from different places where the project activities will be taken. It is evident that many natural habitats are infested with invasive species a species have been altered the composition of natural elements and revisiting those places will give us an opportunity to look back how these habitats fared once and how they are now. The assessment process will produce set of significant indicators for invasive spread status, which can be monitored over time and will facilitate to develop proper management strategy.

- **Project Objective(s)**

a. To evaluate the rate of spread of *Ageratina* and *Mikania* by analyzing their abundance, rate of aboveground growth during different seasons in different ecological habitats;

b. To determine the reproductive potential by analyzing their seed production and seedling recruitment and characteristic;

c. To study the similarities and differences in spread pattern and invasive load on early recovery successional landscapes, and its impact on the natural flora and

d. To undertake awareness programmes among all the stalk holders including local people through an interactive local level capacity building programme regarding the consequences of invasive species, if not managed.

- **METHODOLOGIES**

STUDY SITE

Field sampling was conducted in selected landscapes, covering a variety of habitat in the state of Mizoram and Tripura including protected natural forests and the disturbed habitats in fringe villages. The collection was made for *Ageratina adenophora* and *Mikania micrantha*, respectively, corresponding with the period when invasive biomass reaches their peak. To verify the impact pattern found with those invasive plants, the study was conducted during July, 2018 to September, 2021 in the state of Mizoram and Tripura.

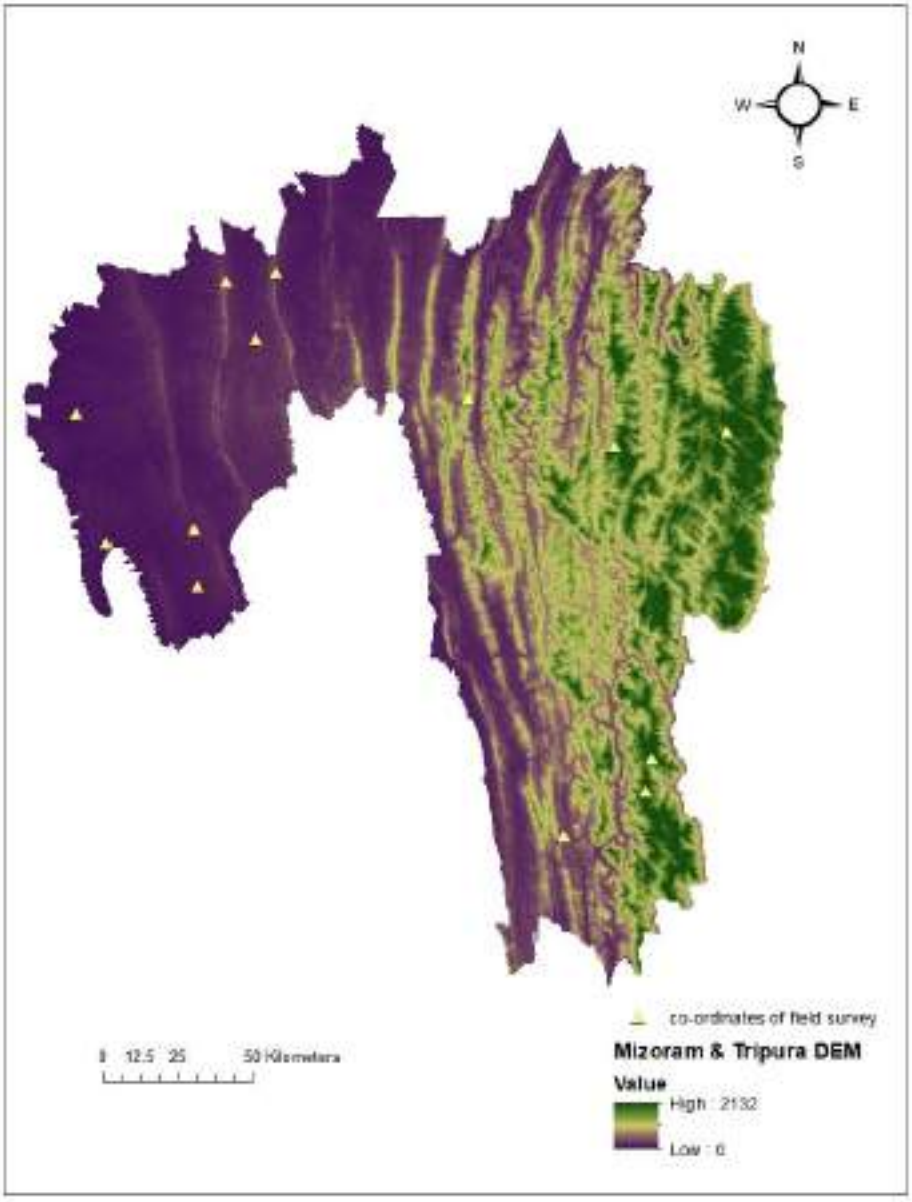


Figure 1: Mizoram and Tripura digital elevation map along with study site co-ordinates

In Mizoram, four protected areas were selected as study sites (**Figure 2**) viz., Phawngpui national park, Murlen national Park, Dampa Tiger Reserve, Lengteng Wildlife Sanctuary and two were in non–protected areas viz. three to five years old abandoned shifting cultivated fields near Sangau and Aizawl.

In Tripura, six protected areas were also selected as study sites (**Figure 3**) viz. Sepahijola Wildlife Sanctuary, Gomati Wildlife Sanctuary, Trishna Wildlife Sanctuary, Rowa Wildlife Sanctuary, Clouded Leopard national Park and Rajbari national Park.

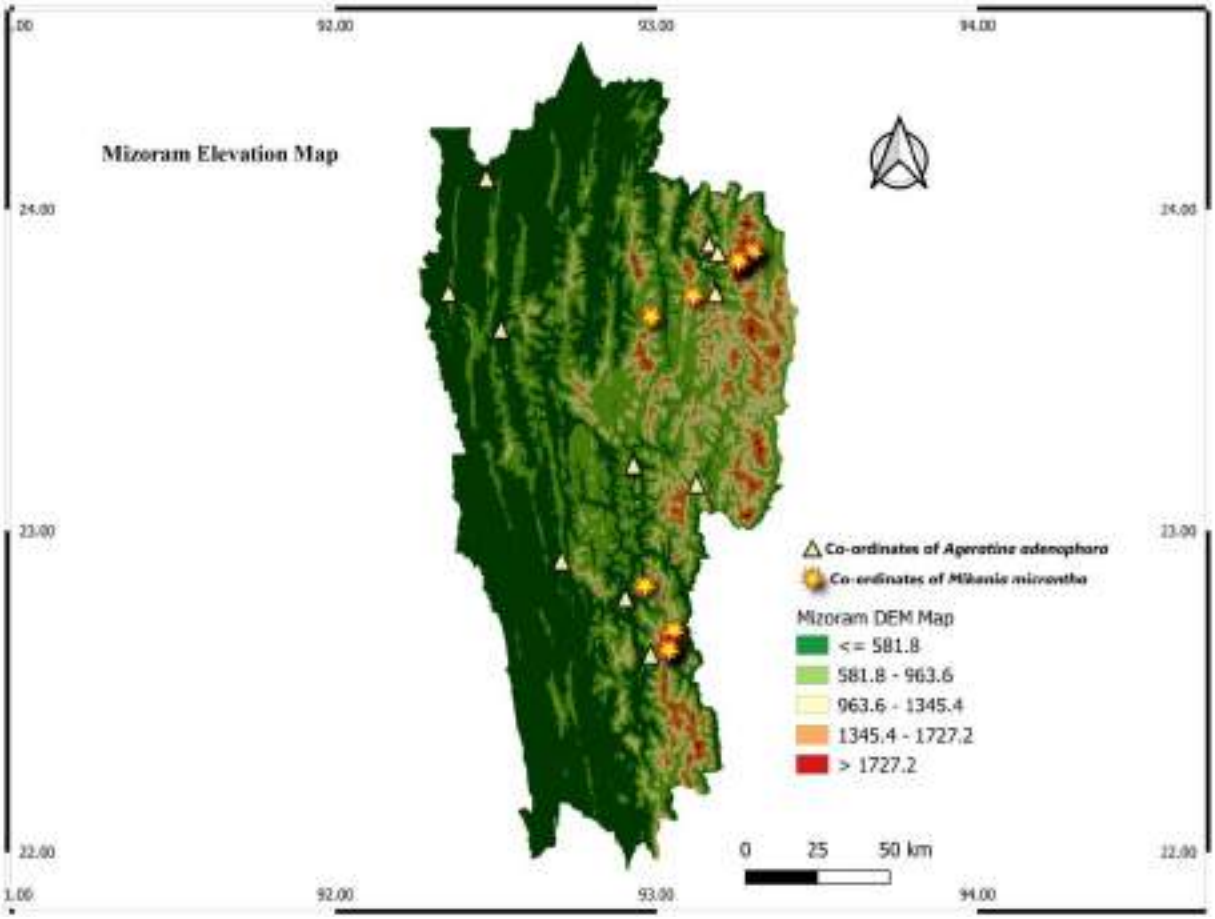


Figure 2: Mizoram digital elevation map along with study co-ordinates

- **ECOLOGICAL INVESTIGATION**

Random sampling technique using nested quadrat method was followed for collection of phytosociological data. Plot sizes of 400 m^2 were selected randomly within which quadrats of 5 m × 5 m were laid for shrubs and 1 m × 1 m for herbs nested within 5 m × 5 m quadrats (Mishra, 1968). Phytosociological data of trees were not considered in the present study because their invasion status is comparatively negligible with reference to herb and shrub invasion in the protected areas. For the collection of data on the mode of introduction and usefulness of alien plants, the local people were interviewed with an open-ended questionnaire.

The comparisons among the phyto-sociological data were analysed. Based on the mode of introduction, rate of invasion, nature of the invaded habitats and importance value index (IVI) ten most obnoxious alien invasive alien plants and top neo-invasive species were determined.

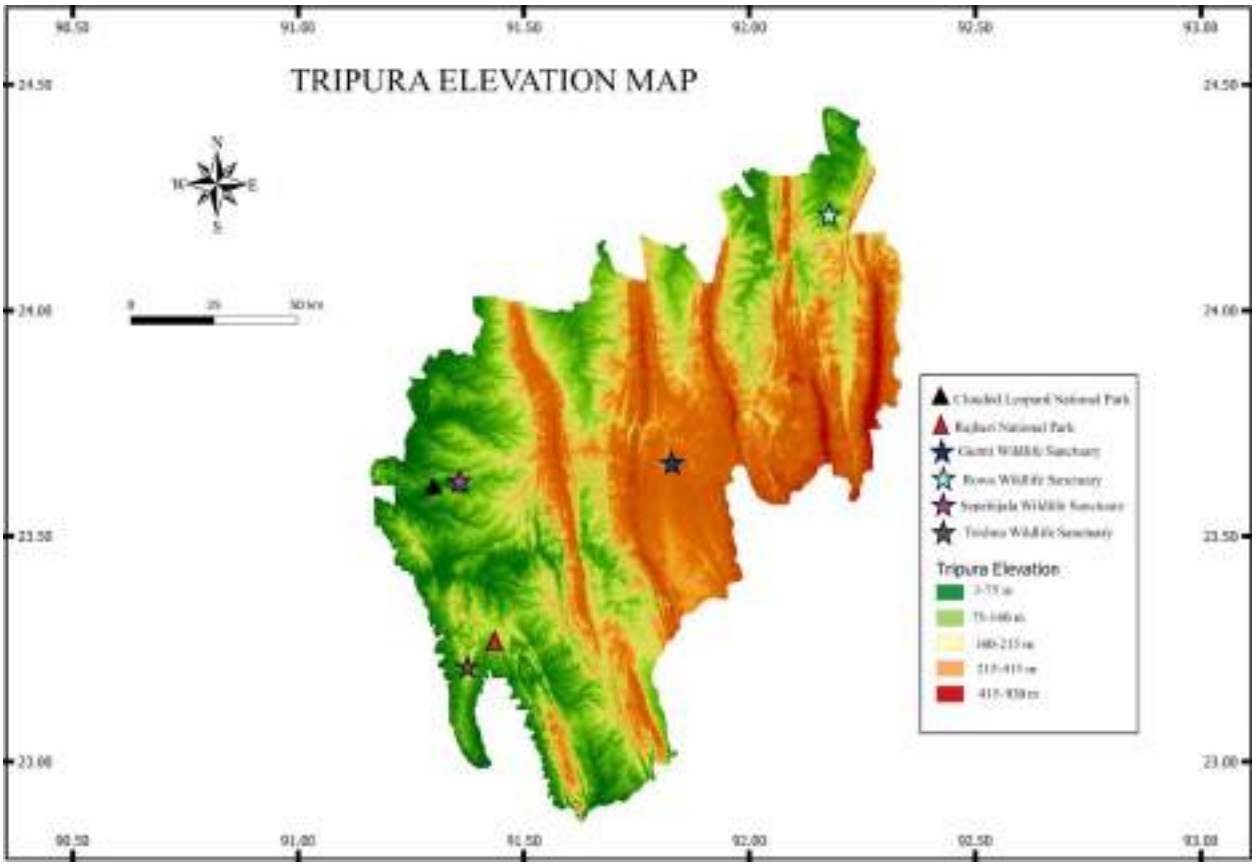


Figure 3: Tripura digital elevation map along with study co-ordinates

Local Level Capacity Building

Generating capacity-building amongst local stake holders is crucial for long-term sustainability biodiversity. Towards this goal, we conducted a series of awareness programmes, workshops to local forest officials, college and school students, and general public. The target group for capacity building was school teachers, frontline staff of forest department; members form village panchayats and local NGO's. Besides, currently there is very attention has been paid towards the impact of invasive species in the states, therefore the importance of plant diversity, need for its conservation, and the impact of invasion species on local flora was briefed through different medium of communication, education and public awareness programmes. The outcomes for the most invasive alien plants were widely disseminated as a pamphlet during the awareness programmes.

