International Journal of Botany Studies
ISSN: 2455-541X; Impact Factor: RJIF 5.12
Received: 06-04-2021, Accepted: 25-04-2021, Published: 30-04-2021
www.botanyjournals.com
Volume 6, Issue 2, 2021, Page No. 661-668

Invasive alien herbaceous species in terrestrial and swampland habitats in India: A review

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Abstract
Invasive alien plants are non-native or non-indigenous species that invade an ecosystem, acclimatize for survival and nutrition, and ultimately manipulate the local environment creating a negative pressure for native plants. Exotic invasion is regarded as the second-highest influencers of native diversity loss after habitat destruction. India is a mega biodiversity hub with enormous species richness due to suitable climatic patterns and geographical attributes. Plants that cannot adapt to the harsher environment of other geographic regions worldwide can suitably mimic and disperse in Indian ecosystems. Therefore unintentional introduction and or invasion of non-native species can create significant hurdles in the regional ecosystems by generating negative influences on native plant species. Invasive alien herbaceous species is a concern for terrestrial and swampland habitats in India with severe propagule expansion within a confined time. Detrimental effects of IAHS include habitat occupancy, widespread dispersal, and secretion of toxic phytochemicals and manipulation of beneficial soil micro-flora. In this review, the authors elaborated the status of IAHS in Indian terrestrial and swampland ecosystems with emphasis on ecosystems of Himalayan foothills, one of the regions for species richness.

Keywords: invasive, mega diversity, swampland, allelochemicals, tropical America, Indian Himalayan region

Introduction

Invasive alien plant species (IAHS) is frequently referred to as exotic/alien/introduced/non-indigenous/non-native entities that tend to harbor a foreign land to endure a dominant establishment. Exotic-invasive plants cope with establishing successfully in a naturalized environment by reintroducing the intimate changes over time. Invasion of exotic species could have a daunting effect on regional floral diversity. Invasive plants pose a significant hurdle in endemic flora recreating habit occupancy during establishment in a region where endemic species might have dominant status earlier. The mega-diversity globally, including China and India has an aggressive invasion of exotic plant species due to increased climatic fluctuations and anthropogenic activities. Human activities are linked to propagation and establishment of invasive plants leading to adverse endemic-invasive competition for habitat and energy partition. Vigorous propagation is an enduring factor in invasive plants that enhanced them so competitive to non-native climate. The extent of establishment of alien plants depends on a variety of factors ranging human population and density, the richness of local species, growth form and adaptive phenology of plant. The traits that separate non-invasive non-natives and invasive non-natives are confusing as various features favour invasiveness in diverse habitat [1]. IAHS pose detrimental cues on biodiversity, crop production, human wellbeing and associated factors [2-5] resulting warfare within a niche. It was evidenced that alien plants' invasibility is correlated with anthropogenic disturbances, where undisturbed tropical forests allowed a few exotic species [6].

The most obnoxious and widespread invasive herbaceous species in most Indian habitats include *Parthenium hysterophorus, Lantana camara, Chromolaena odorata, ageratum conyzoides, Eichhornia crassipes, Eupatorium adenophorum, Ipomoea carnea, Mikania micrantha, Mimosa invisa, Phalaris minor* and *Prosopis juliflora* [7]. Herbaceous invasive plants species introduced for the gardens as ornamental plants for their exotic appearance [8] have created menace in India's regional flora as a whole. It may be cumbersome to track the origin and distribution of invasive species as the expansion and distribution is accelerated due to global trade and human transition throughout the world [9]. Once the propagule landed, they undergo a series of reform and change to adapt and acquire the periphery's habitat and mimic defense regulations.