Data collected and Equipments utilized (limit 500 words)

All the phytosociological data i.e., relative densities, relative frequency, relative dominance, IVI of each species were determined using formulas mentioned by (Misra, 1968). Importance Value Index (IVI) was calculated by the adding of relative values of frequency, density and dominance (Curtis and McIntosh, 1950).

The formulae used for the various calculations are:

$$\text{Density} = \frac{\text{No. of individuals of a species}}{\text{Total No. of quadrats studied}}$$

$$\text{Frequency (\%)} = \frac{\text{No. of quadrats of occurrence of a species}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Abundance} = \frac{\text{Total No. of individuals of a species}}{\text{Number of quadrats of occurrence}}$$

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Frequency of all the species}} \times 100$$

$$\text{Relative Density} = \frac{\text{Density of a species}}{\text{Density of all the species}} \times 100$$

$$\text{Relative Dominance} = \frac{\text{Basalarea of a species}}{\text{Basal area of all species}} \times 100$$

Basal area = πr^2, where, $\pi = 3.14$ and r = radius of the species.

Importance Value Index (IVI) = Relative Frequency + Relative Density + Relative Dominance

Importance Value Index (IVI) was calculated separately for each species of the community. A particular species, that having highest value of importance value index (IVI) is considered as most dominant in the area and the species with lowest importance value is considered as the least dominant.

Equipments used

Sl. No.	Equipments used	Data collected
1	GPS (Garmin Montana 680)	Geo-tagged the collected specimens, GPS record of invasive alien plants, GPS record of highly invaded regions in study sites.
2	Imaging and analysis device (Two)	With the help of the imaging and analysis devices, the analysis of collected field data were performed to determine the importance value index of the invasive alien plants.
3	Camera (Sony Hx400v)	Photographs of the invaded sites, invasive plants, their associated species, disturbations in various habitats, awareness programmes etc were taken.
4	Soil pH meter (Takemura)	On field record of soil pH in invaded habitats.

Information on the nativity of these IAPs were extracted from the website https://www.cabi.org/ISC and secondary literatures. Various information related to introduction history, impact on socio-economy and ethnobotanical use of the IAPs was collected through a semi-structured interview from the local stakeholders with an open-ended questionnaire (Jain, 1989) on usefulness of alien plants.

- **DETAILS OF FIELD SURVEY CONDUCTED**

In Mizoram, the average height of the hills is about 900 m. Phawngpui national park is the highest peak (2,210 m) of the state. Forest cover of the state is 73.68% of the total geographical area composed of 6.75% protected area network. Temperature of the state varies from 18-29°C during summer and 11-24°C during winter with an average annual rainfall of 2160-3500 mm^3. Natural vegetation is categorized based on altitudinal gradient viz. tropical (0-900 m), subtropical (900−1800 m) and temperate (1800–3600 m). GPS co-ordinates of the surveyed village; occurrence of the IAPs were recorded from the field using GARMIN MONTANA 680. The co-ordinates were plotted in digital elevation model using ArcGIS 10.8.2.

For the convenience of the present work, we have selected four protected areas in Mizoram viz. Phawngpui National Park (50 km^2), Murlen National Park (100 km^2), Lengteng Wildlife Sanctuary (60 km^2) and Dampa Tiger Reserve (500 km^2). Besides non-protected areas viz. Sangau, Aizawl, Knahlan were also selected.

Altitude of Tripura ranges from 15m to 780 m. In Tripura, six protected areas were also selected as study sites in Tripura viz. Sepahijola Wildlife Sanctuary (13.46 km^2), Gomati Wildlife Sanctuary (389 km^2), Trishna Wildlife Sanctuary (163 km^2), Rowa Wildlife Sanctuary (0.86 km^2), Clouded Leopard national Park (5.08 km^2) and Rajbari national Park (31.63 km^2).

Extensive field surveys were undertaken in a planned manner in different seasons to collect the plant specimens from selected protected and unprotected areas of Mizoram. Plant samples were collected for preparation of voucher herbarium specimens. The specimens were poisoned with 0.1% Mercuric Chloride ($MgCl_2$), mounted on standard handmade herbarium sheets (28 × 42 cm) and labelled (14.5 × 11 cm), after incorporating all the relevant field information. These were deposited in Central National Herbarium, Botanical Survey of India (CAL) after proper identification.

Field survey for phytosociological data collection were conducted following stratified ecological sampling methods. The comparisons among the phytosociological data were analysed in Microsoft Excel Software (2019 version). GPS locations were investigated and the digital elevation map of the study site was prepared using ArcGIS online tools.Based on the mode of introduction, rate of invasion, nature of the invaded habitats and importance value index (IVI) ten most obnoxious alien invasive alien plants and five top neo-invasive species were determined.

To verify the impact of invasion by the selected invasive alien plants, soil samples from invaded and uninvaded plots were collected following composite sampling methods. The soil physico-chemical parameters were analysed in outsourced soil analysis laboratories.

- **WORK PLAN**

Work plan PERT Chart Year-2018

Activity	Months											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Recruitment of JRF/PDF/Project Staff												
Selection of field stations												
Reconnaissance Site and local authority												
Field Training of staff												
Identification study landscapes												
Field studies												
Establishment of Experimental plots												
Data compilation												
Submission of Progress Report												
Project Review Meeting												

Work plan PERT Chart Year-2019

Activity	Months											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Data compilation												
Protocol based field surveys												
First local level training												
Laboratory analysis												
Growth rate estimation												
Evaluation of rate of spread of invasive species												
Submission of Progress Report												
Project Review Meeting												

Work plan PERT Chart Year-2020

Activity	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Data compilation												
Protocol Based field surveys												
Publication of education awareness protocols												
Second local level awareness programme												

Work plan PERT Chart Year-2021

Activity	Month								
	1	2	3	4	5	6	7	8	9
Data compilation									
Protocol Based field surveys									
Dissemination of Publication									
Project Review Meeting									
Submission of draft final Report									
Final Project consultation workshop									

Submission of final report									

- **KEY FINDINGS AND RESULTS**

Major Activities/ Findings

Results of extensive field exploration tours undertaken in the protected and non-protected areas of Mizoram revealed 163 alien plant species belonging to 135 genera and 51 families. Out of these, 147 species belonging to 122 genera and 43 families were dicotyledons; 11 species belonging to 9 genera and five families were monocotyledons. Five species of gymnosperms under four genera and three families were also recorded.

Maximum percentage of alien plants, i.e., 38.03% (62 taxa) occur in Mizoram were from Tropical American origin followed by 13.49% (22 taxa) from South American, 9.81% (16 taxa) from Tropical African origin. Asteraceae with 29 species represented was the most dominant family and ten most dominating families contribute 59.06% of total alien species found. Observation on invaded habitats revealed that Tropical Wet Evergreen Forest (31%) and Montane sub-tropical forest (17%) were most invaded forests whereas Fallow Lands (22%) and ` (20%) were invaded habitats outside the natural forests.

Based on the phytosociological data, most invasive alien plants in Mizoram were observed highly proliferative. *Ageratina adenophora* (IVI-62.76) was the most dominant invasive alien plant in the herb layer and *Mikania micrantha* (IVI-59.64) was observed dominant in the shrub layer of the invaded habitats. It has also been observed that *Ageratina adenophora* spreading throughout Mizoram between 700 m to 2000 m of elevation. Neo-invasives like *Tithonia diversifolia* (IVI- 26.24), *Ipomoea cairica* (IVI-25.18), *Crassocephalum crepidioides* (IVI-11.51), *Galinsoga parviflora* (IVI- 20.30) were observed invading into the natural vegetation which may pose a significant threat to the natural flora of Mizoram in future.

In Tripura,186 alien plant species were identified from these protected areas belonging to 144 genera and 51 families. Out of these, 164 species of 126 genera and 44 families were from dicotyledons and 18 species belonging to 15 genera and 6 families were from monocotyledons. Four species of gymnosperms under 4 genera and 3 families were also recorded.

Out of the total alien species in Tripura, 34.40% (64 taxa) were from Tropical American origin followed by 16.12% (30 taxa) from South American, 10.21% (19 taxa) from Tropical African origin. Asteraceae with 31 species (16.66%) represented the most dominant family. The top ten dominating families contributed 57.52% of the total alien species found in Tripura.

In Tripura, the invasion by *Ageratina adenophora* was not observed as predominant but *Mikania micrantha* invaded gregariously in protected and non-protected areas. *Mikania micrantha* (IVI-57.75) was observed as the most dominant in shrub layer followed by *Lantana camara* (IVI-41.20), *Chromolaena odorata* (IVI-38.23).

Ecological investigation in Tripura revealed that noxious invasive alien plants like *Mikania micrantha*, *Chromolaena odorata*, *Ageratina adenophora*, *Lantana camara*, *Parthenium hysterophorus* have already spread and established in the protected areas of Tripura with high to moderate dominance over the native plant community.

- **Key Results**

- In Mizoram, 163 alien plant species belonging to 135 genera and 51 families were identified.

- In Tripura,186 alien plant species were identified from these protected areas belonging to 144 genera and 51 families.

- Asteraceae represented the most dominant family and ten most dominating families contribute >50% of total alien species found.

- Plants of Tropical American and South American origin represented majority of alien plants in Mizoram and Tripura.

- *Ageratina adenophora* was the most dominant invasive alien plant in the herb layer in Mizoram but not in Tripura whereas *Mikania micrantha* was observed to be dominant in the shrub layer in both Mizoram and Tripura.

- In shrub layer, Mikania micrantha was observed to be most dominant with in lower hills up to 1200 m elevation in Mizoram and 780 m in Tripura (highest peak of Tripura).

- In herb layer, Ageratina adenophora was observed to be most dominant with spreaded from lower hills (upto 900m) to 2268 m (highest peak) in Mizoram whereas in Tripura, A. adenophora was observed to be present and dominant only at 700 – 780 m range.

- Based on Soil-Physico chemical analysis, invasion by *Ageratina adenophora* reduced soil pH but increased organic carbon content compared to uninvaded soil whereas *Mikania micrantha* exhibited increase soil pH but decreased organic carbon content compared to uninvaded soil.

- The high aggressive invasion of M. micrantha and A. adenophora in disturbed natural vegetations (particularly in the shifting cultivated regions) may be attributed to the modified pH value of the surface soil that increases after the burning of jhum land.

- Overexploitation of natural resources, year-round tourist activities or unorganized land use pattern near protected region paves the way for invasion by alien plants like M. micrantha and A. adenophora in both the states, especially in protected natural forests.

- The gregarious spread of these invasive species greatly hinders regeneration of secondary forests.

- In this connection, during the study period (2017-2021), two awareness programmes were organized by the authors in collaboration with state Forest Department in Phawngpui national park and Mizoram University which had a great positive impact in the local stakeholders.

- One national seminar National Seminar on Invasive Alien Species: An undesirable guest to the natural ecosystem, was held at Central National Herbarium, Botanical Survey of India, AJC Bose Indian Botanical Garden Howrah-711103 on 30th March, 2022.

Conclusions

Majority of the population are forest dwellers are mainly dependant on forest resources in both the states. Therefore, first-hand information on native flora and invasive flora is needed for formulating scientific management strategy for long-term sustainable utilization. Despite of possessing rich, unique and diverse flora, natural vegetations in Mizoram and Tripura are vulnerable to invasion by non–native plants. There is a need to relook into the high rate of trade import, unorganized tourism in protected areas, unscientific shifting cultivation at policy level. The occurrence of these obnoxious invaders in the highest peak of Mizoram (2268 m) substantiates the fact that, there is an aggressive invasion by *Ageratina adenophora* in herb layer in invaded natural forests in Mizoram and in higher altitudes (700-780 m) in Tripura exhibiting an upward shifting of invasion in higher elevations. Similarly, *Mikania micrantha* invasion in shrub layers of invaded natural forests in Mizoram and Tripura is concerning. The consequences may lead to homogenization of flora, causing significant and irreversible species loss in near future. Practicing a longer shifting cultivation cycle, restricting tourism, growing of native tree as shading plants, regulating

import of foreign seeds can be implemented to minimize the chances of spread & establishment of these alien species in Mizoram and Tripura. Therefore, early detection and ecological risk assessment of invasive plants is very crucial providing an opportunity to implement suitable management strategy. Regular awareness programmes may also to be conducted to appraise the local inhabitants about the impacts and control of invasive alien plants. Since, the impact of invasive plants on ecosystems is highly variable with respect to their socio–ecological conditions, it is necessary in future studies to devise sustainable management policies and safeguard the livelihood benefits. Outcome of this study provides a baseline data regarding the invasive load as well as the impact of *A. adenophora* and *M. micrantha* on natural flora of Mizoram and Tripura. Outcomes of the project also revealed the ecological status of invasion and preliminary awareness to the local stakeholders for further control and management of the invasive alien plants in natural forests of the states.

4.1. Achievement on Project Objectives/ Target Deliverables

	Project Objectives	**Monitoring Indicators**	**Quantified Output/ Outcome achieved**	Deviations made, if any, & Reason thereof
1.	Identifying established and new Invasive Alien Vascular Plant Species (IAVPS) in all the 15 Indian Hilly States of Himalaya and estimating the invasion load	New Datasets: Complete inventory, distribution and areas infested by Invasive Alien Species in the Indian Himalayas	✓ A comprehensive inventory of 163 IAVPS is documented for Mizoram. ✓ A comprehensive inventory of 186 IAVPS is documented for Tripura. **(For details, see Appendix 1)**	None
2.	Characterizing the IAVPS on the basis of their life-forms, lifespan, nativity, status of invasion and purpose of invasion/introduction		✓ During the study 163 Invasive or potential invasive alien plant species belonging to 135 genera in 51 families have been recorded from Mizoram ✓ From Tripura, 186 Invasive or potential invasive alien plant species have been recorded belonging to 135 genera in 51 families. . ✓ The largest families include: Asteraceae with 30 species	None

			followed by Leguminosae (*s.l.*), Amaranthaceae and Convolvulaceae. **(For details, see Appendix 1)**	
3.	Preparing protocols for prediction, early detection and risk assessment of IAVPS	Dynamic model: Rate & mode of spread (including vectors responsible) with GPS & ground truthing	✓ More than 100 GPS co-ordinates are taken in each state for present occurrence of invasive alien plants in Mizoram & Tripura.	**None**
4.	Assessment of Ecological & Environmental Impact of invasion and spread with special reference to Phyto-diversity and soil especially in relation to climate change; This will include the level of disappearance of native species	Base line studies & Assessment Reports to state agencies of the disappearance of native plant species (If any).	✓ Soil impact result of 3 invaded sites was analyzed for invasion by ***Mikania micrantha*** & ***Ageratina adenophora*** as well as 2 non-invaded sites in Mizoram.	None
5.	Selection of at least 10 most noxious established and	Value addition and sustainable utilization of bio-resources for	✓ A list has been prepared for the 10 most noxious and 5 neo-invasive	None

	10 Neo-invasives and consolidation of all available information including their biology, itemizing at the same time the knowledge gaps	livelihood of local communities	established invasive alien plants in protected areas in Tripura & Mizoram; their ecological data have been analyzed. Frequency, Abundance, Density, IVI of each plant calculated.	
6.	Identification of a cross-sectoral group to assess the situation in the form of case-studies on these species, and also to formulate workable management strategies aiming to prediction, prevention and control	Policy and legislative mechanisms for management / eradication / mitigation will get framed.	✓ A "One day Awareness Programme cum Workshop on Invasive Alien Plants in Himalayas: Status, Ecological Impact and its Management" was conducted in 26th April, 2019 at Mizoram University Campus with a targeted audience of more than 60 participants from different areas of Mizoram. A brief report of the awareness programme is attached in ✓ A "One day national seminar on Invasive	None

			Alien species in India" was conducted in 30th March, 2022 at Central National Herbarium Campus, Kolkata with a targeted audience of more than 226 participants from different areas of India. A brief report of the awareness programme is attached in **(see Appendix 3)**	

Interventions

	Interventions	Reason thereof
1.	Covid-19 scenario	Due to the covid-19 pandemic throughout the globe and the study areas, as a precautionary step, the local governing bodies (Village councils in Mizoram and Tripura) did not approve permission to the working team to enter in the selected study sites which hampered work flow from March, 2020 to August, 2021.
2.	Inaccessibility, tough terrain and transport	In few natural forest areas of Mizoram and Tripura, transport or local guide was completely unavailable due to the inaccessibility of the area and rainy season.
3.	Resignation of project fellow	A project fellow resigned in 2020 who was assigned specific work areas to various study sites in Tripura as well as Mizoram. The other remaining project fellow and field assistant had to perform the work for the same within limited time and covid-19 pandemic which hampered the work flow.

On-field Demonstration

Two major workshops cum awareness programme and seminar were organized with the aim to make the local stakeholders aware of impact of alien plants (especially *A. adenophora* and *M. mikania*). The

awareness programmes were followed by an interactive session where the audience participants and the speakers interacted about their interests, doubts and further evaluations. Workshop during the awareness programmes was conducted in an interactive manner which included field demonstration to the audience, local stakeholders and forest officials regarding the impact of selected noxious invasive alien plants in Mizoram and Tripura. The awareness cum workshop was attended by students and teachers from different schools, universities, local residents and forest department officials. Dissemination of participation certificates, information manual on IAPs were done to the participants. This was set in order to ascertain whether the project's goal was reached to the local stakeholders. (Detailed report on **(For details, see Appendix 3).**

Green Skills developed in in State/ UT

Not applicable

Addressing Cross-cutting Issues

- Top ten obnoxious invasive alien plants were identified, especially *Ageratina adenophora, Mikania*
- *micrantha, Lantana camara, Chromolaena odorata* and *Ageratum conyzoides* with high volume invasion in natural forests in Mizoram and Tripura.
- Five most neo-invasive species were identified, especially *Tithonia diversifolia, Ipomoea hederifolia Crassocephalum crepidioides, Galinsoga parviflora* were the most potential invasive species in 250 – 780 m in both the states.
- A comprehensive inventory for invasion alien plants in both the states were prepared.
- Ecological status of most noxious plants was addressed for natural forest areas in Mizoram and Tripura.
- Multiple workshops and awareness programmes were conducted to spread awareness among local stakeholders.

➢ PROJECT'S IMPACTS IN IHR

Socio-Economic impact

- Identification and preparation of comprehensive inventory of invasive load of Mizoram and Tripura which fulfils the gap of knowledge in these two states in IHR.
- Improvement of awareness on invasive alien plants and their impact on natural forests by conducting multiple awareness programmes in Mizoram and distribution of pamphlets on invasive alien plants for their easy identification by the forest guards and local stakeholders.
- Involvement of local community for getting to know about the impacts and introduction history of the selected noxious invasive alien plants, their impacts on local natural forests and agriculture and identification of anthropogenic activities which triggers invasion in Mizoram and Tripura.
- Preparation of geo-tagged locations and map of most noxious invasive alien plants for a better priority-based control by the local forest officials.

Impact on of Natural Resources/ Environment

- *Ageratina adenophora* and *Mikania micrantha*, both invasive alien plants were noxious in herb and shrub layer respectively in the invaded regions including the natural forests and agricultural fields of Mizoram and Tripura.
- The species richness of the invaded study plots was less than the uninvaded plots inferring threat to the natural flora.
- The main reason behind the invasion by these alien plants could be attributed to the shifting cultivation pattern, anthropogenic disturbances (viz. habitat destruction, reduced fallow periods, industrialization without appropriate planning, construction etc.), amendable quarantine policy for seed and horticultural alien plants etc.

Conservation of Biodiversity

- A total of 163 species and 186 species of alien plants were reported from Mizoram and Tripura.
- As a serious impact of invasion by alien plants like *A. adenophora* and *M. micrantha* leads to reduced biodiversity and species richness in invaded areas including the natural forests of protected areas like Phawngpui national park, Lengteng wildlife sanctuary, Dampa tiger reserve in Mizoram and Trishna wildlife sanctuary, Clouded Leopard national Park, Rowa wildlife sanctuary, Sepahijola wildlife sanctuary, Gomati wildlife sanctuary in Tripura.
- Anthropogenic disturbances like extraction of fuelwood, NTFP and fodder from natural forests, clearing of natural forests for shifting cultivation paves the way for invasion by alien plants.
- Ecological status of noxious invasive alien plants revealed that *Ageratina adenophora*, *Mikania micrantha*, *Ageratum conyzoides*, *Chromolaena odorata* pose significant threat to the natural flora of Mizoram and Tripura.

➢ EXIT STRATEGY AND SUSTAINABILITY

➢ Utility of project findings

1. As per CBD (2020) Aichi protocol target-9, it must be ensured that invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment. The present findings of the project fulfil the gap for comprehensive database of invasive alien plants in Mizoram and Tripura along with their ecological status. Most obnoxious and prioritized species were also identified, namely *Ageratina adenophora, Mikania micrantha, Lantana camara, Chromolaena odorata* and *Ageratum conyzoides* along with their potential threats to the natural ecosystems. The ecological status of the noxious invasives and reproductive potential for *Ageratina adenophora* and *Mikania micrantha* were investigated which revealed their invasion dynamics in Mizoram and Tripura. The awareness programmes conducted during the project tenure also made sure that local stakeholders and communities were involved so that awareness dissemination materials could be distributed among the local communities so that the invasive identified plants could be identified and controlled in local scale.

2. The information generated under the project can be used by Government of India for reporting purpose under the several international commitments such as CBD, IPBES etc as well as it will also be useful in addressing sustainable development goals.

3. The project activities directly supported enhancing livelihood by identifying the threat from invasion by alien plants, biodiversity conservation and flow of ecosystem services. Further,

scaling up trial eradication activities by local forest departments would help in control and management of invasion by alien plants.

4. The awareness programme cum workshops for the stakeholders will be effective in creating of skilled personals in the selected states who can be involved in various green projects, as well as in eco-tourism in the landscape for livelihood generation.

- **Other Gap Areas**

Outcomes of the project revealed the status of invasion by alien plants in the state of Mizoram and Tripura which provides a baseline data for the control and management of most noxious invasive alien plants. Various control methods like mechanical eradication, chemical eradication and biological eradication could be implemented in future based on this baseline data on invasive alien plants. Most noxious invasive alien plants could be explored for their bioprospecting aspects.

- **Major Recommendations/ Way Forward**

1. Preparation of suitable control and management strategies that are easily available at national, state, district and village levels is essential with the awareness activities for optimising the interventions output and viability. One should ensure sustainable approach for ecological impact of the invasion by alien plants and the acceptance by providing clear picture of socioeconomic, environmental and future benefits of any interventions and any new bioprospecting introduced to the local communities.

2. Developing market linkages and a wider outreach strategy for use of invasive alien plants as bioprospecting resources should be implemented for creating and increasing awareness of ongoing project outcomes.

3. In order to continue the control of invasion by alien plants due to climate change impacts, adaptation and mitigation actions as a part of project exit strategy, involvement of GIS based identification of most invasion prone areas by the local forest department is necessary.

4. Further workshops/ awareness programmes/ training programs should be conducted at district and village levels for widespread knowledge on impact of invasion by alien plants in the study area in order to ensure project success and sustainability.

5. Further long-term monitoring for the invasive alien plants should be developed using the baseline data generated through the project and Forest Departments of the States should be collaborated accordingly by adopting the strategies into regular control and management programmes at Forest Division level.

- **Replication/ Upscaling/ Post-Project Sustainability of Interventions**

The project strategy should be customized and replicated in forest action planning as per requirement of different geographical regions in India driven by ecological impact, socioeconomic impact and available natural control methods and livelihood bioprospecting to control and manage invasive alien plants in natural forests.

The frontline staff who were trained under the project can be used by the respective forest management units to enhance capacity of the other staff by identifying them as trainers.

Developing Mountain Infrastructures

- Interacted with the local community and investigated the socio-economic uses of invasive alien plant. Study on the use pattern of the alien species among the local inhabitants revealed that some invasive alien plants had been used as medicinal purposes, ornamental, foods, fuel woods and green manure but their non-native origins as well as harmful impact on environment were not known to the locals. The outcomes of the project including the awareness programmes made them well informed about the impact of invasive alien plants on natural forests in Mizoram and Tripura.

- A baseline database on invasive alien plants of Mizoram and Tripura was prepared which was also communicated with the local forest officials in printed pamphlet format which will pave a way for multistep management strategy towards the conservation of native flora and eradication of invasive species.