Status on India's invasive alien flora

The invasion status of exotic plants has been explored by many researchers throughout India. Invasion studies from time to time signify the abundance and distribution of non-native species in India soil and their involvement in manipulating native floral composition in India. An extensive survey of Khuroo *et al.* (2012) on invasive alien flora of entire India revealed a fascinating introduction of the region's non-native species. The report showed 1,599 species, belonging to 842 genera in 161 families representing 8.5% of the total Indian vascular flora. The three most species-rich families were Asteraceae (134 species), Papilionaceae (114 species) and Poaceae (106 species). Whereas the three largest genera represented were Eucalyptus (25 spp.), Ipomoea (22 spp.), and Senna (21 spp.). Of the total 161 families represented, the 20 most prominent families contribute 959 species, with average family: species ratio of 1:48 and the remaining 141 families, representing 640 species with the ratio of the family: species is (1:4.5) [10]. Similarly, Reddy (2008) documented 173 invasive alien species belonging to 117 genera and 44 families. Almost 80% of the species reported were introduced from Neotropical world.

The research on plant invasion in Indian Himalayan Region (IHR) bears enormous significance due to richness in

species diversity. The region is also designated as one of the global biodiversity hotspots. Pathak *et al.* (2019) reported 297 naturalized alien plant species belongs to 65 families from this region. Of the total 297 naturalized exotic plant species. The predominant states in terms of species richness were Himachal Pradesh (78.1%), Jammu & Kashmir (64.6%) and Uttarakhand (60.90%). Among various invasive species, including *Lantana camara*, *Ageratina adenophora*, *Parthenium hysterophorus* and *Ageratum conyzoides* have been reported from most IHR states a larger area. Sekar *et al.* (2012) had recorded a total of 190 invasive alien species under 112 genera, and 47 families in the IHR. Among the total flora recorded, dicotyledons were represented by 40 families, 95 genera and 170 species. Simultaneously, the monocotyledons were represented by seven families, 17 genera and 20 species. The herbs (148 species) were predominant followed by shrubs (19 species), Grass (11 species), Trees (4 species), sedges and climber (3 species each). Most invasive species were annual habit (63%) [11]. From the Indian state of Uttarakhand belonging to IHR, Sekar *et al.* (2012) documented 163 invasive alien species under 105 genera, belonging to 46 families. The invasive species were found in a variety of habitats including wastelands (48%), cultivated fields (20%), along roadsides (14%) and forests (8%) [12]. Negi and Hajra (2014) prepared a list of 436 alien species comprising of 308 woody (45.69%) and 128 (19.4%) exotic herbaceous species from Doon valley of North-West Himalaya [13]. Khuroo *et al.* (2007) documented 571 invasive species belonging to 352 genera and 104 families from Jammu and Kashmir. The native ranges of the alien species were outside of South Asia, Africa, North America, South America, and Australia. They reported seven new exotic introductions for the first time from this region: *Lavendula officinalis*, *Chaix* sp., *Rosmarinus officinalis*, *Godetia amoena*, *Digitalis grandiflora*, *Nigella sativus* and *Ranunculus asiaticus* and *Petunia hybrid* [14]. Jaryan *et al.* (2012) investigated the alien species of Himachal Pradesh that revealed a total of 497 exotic species (85 families) introduction to this region. The reported dominant families were Asteraceae (59 species), Poaceae (47 species) and Fabaceae (43 species) and Ipomoea (9 species), Euphorbia (7 species each) were the influential genera [15].

Table 1: Floristic studies on invasive alien plant species in India and the status of most aggressive species in terrestrial and swampland habitats.