Strengthening Networking in State/ UT

- Strengthening Networking in IHR were performed via conducting awareness programmes in collaboration with research institutes, universitites, govt. department, NGO and local Community to implement the project activities. The main organizations involved include:
- **Project Implementing Partners**
    1. Department of Botany, Panjab University, Chandigarh
    2. Department of Botany, University of Kashmir
    3. Department of Environment Studies, Panjab University, Chandigarh
    4. Plant Ecology and Climate Change Science Division CSIR- National Botanical Research Institute, Lucknow
    5. Botanical Survey of India, Kolkata, West Bengal
    6.Department of Forestry, North Eastern Regional Institute of Science & Technology (NERIST), Nirjuli, Arunachal Pradesh
- **Local Technical Partners**
    1. Environment, Forests & Climate Change Department, Government of Mizoram
    2. Tripura Forest Department, Government of Tripura
    3. University of Mizoram
    4. Sangau Village Council, Mizoram
    5. Vapar Village Council, Mizoram
    6. Local Communities in Mizoram and Tripura

FOR ARUNACHAL PRADESH, NAGALAND, MANIPUR (Prof. L.B. Singha)

- **INTRODUCTION**
- **Background** (max. 500 words)

Invasive Alien Plants pose a major threat to the ecology and economy by homogenizing the vegetation and threaten biodiversity. Though this phenomenon has been occurring since long, yet the problem of plant invasion did not engage sufficient attention in Northeast region, India as a whole and elsewhere. The magnitude of impact varies from place to place depending upon the geographical features, landscape and population density of the area invaded. Realising the seriousness of the issue, the coordinating institute has organized several multi-level and multi institutional meetings, where serious discussions were made to expound the concerns regarding ecological and economic impact due to invasive alien species in and around India. As outcome of those meetings, decisions were made to formulate effective strategies for the early prediction. rapid response and management of IAS as per the objectives of Convention on Biological Diversity due to the following reasons:

- India is a mega-diversity country with 4 of the 34 MAB recognized Biodiversity Hotspots and 10 bio-geographic regions has become a favoured place of invasion by alien species.
- States namely, Arunachal Pradesh, Manipur, Nagaland and Mizoram in the northeast are hilly terrain and very rich in biodiversity with global recognition as Indo-Burma biodiversity hotspot. In addition, many trans Himalayan Eco regions are also associated to these states namely, Indo-China, Indo-Bhutan, Indo-Myanmar and Indo-Bangladesh, which are also very rich in unique, endemic and RET species.
- Wide range of latitude, longitude and altitude, diversity in climate and socio-cultural factors, apart from universal anthropogenic reasons have contributed to "large-scale" invasion by plants, animals and micro-organisms.
- The fast increasing economic growth coupled with tourism and trade is expected to result into more trans-boundary influx of exotic species and thus resulting to homogenization of flora and fauna.

It was also strongly felt that the region has already crossed the lag-phase of invasion by alien species. Any delay in combating the precarious situation would lead to a regional and national ecological disaster.

- **Overview of the major issues addressed** (max. 500 words)

Invasive Alien Species (IAS) pose a major threat to the ecology and economy in invaded regions of Northeast, especially forest and Hill ecosystems. They cause a major change in vegetation at the trans

Himalayan biodiversity hotspots of the region, namely Indo- China, Indo-Bhutan and Indo-Burma that threaten the rich biodiversity. Though this phenomenon has been occurring since long, yet the problem of invasion has gained momentum in the last two decades because of many reasons including human interventions and global economic growth. The magnitude of impact varies depending on the geographical features of the region, population density and type of landscape.

Significant loss of biodiversity due to invasive alien species could have far-reaching consequences. Detail information on such invader species, such as, diversity, their actual distribution pattern, identification of their point of entry, nature and pattern of invasion, regeneration status, phenology and total geographical area occupied etc. is very meagre at local, regional as well as national level. It is a well-known fact that the areas invaded by alien plants attract alien dependent fauna. The latter could serve as an initial carrier of plant propagule, but primary invaders, by and large, are the plants. Thus, the invasion by plants, the producer, is obviously a basic issue, since all other forms of biota are dependent on them. Therefore, invasion by alien plants assume the primary focus.

The ecological impacts of IAS on fragile forest ecosystems in this hilly region of India have attracted the attention for resolving the problems caused by IAS and conservation of the ecologically and socially important rich biodiversity of the region. As per the reports of World Conservation Union (WCU), the Convention on Biological Diversity (CBD), and the Global Invasive Species Programme (GISP), IAS proliferate and spread in new environments and are detrimental to human and national interests. The real challenge is to control their spread and save the local, national and global ecology from destruction by understanding their distribution pattern and rate of spread as well analysing their regeneration ecology. Identification and development of suitable control measures including scope for their utilization in domestic purposes, at local, regional and national level.

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

Sl. No.	Objectives	Deliverables
i.	Identifying established and new Invasive Alien Vascular Plant Species in the Indian Himalayan Hills and estimating the invasion load.	New Datasets: Complete inventory, distribution and areas infested by Invasive Alien Species in the Indian Himalayas.
ii.	Characterizing the Invasive Vascular Alien Plants on the basis of their life-forms, lifespan, nativity, status of invasion and purpose of invasion/introduction	Dynamic model: Rate & mode of spread (including vectors responsible) with GPS & ground truthing.

iii.	Preparing protocols for prediction, early detection and risk assessment of alien invasive plant species for each region	Data on Baseline studies and Assessment of IAVPS
iv.	Assessment of Ecological & Environmental Impact of invasion and spread with special reference to biodiversity and soil especially in relation to climate change; This will include the level of disappearance of native species	Reports to state agencies of the disappearance of native plant species
v.	Selection of at least 10 most noxious invasive species from different regions and consolidation of all available information including their biology, itemizing at the same time the knowledge gaps.	List of noxious Invasive species, their value addition and utilization for livelihood of local communities.
vi.	Identification of a cross-sectoral group to assess the situation in the form of case-studies on these species, and also to formulate workable management strategies aiming to prediction, prevention and control	Policy and legislative mechanisms for management / eradication / mitigation will get framed.

- **METHODOLOGIES/STARTEGY/ APPROACH**

Digital Elevation Maps (DEMs) of 300m elevation gradients of the 3 states were prepared from the land use land cover maps. Exploration for IAVPS in random sample plots with reference to DEM at different climate regions covering representative forest types available were conducted through suitable quadrat/transect methods and the plant samples were collected. They were later identified by consulting herbarium, local flora and online sources like Royal Botanical Garden and their nativity were also sourced. Assessment of the life forms for the targeted IAVPS was recorded by morphological studies and observation for their phenological characteristics including total lifespan. Tracing of the origin and documentation of the purpose of introduction of IAVPS if so, is done by interactions with the local departments/ bodies/ inhabitants and from the available literatures. Phytosociological analysis of IAVPS was carried out by following Misra (1968), Mueller-Dombois and Ellenberg (1974), Magurran (1988) and Curtis and McIntosh (1950). GPS coordinates were tagged for respective IAVPS at different locations and georeferenced distribution map of IAVPS developed using Arc-GIS software. For the study of impacts of IAVPS on soil, soil samples were collected from different localities sampled as per the standard methodologies and the soil pH, and available forms of NPK were analysed. The dominating IAVPS recorded from the three states were listed out and the matured seeds of the selected plants were collected. Germination tests were performed in replicates using blotting papers and petri dishes to identify their germination capacities. As part of the value addition, vermicomposting experiment was carried out using the plant parts of *Ageratina, Ageratum, Chromolaena, Lantana,* and *Mikania* with *Eisenia foetida* in

composting bins. The digested compost was harvested and the parameters namely pH and total concentrations of organic carbon were analysed following the standard methods.

Data collected and Equipments utilized (max. 500 words)

Methods used for the calculation of phytosociological parameters:

i. Frequency %:

$$\text{Frequency\%} = \frac{\text{Quadrates in which the species occured}}{\text{Numbers of quadrates studied}} \text{ X } 100$$

$$\text{Relative Frequency, RF} = \frac{\text{Frequency of the species}}{\text{Total frequencies of all the species}} \text{ X } 100$$

ii. Density/unit square:

$$\text{Density, D} = \frac{\text{Total individuals of the species recorded}}{\text{Numbers of quadrates studied}}$$

$$\text{Relative Density, RD} = \frac{\text{Density of the species}}{\text{Total densities of all the species}} \text{ X } 100$$

iii. Abundance:

$$\text{Abundance} = \frac{\text{Total individuals of the species observed}}{\text{Quadrates in which the species occured}} \text{ X } 100$$

$$\text{Relative Abundance, RD} = \frac{\text{Abundance of the species}}{\text{Total abundance of all the species}} \text{ X } 100$$

iv. Dominance and Cover:

Dominance for trees = Tree basal area X Density

$$\text{Relative Dominance, } RD_{do} = \frac{\text{Dominance of the species}}{\text{Total dominance of all the species}} \text{ X } 100$$

Plant Cover for shrubs and herbs= Basal cover X Density

$$\text{Relative Cover, RC} = \frac{\text{Plant Cover of the species}}{\text{Total plant cover of all the species}} \text{ X } 100$$

v. Important Value Index:

Important Value Index, IVI = RF + RD + RD_{do} or RC

Methods for the analysis of chemical Parameters

i. pH Standard pH Method (Bio-Era pH Meter)
ii. Organic Carbon by Walkley and Black Method
iii. Total Nitrogen Kjeldahl Method
iv. Total Phosphorus Molybdenum Blue Method
v. Total Potassium Flame Photometric Method

- **Details of Field Survey conducted, if any** (max 500 words)

April,2018 to March,2019

Visit to Kimin, Yazali of Papum Pare dist. Yachuli & Ziro of Lower Subansiri: 18-20 Aug 2018

Visit to Pamto & Hoj of Papum Pare dist. : 12-13 Nov 2018.

Visit to Bhalukpong, Nechiphu, Rupa, Shergaon, Bomdila and Dirang of West Kameng dist.: 22 Nov- 5 Dec 2018.

Visit to Nine districts of Manipur: 20 Dec 2018 to 5 Jan 2019.

Visit to Dimapur, Kohima and Wokha dist. of Nagaland: 10 -20 March 2019.

April,2019 to March,2020

Visit to Lamdeng, Nongmaiching, Laimaton, and ChhotoBegra in Manipur: 11-23 June, 2019

Visit to Nechiphu and Bhalukpong of West Kameng dist. in Arunachal Pradesh: 20-24 August, 2019.

Visit to Kwatha, Kwatha Khunou and Lairouching in Manipur: 20 Dec 2019 to 5 Jan 2020.

One day local visit to Old Sagalee road in Arunachal Pradesh: 12 Jan 2020.

April,2020 to March, 2021

Visits to the premises of Loktak Lake in Manipur: 14 October, 2020 to 26 October, 2020

Field visits to various tropical, subtropical and temperate localities in Manipur: December 2020 to January 2021

- **Strategic Planning for each activity with time frame**

	WORK UNDERTAKEN	

PROJECT ACTIVITIES	April, 2018- March, 2019		April, 2019- March ,2020		April, 2020- March, 2021		OUTPUT
	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	
Recruitment of RA, JRF & Tech. staff	Recruitment process & appointment of manpower done in the last year						1-JRF, 01-JPF and 1-FA were appointed & trained
Field survey and Selection of study sites	Random survey for IAVPS at different localities in Manipur as per the DEM	Random survey for IAVPS at different localities Arunachal Pradesh per the DEM	Random survey for IAVPS at different localities in Manipur as per the DEM	Random survey for IAVPS at different localities Arunachal Pradesh per the DEM		Random survey for IAVPS at different localities in Manipur as per the DEM	50 more species were observed till the last sampling from the new localities
Procurement of equipment, ecological software, chemicals & LISS IV data			Procurement of GPS and softwares	Procurement of chemicals			Procured GPS model, Ecological software and consumables. LISS IV data could not be procured due to insufficient funds.
Field data collection & processing	Collection of data for phyto-sociological parameters and soil samples from the microhabitats of	Collection of data for phyto-sociological parameters and soil samples from the microhabitats of IAVPS & analyzing	Collection of data for phyto-sociological parameters and soil samples from the microhabitats of IAVPS & analyzing	Collection of data for phyto-sociological parameters and soil samples from the microhabitats of IAVPS & analyzing		Identification of the newly observed IAVPSCollection of data for phyto-sociological parameters and soil samples	Collected and analyzed data on diversity and distribution of IAVPS in few districts of Arunachal Pradesh and Manipur.

	IAVPS & analyzing their distribution in Manipur	their distribution in Arunachal Pradesh	their distribution in Manipur	their distribution in Arunachal Pradesh		from the microhabitats of IAVPS & analyzing their distribution in Manipur	
Edaphic / physiographic Characterization	Analysis of Chlorophyll (a, b and total) of the selected IAVPS.	Analysis of soil physico-chemical parameters for microhabitats of selective IAVPS.	Analysis of total nutrient content of selected IAVPS vermicompost				Generated data on soil pH, moisture and Available NPK content of microhabitats for selective IAVPS of Arunachal Pradesh, Manipur and Nagaland.
Studies on population ecology and seed biology of IAVPS with their GPS tagging		GPS tagging done for unique microhabitats of selected IAVPS. Population data was recorded & is under analysis.		Seed germination experiments for the selected IAVPS were conducted.		Seed germination experiments for the selected IAVPS were conducted.	GPS tag for the IAVPS at multiple localities were made for future studies

- **KEY FINDINGS AND RESULTS**

Diversity of IAVPS

During the extensive study conducted in the three states Indo-Himalayan region (IHR), various localities which are already invaded by IAVPS were identified and the GPS coordinates of the areas invaded by different species were noted. A total of one hundred thirty-one alien and invasive plants were recorded from multiple samplings conducted across the region, where most of them are native of American continent (Annexure I). These plant species were composed of thirty-six different families and one hundred and four genera. Among these IAVPS, the most dominant plants were observed to be the asterids. More than one-fourth i.e. thirty-one plant species were belonged to Asteraceae family while Fabaceae and Poaceae were recorded with thirteen and eleven plant species respectively (Figure 1).

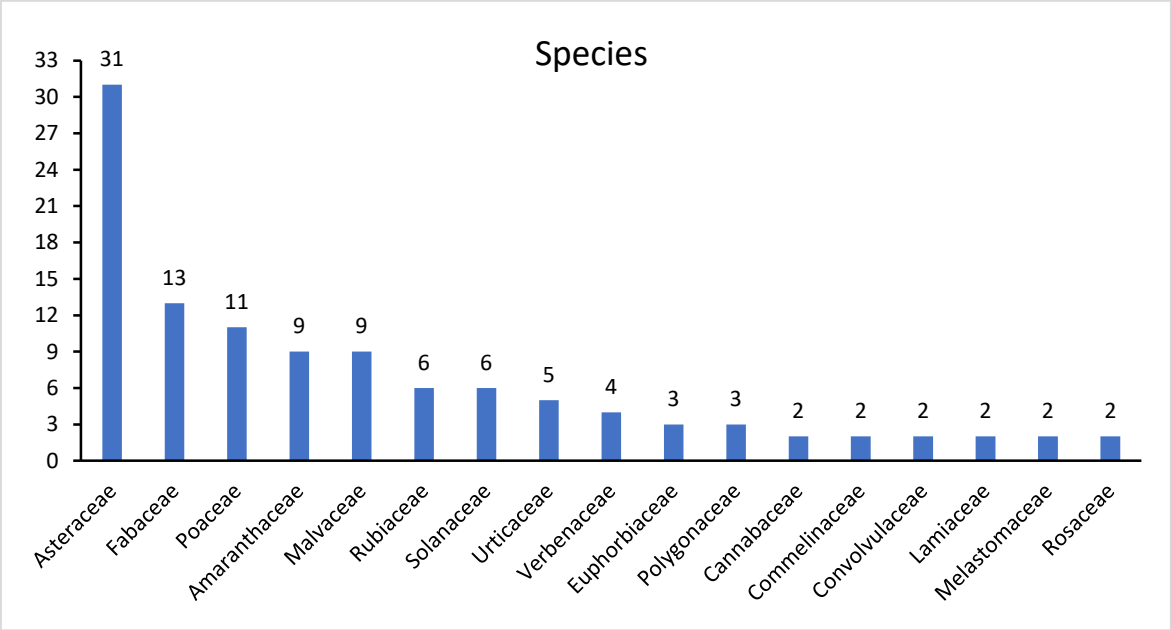


Figure 1.Dominant seventeen families and their respective number of species.

Some other dominant families to be mentioned are Amaranthaceae, Malvaceae, Rubiaceae, Solanaceae Urticaceae, Verbenaceae, Euphorbiaceae and Polygonaceae (Table 1). Out of the observed IAVPS, the greatest number of IAVPS was reported from Manipur with 110 species followed by Arunachal Pradesh with 89 species while Nagaland was recorded with 51 IAVPS (Figure 2). Most of IAVPS observed were herbaceous plants six of them are climbers and three of them are trees (Figure 3).

Table 1. List of families observed with their respective number of plant species recorded in the three IHR states

Sl. No.	Family	Species
1	Asteraceae	31
2	Fabaceae	13
3	Poaceae	11
4	Amaranthaceae	9
5	Malvaceae	9
6	Rubiaceae	6
7	Solanaceae	6
8	Urticaceae	5
9	Verbenaceae	4
10	Euphorbiaceae	3
11	Polygonaceae	3
12	Cannabaceae	2
13	Commelinaceae	2
14	Convolvulaceae	2
15	Lamiaceae	2
16	Melastomaceae	2
17	Rosaceae	2
18	Apocynaceae	1
19	Araceae	1
20	Boraginaceae	1
21	Brassicaceae	1
22	Caryophyllaceae	1
23	Cleomaceae	1
24	Cyperaceae	1
25	Ephedraceae	1
26	Lythraceae	1
27	Moraceae	1
28	Onagraceae	1
29	Papaveraceae	1
30	Piperaceae	1
31	Plantaginaceae	1
32	Pontederiaceae	1
33	Portulacaceae	1
34	Scrophulariaceae	1
35	Smilacaceae	1
36	Tiliaceae	1
	Total	131

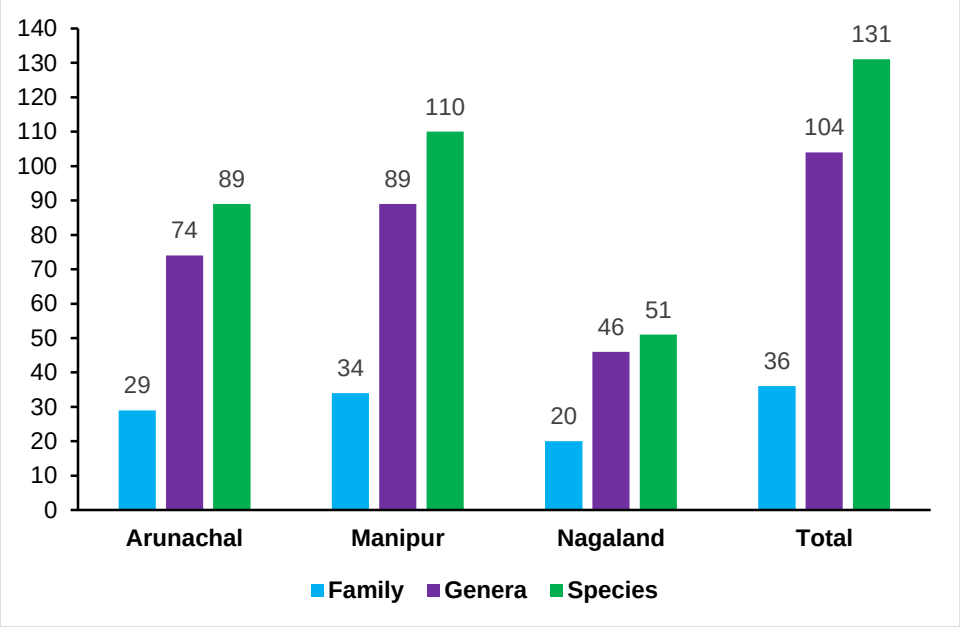


Figure 2. Number of Taxa reported from each of the three states.

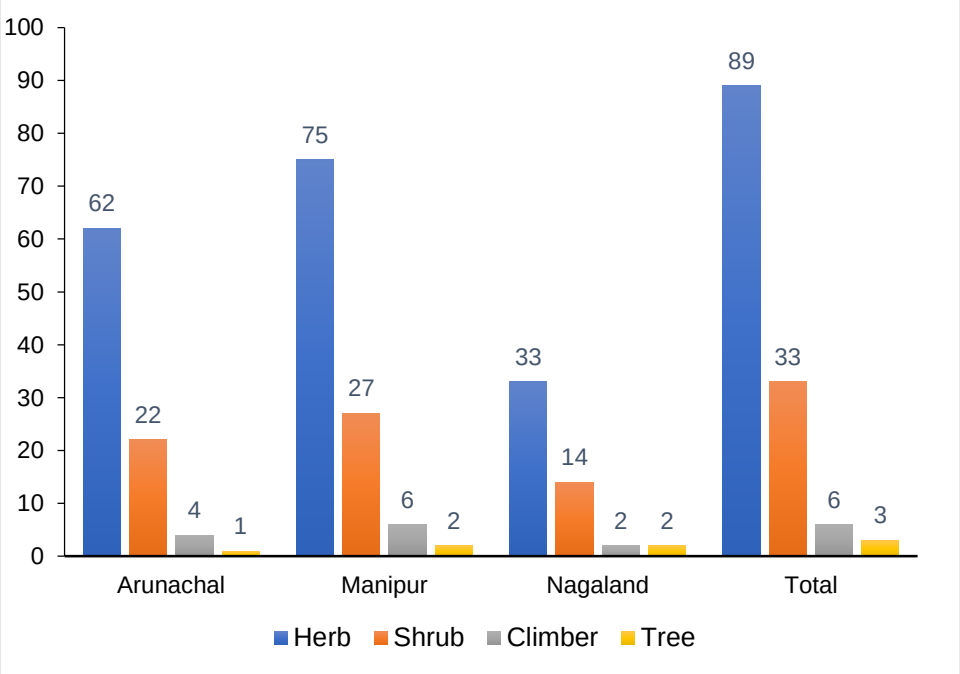


Figure 3. Characterisation of plant species on the basis of life forms.

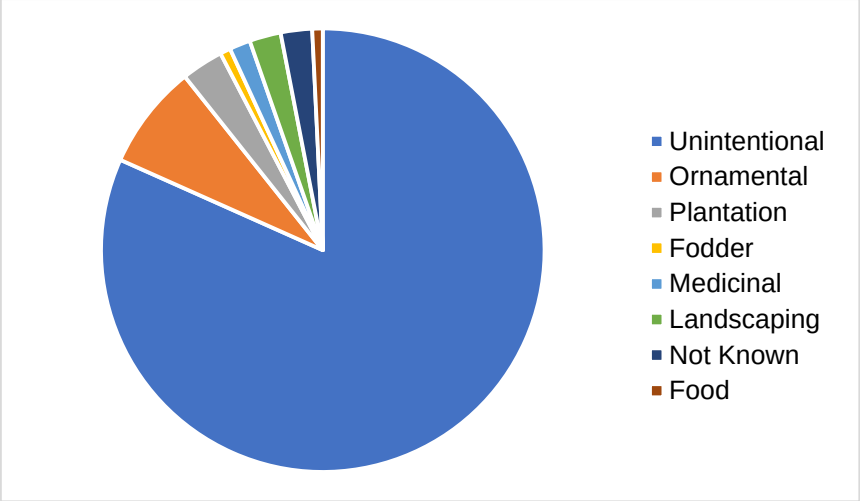


Figure 4 Characterisation of the plant species on the basis of their mode of introduction

Noxious IAVPS in the region

More than thirty-two species observed were already widely distributed and established invasives in the region. Some of the important noxious species are *Ageratina adenophora, Ageratum conyzoides, Ageratum houstonianum*, *Bidens pilosa*, *Chromolaena odorata*, *Chrysopogon aciculatus, Hyptis suaveolens, Imperata cylindrica*, *Mimosa pudica*, *Mucuna bracteata, Parthenium hysterophorus*, *Pontederia crassipes*, *Senna alata, Tithonia diversifolia, Urena lobata* and *Xanthium strumarium*, etc. Based on their frequent distribution and dominance in various ecoregions, ten most noxious IAVPS were selected as below,

Table 2. Ten most noxious invasive species in the three IHR states.