Province /Area	Status of invasive plants on floristic study	Dominant invasive species	Reference (s)
India	1,599 species, 842 genera, 161 families	*Ipomoea* spp., *Senna* spp., *Euphorbia* spp., *Alternanthera* spp.,	[10]
	173species, 117 genera, 44 families	*Alternanthera philoxeroides, Ludwigia perennis, Pistia stratiotes, Eichhornia crassipes, Lantana camara, Parthenium hysterophorus*	[16]
IHR	297 species belonging to 65 families	*Lantana camara, Ageratina adenophora, Parthenium hysterophorus and Ageratum conyzoides*	[17]
	190 species, 112 genera, and 47 families	*Ageratum conyzoides, Cassia alata, Catharanthus pusillus, Celosia argentea, Chenopodium album, Eichhornia crassipes*	[11]
IHR (Uttarakhand)	163 species, 105 genera, belonging to 46 families	*Ipomoea* spp., *Solanum* spp., *Cassia* spp., *Indigofera* spp. *Corchorus* spp., *Datura* spp., *Euphorbia* spp., Physalis spp.	[12]
	436 alien species	*Lantana camara, Mikania micarantha, Parthenium hysterophorus, Malvastrum coromandelianum*	[13]
IHR (Jammu & Kashmir)	571 species, representing 352 genera and 104 families	*Amaranthus* spp., *Chenopodium* spp., *Galium* spp., *Polygonum* spp., *Rumex Artemisia* spp., *Cyperus* spp., *Ranunculus* spp., *Hibiscus* spp., *Ipomoea* spp., *Mentha* spp., *Nymphaea* spp., *Papaver* spp., *Poa* spp.	[14]
	15 invasive alien plant species recorded from Asteraceae	*Ageratum conyzoides, Anthemis tinctoria, Aster pilosum, Bidens pilosa, Cichorium intibus, Cirsium arvense, Eclipta prostrata, Emilia sonchifolia, Parthenium hysterophorus, Silybum marianum, Sonchus arvensis, Sonchus asper, Tridax procumbens, Xanthium strumarium and Youngia japonica*	[18]
IHR (Himachal Pradesh)	497 species from 85 families	*Ipomoea* spp., *Euphorbia* spp., *Amaranthus* spp., and *Solanum* spp.	[15]
	125 species, 83 genera, and 39 families	*Acacia mearnsii, Ageratum conyzoides, Catharanthus pusillus, Celosia argentea, Catharanthus pusillus, Celosia argentea, Ipomoea eriocarpa, Lantana camara*	[19]
IHR (Assam)	18 species, 10 families	*Ageratum conyzoides, Argemone mexicana, Lantana camera, Mikania micrantha, Parthenium hysterophorus*	[20]
IHR (Manipur)	127 invasive species	Ageratum conyzoides, Chromolaena odorata, Lantana camara, Parthenium hysterophorus	[21]
IHR (Tripura)	216 species, 158 genera, 58 families	*Alternanthera* spp., *Ipomoea* spp., *Senna* spp., *Brassica* spp.	[22]

Terrestrial habitat of IAHS in India

India is a mega biodiverse country with rich endemic flora. The suitability of tropical climate and geographical patterns is prominent for many plant species in India's forests and agroecosystems. However non-native plant species invasion is a major concern for habitat loss and impairs indigenous species' distribution. Plant invasions pose challenges for a wide range of causalities in native flora including spatial distribution, struggle for habitat and nutrition, germination and seed vigour. Indian terrestrial habitats are mostly occupied by obnoxious nuisance invasive species and created negative pressure. Obnoxious weeds including

Parthenium, *Lantana*, *Mikania*, and *Ageratum* are most prevalent invasive species with tremendous impact on the forest, grassland and cultivated ecosystems. *Lantana* is a shade-tolerant plant that grows under the canopy of forest trees or other plantations. It is widespread in pastures, grasslands, riverbanks, roadsides and agricultural fields. *Parthenium* is primarily a weed of wastelands to invade any habitat and abundant in riparian ecosystems. It is a common weed in pastures, agricultural farms, degraded areas, roadsides, and railway tracts. The plant is also able to grow in depleted soil moisture contents. *Ageratum*s is a weed of arable land found mostly in cultivated areas, grasslands, and the outer boundary of forests interfering with other crops' growth and development in its vicinity [23] (Table 2).

IAHS in swamplands

Not only were the terrestrial ecosystem exotic invasive herbaceous species also aggravated the aquatic ecosystems and their transition zone, creating a dubious environment for endemic flora of India. Aquatic ecosystems are choked by invasive alien species resulted in impaired navigation, water channels and resource acquisition. Reddy (2008) extensively reported 33 invaders in the Indian wetland ecosystems. The most obnoxious swampland species were *Alternanthera philoxeroides*, *Ludwigia perennis*, *Pistia stratiotes*, *Eichhornia crassipes*, *Eclipta prostrata*, *Monochoria vaginalis*, *Ipomoea carnea*, *Gnaphalium coarctatum* and *Rorippa dubia* [16]. Swampland dweller indigenous plants are at risk of habitat constriction resulted in a threat to local plant communities.