Sl. No.	**Species**	**Family**	**axonomic Group**	**Taxonomic sub-group**	**Purpose of Introduction**	**Invasion Status (Casual/ Naturalising/ Established)**
1	*Ageratina adenophora*	Asteraceae	An	Dicot	Un-intentional	Established
2	*Ageratum conyzoides*	Asteraceae	An	Dicot	Un-intentional	Established
3	*Ageratum houstonianum*	Asteraceae	An	Dicot	Un-intentional	Established

4	*Bidens pilosa*	Asteraceae	An	Dicot	Un-intentional	Naturalising
5	*Chromolaena odorata*	Asteraceae	An	Dicot	Un-intentional	Established
6	*Lantana camara*	Verbenaceae	An	Dicot	Ornamental	Established
7	*Mikania micrantha*	Asteraceae	An	Dicot	Un-intentional	Established
8	*Tithonia diversifolia*	Asteraceae	An	Dicot	Ornamental	Established
9	*Parthenium hysterophorus*	Asteraceae	An	Dicot	Un-intentional	Naturalising
10	*Urena lobata*	Malvaceae	An	Dicot	Un-intentional	Naturalising

In tropical open forests, *Mikania micrantha, Ageratum conyzoides and Chromolaena odorata* were recorded in pure patches as well as in mixed population, where both the species were recorded from low to high elevations. *Lantana camara* was localized in open forests and not recorded under the tree canopies occurring in both tropical and sub-tropical belts. Densely regenerated population of *Ageratum conyzoides* succeeds most forest floors. *Parthenium hysterophorus* was recorded near the roadsides adjoining to the evergreen forests at higher range of tropical belt, but with limited population in all the states while its aggressive growth was observed in disturbed roadsides near human habitations. *Ageratina adenophora* and *Tithonia diversifolia* were absent in tropical belt in Arunachal Pradesh but were observed at sub-tropical forests. Dense populations of *Chromolaena odorata* and *Lantana camara* were widely grown in tropical belts of Papum Pare and pockets of Lower Subansiri, Arunachal Pradesh and in many places of Manipur at higher tropical regions. These two species were also dominating in the lower tropical plain areas in Nagaland while *Ageratina adenophora* dominated in the higher subtropical hills. It was ascertained that *Lantana camara* was used as live fencing and *Ageratina adenophora* as soil binder in different parts of Manipur. *Ageratina adenophora* was found to be growing frequently and thickly on the sub-tropical locations while *C. odorata* and *L. camara* were found to be growing dominant on localities having elevation

less than 300m. Only *Ageratina adenophora, Artemisia nilagirica* and *Tithonia diversifolia* were the invasive plants to observed at 2600 m amsl altitudes, but with a limited population

Germinative Capacity of the selected IAVPS

Seed germination tests were conducted for the six selected species *Ageratum conyzoides, Ageratum houstonianum, Bidensp pilosa, Chromolaena odorata, Lantana camara* and *Mikania micrantha.* Except for *Lantana camara,* seeds of the five species showed germination response. Highest germination percent was attained by *Bidens pilosa followed* by *Mikania micrantha* and *Ageratum conyzoides. Chromolaena odorata* exhibited the lowest germination percent but attained the peak germination on the 2.2 ± 0.45 days after introduction into petridishes (Table 3).

Table 3. Seed biology parameters of the seeds collected from study sites (in mean±SD)

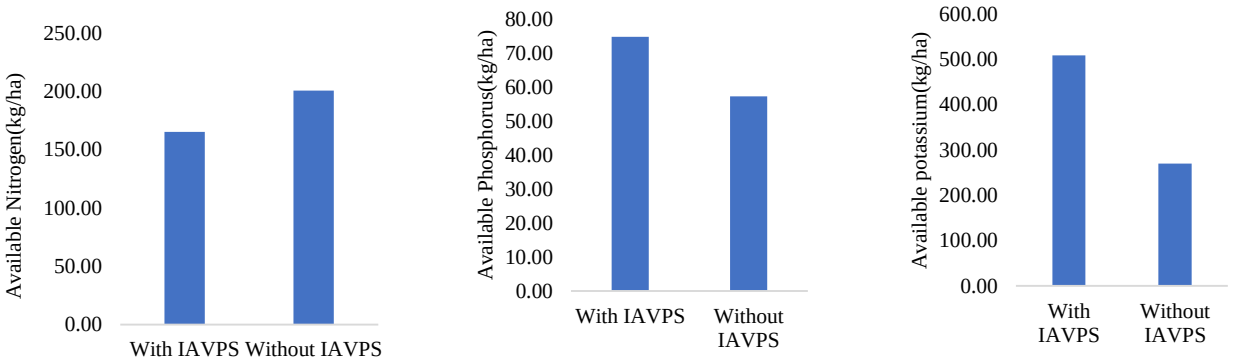
Sl. No.	**Species**	**Seeds Geminated (Mean±SD)**	**Seeds Sown**	**Germination Percent (Mean±SD)**	**Germination Period (in days) (Mean±SD)**
1	*Ageratum conyzoides*	43.6 ±3.05	50	87.2 ±6.10	5.8 ±0.45
2	*Ageratum houstonianum*	38 ±1.58	50	76 ±3.16	6.4 ±0.54
3	*Mikania micrantha*	44 ±1.22	50	88 ±2.45	4.8 ±0.55
4	*Chromolaena odorata*	25.4 ±3.21	50	50.8 ± 6.42	2.2 ± 0.45
5	*Bidens pilosa*	28.2 ±0.84	30	94 ±2.79	4.6 ±0.89
6	*Lantana camara*	-	30	-	-

Impact of IAVPS on Soil

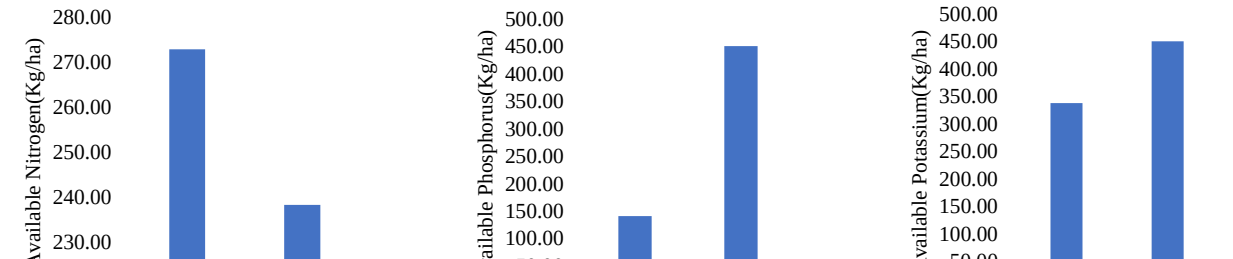
- Detail investigation of soil properties were carried out by collecting samples from both the invaded and non-invaded from different study sites of Arunachal Pradesh, Manipur and Nagaland.
- One of the goals of our research was to see if there was any link between invaded soil and non-invaded soil condition using broad samples from different study sites.
- **Soil pH**: Soil of Arunachal Pradesh was less affected by acidity, whereas Manipur and Nagaland soil was highly affected by acidity. The soil acidity decreased at lower elevation in all the three states, however there was modest rise in the alkalinity of the soil. Soil without IAVPS in all the three states were affected by acidity, however gradual decrease in acidity was observed with IAVPS.
- **Soil NPK:** IAVPS have the potential to alter ecosystem function. However, generalizations were difficult to make because impacts appeared to be species- and site-specific. Most of the soil where IAVPS were established had shown lower nutrient content to that of the soil without IAVPS. Soil nutrients content of Manipur was found to be lower than that of Arunachal Pradesh and Nagaland. Nitrogen and potassium were found less affected by IAVPS whereas Most of the soil samples from study sites where IAVPS established had shown lower phosphorus content than that of the soil without IAVPS. *Ageratina adenophora* was observed less deteriorating the soil nutrients whereas other IAVPs, *Ageratum conyzoides, Mikania micrantha, Chromolaena odorata* and *Lantana Camara* were observed deteriorating the soil nutrients most in all 3 states at the different elevation gradient irrespective of their dominance.

Figures 5: Variation of soil nutrient in Arunachal Pradesh at different elevation.

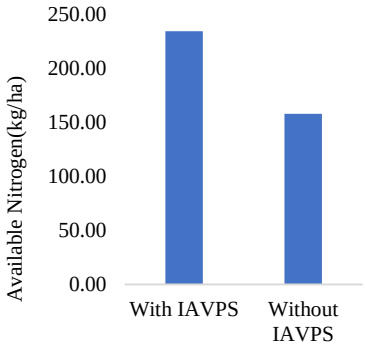
(a) Elevation: 0 – 300 m asl

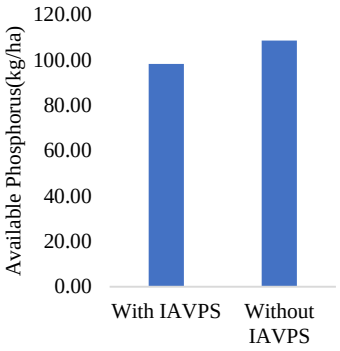


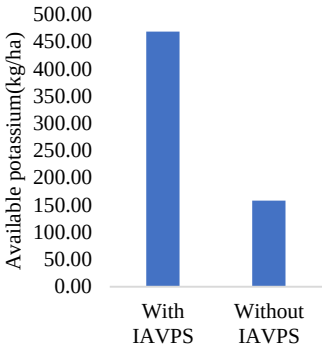
(b) Elevation: 600 – 900 m asl



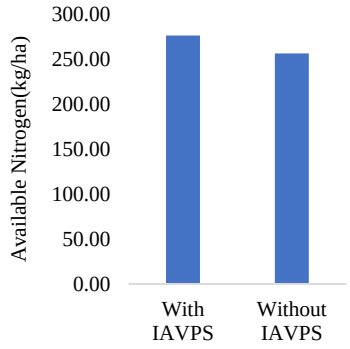
(c) 1200-1500 m asl

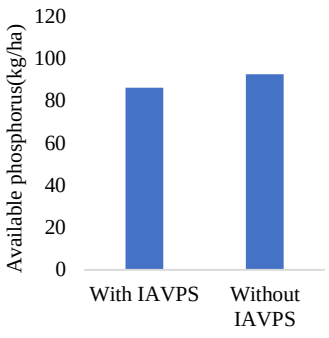


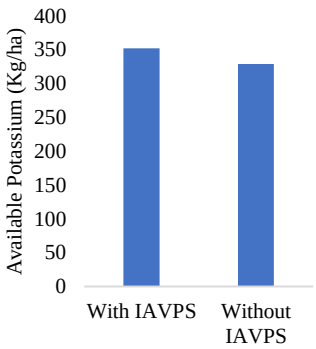




(d) 1500-1800 m asl

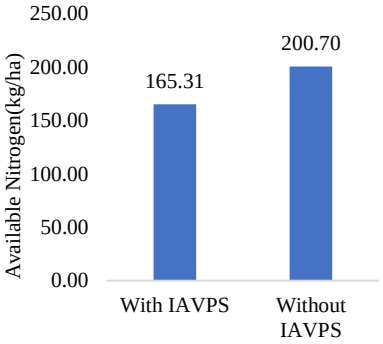


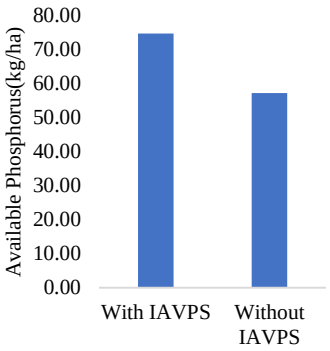


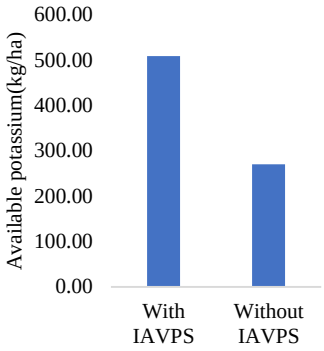


Figures 6: Variation of soil nutrient in Nagaland at different elevation.

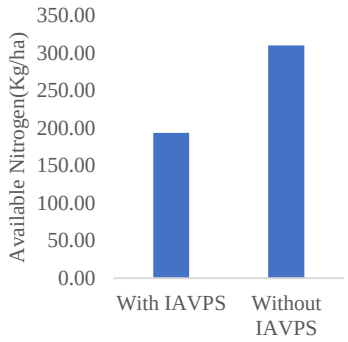
(a) Elevation: 0 – 300 m asl

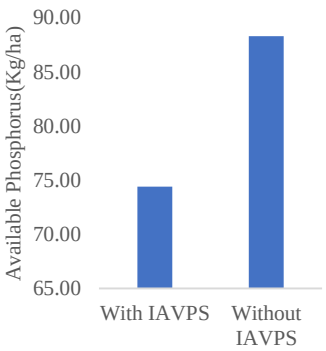


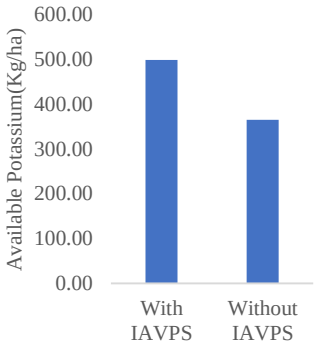




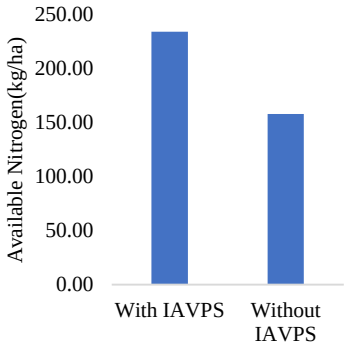
(b) Elevation: 600 – 900 m asl

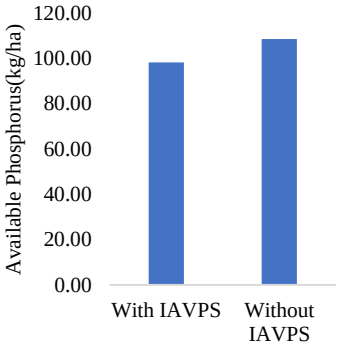


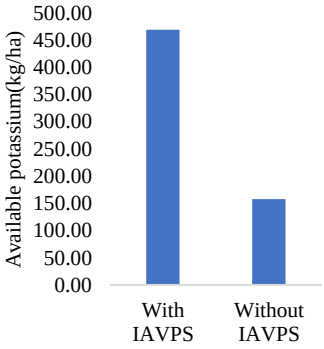




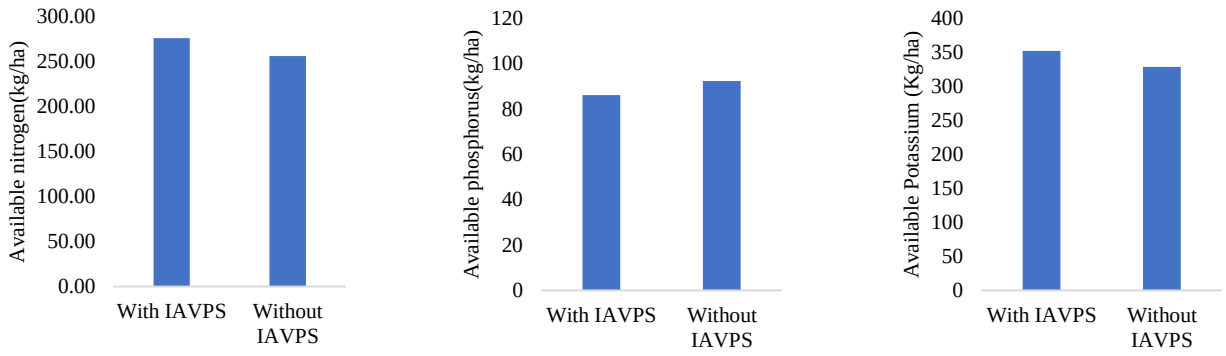
(c) 1200-1500 m asl





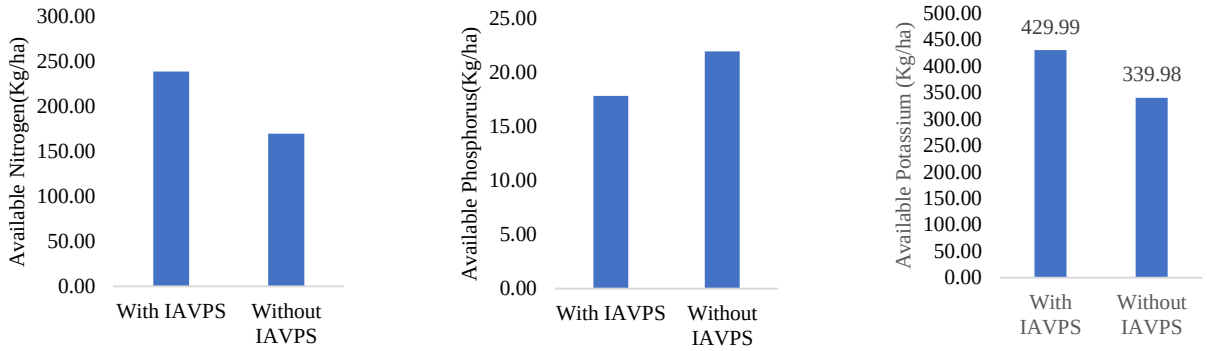


(d) 1500-1800 m asl

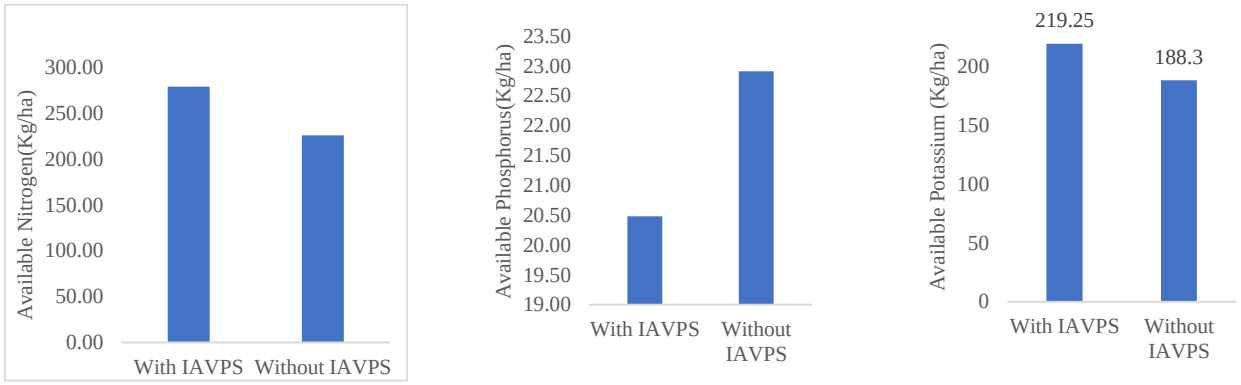


Figures 7: Variation of soil nutrient in Manipur at different elevation.

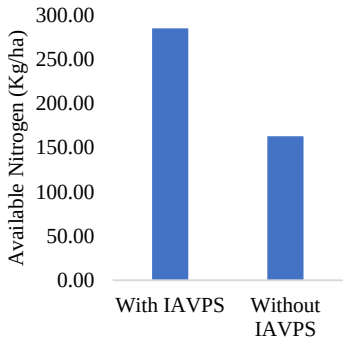
(a) Elevation: 0 – 300 m asl

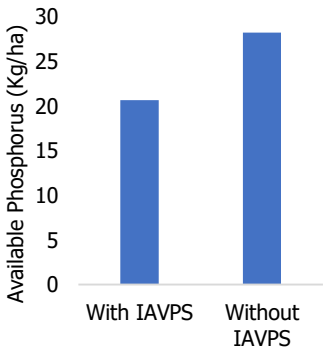


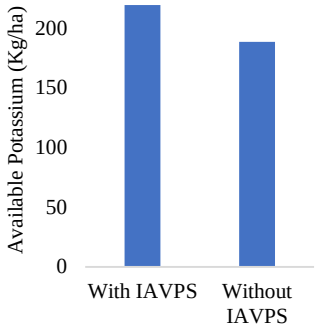
(b) Elevation: 600 – 900 m asl



(c) 1200-1500 m asl







- **Key Results (max. 500 words in bullets covering all activities)**
  - ✓ From the three states altogether 131 alien and invasive plants were documented from different habitats located in different altitudes and several localities under invasion were identified.
  - ✓ As usual, plants belonging to the Asteraceae family were found to be dominant in the region also.
  - ✓ Considering about their nativity, most of them were found to be originated from the American continent.
  - ✓ Three species namely, *Ageratina riparia, Croton boplandianus* and *Solidago canadensis* were newly observed and recorded from different localities of Manipur.
  - ✓ *Ageratina adenophora, Ageratum conyzoides*, *Ageratum houstonianum, Bidens pilosa, Chromolaena odorata, Lantana camara, Mikania micrantha, Parthenium hysterophorus, Tithonia diversifolia* and *Urena lobata* were most noxious IAVPS observed.
  - ✓ Less number of IAVPS was recorded in the subtropical and temperate localities. Only *Ageratina adenophora* was reported upto 2100-2400m asl altitude while it was absent in higher localities than this. *Tithonia diversifolia* though having low frequency, it was observed to be dominating along the hillsides located in the subtropical climates in Manipur.
  - ✓ Both *A. conyzoides* and *A. houstonianum* were frequent in all the three states alongside *Bidens pilosa*. *Parthenium hysterophorus* has limited population in the forest while it was observed with aggressive growth and infestation along the roadside vegetation.
  - ✓ *Lantana camara* was observed to be the dominating shrub with *Chromolaena odorata* in localities under 600m asl of Papum Pare in Arunachal Pradesh while the high regions were dominated with *Ageratina adenophora*.

- ✓ Most of the soil where IAVPS were established had shown lower nutrient content to that of the soil without IAVPS. Soil nutrients content of Manipur was found to be lower than that of Arunachal Pradesh and Nagaland. Nitrogen and potassium were found less affected by IAVPS whereas Most of the soil samples from study sites where IAVPS established had shown lower phosphorus content than that of the soil without IAVPS. Ageratina adenophora was observed less deteriorating the soil nutrients whereas other IAVPs, Ageratum conyzoides, Mikania micrantha, Chromolaena odorata and Lantana Camara were observed deteriorating the soil nutrients most in all 3 states at the different elevation gradient irrespective of their dominance.
- ✓ The total nitrogen content of the digested compost was highest in *Chromolaena odorata* (1.83 %) and lowest in *Ageratina adenophora* (1.44%). The total phosphorus content was observed highest in *Ageratina adenophora* (1.56 %) and lowest in *Mikania micrantha,* (1.32 %), and the total potassium content in *Mikania micrantha* (12.82%), and lowest in *Ageratum conyzoides* (4.91 %).
- ✓ Seed germination experiments were conducted for *Ageratum conyzoides, Ageratum houstonianum*, *Bidens pilosa*, *Chromolaena odorata*, *Lantana camara*, *Mikania micrantha* and *Tithonia diversifolia*. Highest germination was exhibited by *Bidens pilosa* (94 ±2.79%) followed by *Mikania micrantha* (88 ±2.45%) and *Ageratum conyzoides* (87.2 ±6.10%) while no seeds of *Lantana camara*.were germinated under multiple trials. It was observed to be regenerated from the bird droppings after their berries were eaten.

- **Conclusion of the study (max. 500 words in bullets)**
  - ✓ A total of 131 IAVPS were recorded from the three IHR states viz. Arunachal (89), Manipur (110), Nagaland (51) during the study. More sampling at Manipur state might be attributed to the higher number of invasive species observed. Hence, further vegetative sampling is suggested in these two states and more IAVPS will be recorded.
  - ✓ Limited distribution of IAVPS was observed in higher altitudes and temperate sites while most of them were distributed in tropical and subtropical climates, it must be due to the topography and climatic factor that allows unfavourable condition for the introduction and establishment of the new invasives.
  - ✓ Alien invasive plants have the potential to alter ecosystem function. However, generalizations were difficult to make because impacts appeared to be species- and site-specific.

- ✓ *Ageratina adenophora* was observed less deteriorating the soil nutrients whereas other IAVPs, *Ageratum conyzoides, Mikania micrantha, Chromolaena odorata* and *Lantana camara* were observed deteriorating the soil nutrients most in all 3 states at the different elevation gradient irrespective of their dominance.
- ✓ Set up cost and returns from the vermicomposting have been estimated; proposed composting of selected IAVPS as an efficient and ecofriendly practice for income generation. There is need of identifying tools and techniques where such IAVPS can be put into significant use.
- ✓ Considering the utilisation of IAVPS for value addition of bioresources, *Hyptis suaveolens* is also identified as a good source of income generation by harvesting its seeds there by keeping its population under control.
- ✓ It has come to our knowledge that villagers still prefer and practice the traditional mechanical removal and cutting technique for the control of such plant's invasion.

- **OVERALL ACHIEVEMENTS –** *supporting documents to be attached.*
- Achievement on Project Objectives/ Target Deliverables (max. 500 words)]

- Identifying established and new Invasive Alien Vascular Plant Species in all the 12 states of the Indian Himalayan Hills and estimating the invasion load:

A comprehensive checklist of new and established IAVPS in Arunachal Pradesh, Manipur and Nagaland is developed. A total of 131 species was identified and documented out of which 33 species are established invasive plants.

- Characterizing the Invasive Vascular Alien Plants on the basis of their life-forms, lifespan, nativity, the status of invasion and purpose of invasion/ introduction:

GPS coordinates of the selected IAVPS dominated locations in Arunachal, Manipur and Nagaland were tagged and extrapolated in the DEMs. A comprehensive checklist of IAVPS was developed characterizing the Invasive Vascular Alien Plants on the basis of their life-forms, lifespan, nativity, the status of invasion and purpose of invasion/ introduction and their common names was also recorded.

- Preparing protocols for prediction, early detection and risk assessment of alien invasive plant species for each region Baseline studies and Assessment Reports to state agencies of the disappearance of native plant species Publication of Assessment Reports (No.):

Assessment reports and significant findings were presented in national and international seminars, workshops and conferences.

- Assessment of Ecological & Environmental Impact of invasion and spread with special reference to biodiversity and soil especially in relation to climate change; (This will include the level of the disappearance of native species; value addition and sustainable utilization of bio-resources for the livelihood of local communities);

IAVPS have the potential to alter ecosystem function. However, generalizations were difficult to make because impacts appeared to be species- and site-specific. Most of the soil where IAVPS were established had shown lower nutrient content to that of the soil without IAVPS. Nitrogen and potassium were found less affected by IAVPS whereas Most of the soil samples from study sites where IAVPS established had shown lower phosphorus content than that of the soil without IAVPS. *Ageratina adenophora* was observed less deteriorating the soil nutrients whereas other IAVPs, *Ageratum conyzoides, Mikania micrantha, Chromolaena odorata* and *Lantana Camara* were observed deteriorating the soil nutrients most in all 3 states at the different elevation gradient irrespective of their dominance.