Disturbed communities and associated IAHS

Invasive alien species are considered the second threat to biodiversity loss because of their dominant influences in regional ecosystems. Invasive plant species cause biodiversity loss, including species extinctions and hydrology changes and ecosystem functions [24]. In the disturbed habitats invasive plant's dominance indicates mitigating the harsh situation. The consequences made them more aggressive for habitat occupancy and nutrition acquisition. In disturbed communities including roadside, contaminated lands invasion of *Parthenium*, *Ageratum*, *Ipomoea*, *and Eichhornia*, *they are most widespread and defend* most of the extremities.

Table 2: An annotated list of invasive herbaceous species in terrestrial and swampland habitats in India [7, 11-15].

SI No	Plant species	Family	Native range
1	*Acacia farnesiana* (L.) Wild	Mimosaceae	South America
2	*Acacia mearnsii* De Wild	Mimosaceae	Tropical America
3	*Acanthospermum hispidum* DC.	Asteraceae	Brazil
4	*Aerva javanica* (Burm.f.) Juss.ex Schult	Amaranthaceae	Tropical America
5	*Aeschynomene americana* L.	Papilionaceae	Tropical America
6	*Ageratina adenophora* (Spreng.) King & Robinson	Asteraceae	Tropical America
7	*Ageratum conyzoides* L.	Asteraceae	Trop. America
8	*Ageratum houstonianum* Mill.	Asteraceae	Tropical America
9	*Alternanthera paronychioides* A. St. Hil.Voy.	Amaranthaceae	Tropical America
10	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	Tropical America
11	*Alternanthera pungens* Kunth in H.B.& K	Amaranthaceae	Tropical America
12	*Alternanthera sessilis* (L.) DC.	Amaranthaceae	Tropical America
13	*Alternanthera tenella* Colla, Mem.	Amaranthaceae	Tropical America
14	*Amaranthus spinosus* L.	Amaranthaceae	Tropical America
15	*Anagallis arvensis* L.	Primulaceae	Europe
16	*Antigonon leptopus* Hook. & Arn.	Polygonaceae	Tropical America
17	*Argemone mexicana* L.	Papaveraceae	Tropical Central & South America
18	*Argemone ochroleuca* Sweet	Papaveraceae	South America
19	*Asclepias curassavica* L.	Asclepiadaceae	Tropical America
20	*Asphodelus tenuifolius* Cav.	Liliaceae	Tropical America
21	*Bidens pilosa* L.	Asteraceae	Tropical America
22	*Blainvillea acmella* (L. f) Philipson	Asteraceae	Tropical America
23	*Blumea eriantha* DC.	Asteraceae	Tropical America
24	*Blumea lacera* (Burm.f.) DC.	Asteraceae	Tropical America
25	*Blumea obliqua* (L.) Druce	Asteraceae	Tropical America
26	*Calotropis gigantea* (L.) R.Br	Asclepiadaceae	Tropical Africa
27	*Calotropis procera* (Ait.) R.Br	Asclepiadaceae	Tropical Africa
28	*Cannabis sativa* L.	Cannabaceae	Central Asia
29	*Cardamine hirsuta* L.	Brassicaceae	Tropical America
30	*Cardamine trichocarpa* Hochst. ex A.Rich.	Brassicaceae	Tropical America
31	*Catharanthus pusillus* (Murray) Don	Apocynaceae	Tropical America
32	*Celosia argentea* L.	Amaranthaceae	Tropical Africa
33	*Ceratophyllum demersum* L.	Ceratophyllaceae	Tropical America
34	*Chamaesyce hirta* (L.) Millsp.	Euphorbiaceae	Tropical America
35	*Chamaesyce indica* (Lam.) Croizat	Euphorbiaceae	Tropical South America
36	*Chenopodium album* L.	Chenopodiaceae	Europe
37	*Chenopodium ambrosioides* L.	Chenopodiaceae	Tropical America
38	*Chenopodium murale* L.	Chenopodiaceae	Tropical America
39	*Chloris barbata* Sw.	Poaceae	Tropical America
40	*Chromolaena odorata* (L.) King & Robinson	Asteraceae	Tropical America
41	*Chrozophora rottleri* (Geis.) Spreng.	Euphorbiaceae	Tropical Africa