Ethnobotanical notes of IAVPS in the past and the current days are recorded and were reported to be underutilised. Vermicomposting of IAVPS was identified as a means of value addition and sustainable utilization of bio-resources for the livelihood of local communities.

- Selection of at least 10 most noxious invasive species from different regions and consolidation of all available information including their biology, itemizing at the same time the knowledge gaps

Most noxious species across the region were selected (*Ageratina adenophora*, *Ageratum conyzoides, Ageratum houstonianum*, *Bidens pilosa, Chromolaena odorata, Lantana camara, Mikania micrantha, Tithonia diversifolia, Parthenium hysterophorus,* and *Urena lobate*) and their comprehensive information about their nativity, purpose of introduction, status, distribution, seed biology, etc was recorded.

6. **Identification of a cross-sectoral group to assess the situation in the form of case studies on these species, and also to formulate workable management strategies aiming to prediction, prevention and control. Policy and legislative mechanisms for management/eradication/ mitigation will get framed. Mechanisms: Prepared and Communicated:**

Recorded concrete information from the State Forest Department and villagers who thrive on NTFS and timber species for livelihoods about the status of invading IAPS in different forest types of Arunachal Pradesh, Nagaland and Manipur, were trained for the effective control and management tools.

Interventions (max. 500 words)

On-field Demonstration and Value-addition of Products, if any (max. 500 words)

Vermicomposting

Regarding the value addition of bioresources or income generation from these invasive plants, vermicomposting of IAVPS is also identified as a potential tool for the income generation which ultimately will keep the invasion in control.

Five dominant IAVPS name *Ageratum conyzoides, Ageratina adenophora, Chromolaena odorata, Lantana camara, Mikania micrantha* and and *Ageratina adenophora* were collected for the vermicomposting. 75 adult earthworms were inoculated into each reactor bin. Water was sprinkled daily to maintain the 80% moisture content of the feed materials. The key parameters – moisture content, pH, Nitrogen, Phosphorus, and Potassium are analysed periodically. The composting was carried out for four months using cow dung containing 1.30 % total nitrogen, 1.14 % total phosphorus, and 3.02 % total potassium. The pH of the dung was recorded at 6.72. The total NPK content of the composts was analysed as per methods described by Allen *et al.* (1947) [16].

The pH of selected species composts ranged between 6.0 – 7.0 units. The *pH* values slightly shifted towards the acidic region. *Ageratum conyzoides* compost was the most acidic, with a *pH* of 6.11. The total nitrogen content was highest in *Chromolaena odorata* (1.83 %) and lowest in *Ageratina adenophora* (1.44%). The total phosphorus content was observed highest in *Ageratina adenophora* (1.56 %) and lowest in *Mikania micrantha,* (1.32 %), and the total potassium content in *Mikania micrantha* (12.82%), and lowest in *Ageratum conyzoides* (4.91 %).

Vermicompost	**pH**	**N %**	**P %**	**K %**
Cow Dung (Control)	6.72	1.30	1.14	3.02
Ageratina adenophora	6.52	1.44	1.56	8.50
Ageratum conyzoides	6.11	1.68	1.47	4.91
Chromolaena odorata	6.37	1.83	1.39	9.20
Lantana camara	6.68	1.72	1.44	6.70
Mikania micrantha	6.54	1.54	1.32	12.82

The total NPK content of the compost significantly increased from that of the control. These implicate that all the composts harvested have high nutrient values. The total cost of the experiment was marginal due to the abundant raw materials required for composting. The experimental data suggested that selected invasive species were potential sources for utilising organic compost. These five composts can be categorised as ericaceous composts.

Vermicompost of *C. odorata* yielded greater total N, whereas compost of *A.* a*denophora* and *M. micrantha* yielded greater P and K content than the control.

The production of vermicompost requires a large quantity of biomass; therefore, the abundance of IAVPS provides a potential raw material for producing organic compost. For the production of 10 Kg of compost, the minimal cost for the raw materials was very less as all raw materials are profusely and freely available. The market value per 1 Kg of vermicompost compost in the e-commerce platform ranges between Rs. 67 to 160. For 100 Kg of compost, the total expenditure is 35-40% of the market value. With the vermicomposting technique, rural areas can generate passive income with little human resources and expenditure by producing compost from IAVPS. Composting invasive species will also cut the cost of the fertiliser used in organic farming. IAVPS organic compost will also facilitate the safe use of organic manures in vegetable production and home in North-east India. It will also significantly improve nutrient content and soil properties. The vermicomposting of selected five IAVPS is highly recommended in North-east India to generate profitable income for lower-middle-class families for livelihood.

It was observed that seeds of *Hyptis suaveolens* were harvested and sold in market costing between Rs 2000-2500 per kilogram and were reported to be consumed as a dietary food. It's highly recommended that further research be conducted in this field and that the crop be routinely cultivated for income generation.

Green Skills developed in in State/ UT (max. 500 words)

Addressing Cross-cutting Issues (max. 200 words)

PROJECT'S IMPACTS IN IHR – *supporting documents to be attached.*

Socio-Economic impact (max. 500 words)

The establishment of IAVPS causes significant damage to socio-economy life. Weed invasion annually causes enormous losses in Arunachal Pradesh, Nagaland and Manipur's forest, agriculture, and tourism sectors. IAVPS heavily infest the agricultural land in the plain as well in the hillsides. As a result, crop production yield decreases yearly, and the cost of farming increases. IAVPS were observed invading valuable grazing lands, and their dense growth suppressed grasses and other useful forages under its canopy. Several species like *C. odorata*, *M. micrantha*, and *L. camara* suppress forage species and reduce herbage supply. A significant reduction in the diversity and population of grass species is commonly observed in the region. As compared to forage species, most IAVPS are poisonous to livestock, while

others may provide mediocre forage or be unpalatable to livestock. Ingestion of foliage causes cholestasis and hepatotoxicity, and continuous feeding of this plant causes fatal respiratory diseases in grazing animals. They also inhibit the movement of livestock and reduce their access to forage or water. As a result, animal productivity is reduced, stock handling and management have become more challenging, and property values are significantly diminished.

Until now, humans have not retained any lethal events caused by ingesting invasive species. However, some species may cause severe damage to organs and even death if ingested repeatedly. Daily exposure to the pollen grain of *Parthenium hysterophorus* affects the physiology of the peripheral endocrine glands. Hydroxyproline-rich glycoprotein is responsible for an allergic health problem to *Parthenium hysterophorus* pollen. Symptoms of *Parthenium hysterophorus* also include diarrhoea, severe papular erythema, breathlessness, and choking.

Impact on of Natural Resources/ Environment (max. 500 words)

An extensive field assessment and studies reported significant encroachment into the natural forest of the Himalayas, where all forest types and their surroundings were seen to be severely affected. IAVPS cause severe inhibitory effects to native plant species and important commercial local crops vegetables. Many physiological processes are interfered with, which is devastating to the native flora and fauna of IHR. The establishment of IAVPS directly or indirectly alter the structure and functions of the microbial community releasing secondary metabolites known as allelochemicals in the soil by [3, 4]. This leads to a change in soil pH, total and available NPK, SOM, and micronutrient availability. Transmutation in the microbial community or biochemistry of soil was observed long-term effects however some allelochemicals were observed to have stimulated plant growth in the short term [5]. The disruption in the nutrient cycle influences the growth of the surrounding plants. There are substantial evidence allelochemicals inhibit nutrient uptake, disrupt cell division, and shoots elongation of the native plants species [6]. Interaction of allelochemicals with plants also reduces a substantial amount of micro and macronutrients.

The influx of invasive species adversely affects all animals, birds, insects, and humans. Contamination of food with toxic allelochemicals poses a significant health risk to all types of organisms. Aerial parts and roots contain allelochemicals that affect the insect larvae, affecting the food chain of small animals. A decrease in overall animal diversity, animal abundance, and fitness has been attributed to invasive plants [48, 49]. There are a large number of allelochemicals that are responsible for chronic toxicities in both humans and livestock. A study revealed pyrrolizidine alkaloids (PAs) leached from the decomposing leaves, flowers, and roots stumps deposits on the surface of the soil. A high level of PAs

accumulation was detected in maize sown on *C. odorata* treat-s-burn and treat-s-mulch plots. Furthermore, PA contamination can also affect herbal products, causing side effects that can be harmful to human health. Ingestion of *Lantana camara* foliage causes cholestasis and hepatotoxicity in grazing animals. Aravind et al. (2010) reported lower species diversity, species richness, and abundance of bird species in the Male Mahadeshwara Reserve Forest with high densities of *Lantana camara*. The toxic effects of *Adenophora adenophora* on the respiratory system are evident in animals [52]. Continuous feeding of this plant causes fatal respiratory diseases to animals [53].

Conservation of Biodiversity/ Land Rehabilitation in IHR (max. 500 words)

Developing Mountain Infrastructures (max. 200 words)

Few advanced technologies have been developed to detect and rapidly respond to IAVPS. Frequent field mapping is an essential action for the early detection of IAVPS. Extensive ground sampling is difficult in the Himalayan region. Unmaned aerial systems (UAS) may serve as an effective technology for invasive species control based on early detection and regular monitoring. It can provide data with high temporal and spatial resolutions. Another technological approach is the application of remote sensing tools and methods. Remote sensing develops a detailed spectral profile for both native and non-native plant species. Remote sensing data can be used to evaluate, compare, and monitor over the long term the conditions of pre-invaded and invaded vegetation over a large area. It is most intuitive and straightforward to detect alien plants by visually inspecting their spatial distribution using high-resolution remote sensing images captured in high spatial resolution. Alien and native plant species can be pinpointed based on their unique spatial patterns or phenological characteristics. Optical characteristics of native and invasive species can be utilised to evaluate the effectiveness of control techniques for alien invasive plants over large areas. The region highly infested by alien plant species can be pinpointed and targeted immediately for control action. It is essential to incorporate technological approaches along with other management strategies to eradicate IAVPS from the invaded regions.

Strengthening Networking in State/ UT (max. 200 words)

The research project helped in creating a good interstate network between the three states through knowledge sharing and cooperating in capacity building in respective states of the study to fight against the challenges of plant invasion between many state and central institutions and departments like state Forest Departments of Arunachal Pradesh, Manipur and Nagaland, Manipur University, Imphal; Central Agricultural University, Imphal; ICAR, Imphal; IBSD, Imphal; Nagaland University, Lumami; ICAR, Medziphema, Nagaland; Rajiv

Gandhi University, Itanagar; Central Agricultural University, Pasighat etc. Joint venture for identifying the forest areas affected from the invading exotic plants and strategy planning to mitigate the failure in natural regeneration by native timber species.

EXIT STRATEGY AND SUSTAINABILITY – *supporting documents to be attached.*

Utility of project findings (max. 500 words)

The findings of this research will be helpful to the different groups from the higher sections like Ministry of Environment, Forest and Climate Change, executives and other allied departments to research scholars and students. The identification of various invasive alien plants in our local flora would support them to carry out more research in the same dimension as well as it would help in the formulation of the control and management strategies together with the villagers for conservation priorities. Further value addition of bioresources by undergoing researches will also enhance their livelihood and together with their constructive support and participation, the threat of plant invasion can be kept under control.

Other Gap Areas (max. 200 words)

Preparation of comprehensive geo-enabled database for the parameters such as plant diversity, community characteristics, microsites conditions, invasion of IAS, area under IAS and rate of spread, potential prone area, soil characteristics, climate information and physiography of IAS invaded areas is very important. This would result a comprehensive information system highlighting the degree and mode of dispersal, colonization and invasion.

Major Recommendations/ Way Forward (max. 200 words)

Development of more sustainable management strategies of control and management of plant invasion in view to climate change is recommended.

Replication/ Upscaling/ Post-Project Sustainability of Interventions (max. 500 words)

Invasive alien vascular plant species (IAVPS) adversely affect the natural habitats and micro-ecosystem, resulting in threats to local biodiversity and species richness. The successful establishment of invasive alien plants in Northeast India resulted from a rapid increase in anthropogenic disturbances of wild ecosystems with the intentional and accidental introduction of alien plants. With the development of connectivity, tourism, and disturbance across many natural ecosystems, invasive alien plants have been successfully established in these natural habitats threatening biodiversity and causing economic losses. They adversely affect the natural habitats and tāhe micro-ecosystems in particular, reducing the biodiversity and species richness. Many plants have been introduced intentionally or accidentally in India, especially in the North-Eastern region. Studies have been working on identifying and documenting these

exotic and invasive plants across the country, including the Himalayan regions. As far as diversity is concerned, these alien floras were reported to negatively impact the native vegetation due to their aggressive growth and propagation. Further research can be focussed on the discovery and identification of more IAVPS from the local and regional flora. Long term studies on their habitat suitability in relation to the climate change and their impacts on the edaphic properties and floral diversity due to their invasion is much recommended.

REFERENCES/BIBLIOGRAPHY

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