42	*Cleome gynandra* L.	Cleomaceae	Tropical America
43	*Cleome isocose* L.	Cleomaceae	Tropical America
44	*Cleome monophylla* L	Cleomaceae	Tropical Africa
45	*Cleome rutidosperma* DC	Cleomaceae	Tropical America
46	*Cleome viscosa* L.	Cleomaceae	Tropical America
47	*Clidemia hirta* (L.) D. Don	Melastomataceae	Tropical America
48	*Convolvulus arvensis* L.	Convolvulaceae	Europe
49	*Conyza anadensis* (L.) Cronquist	Asteraceae	South America
50	*Conyza semipinnatifida* Wall.	Asteraceae	Tropical America
51	*Corchorus aestuans* L	Tiliaceae	Tropical America, Africa
52	*Corchorus fascicularis* Lam	Tiliaceae	Tropical America
53	*Corchorus olitorius* L.	Tiliaceae	Tropical America
54	*Corchorus tridens* L.	Tiliaceae	Trop. Africa and Australia
55	*Corchorus trilocularis* L.	Tiliaceae	Tropical Africa
56	*Crassocephalum crepidioides* (Benth.) Moore	Asteraceae	Tropical America
57	*Crotalaria pallida* Dryand	Papilionaceae	Tropical America
58	*Crotalaria retusa* L.	Papilionaceae	Tropical America
59	*Croton bonplandianum* Boil.	Euphorbiaceae	Temperate South America
60	*Cryptostegia grandiflora* R.Br.	Asclepidaceae	Madagascar
61	*Cuscuta chinensis* Lam	Cuscutaceae	Mediterranean
62	*Cuscuta reflexa* Roxb.	Cuscutaceae	Mediterranean
63	*Cyperus difformis* L.	Cyperaceae	Tropical America
64	*Cyperus iria* L.	Cyperaceae	Tropical America
65	*Cytisus scoparius* (L.) Link	Papilionaceae	Europe
66	*Datura fastuosa* L.	Solanaceae	South America, Mexico
67	*Datura innoxia* Mill. Gard.	Solanaceae	Tropical America
68	*Datura metel* L	Solanaceae	Tropical America
69	*Datura stramonium* L.	Solanaceae	Tropical America
70	*Dicoma tomentosa* Cass.	Asteraceae	Tropical Africa
71	*Digera muricata* (L.) Mart.	Amaranthaceae	South West Asia
72	*Dinebra retroflexa* (Vahl) Panz.	Poaceae	Tropical America
73	*Echinochloa colona* (L.) Link	Poaceae	Tropical South America
74	*Echinochloa crusgalli* (L.) Beauv.	Poaceae	Tropical South America
75	*Echinops echinatus* Roxb.	Asteraceae	Afghanistan
76	*Eclipta prostrata* (L.) Mant.	Asteraceae	Trop. America
77	*Eichhornia crassipes* (C. Martius) Solms-Loub.	Pontederiaceae	Trop. America
78	*Emilia sonchifolia* (L.) Dc.	Asteraceae	Trop. Africa
79	*Eupatorium adenophorum* Sprengel	Asteraceae	Mexico
80	*Euphorbia chamaesyce* L.	Euphorbiaceae	West Africa and Mauritius
81	*Euphorbia cyathophora* Murray	Euphorbiaceae	Tropical America
82	*Euphorbia heterophylla* L.	Euphorbiaceae	Tropical America
83	*Euphorbia hirta* L.	Euphorbiaceae	Tropical America
84	*Evolvulus nummularius* (L.)L.	Convolvulaceae	Tropical America
85	*Flaveria trinervia* (Spreng.) C. Mohr.	Asteraceae	Tropical Central America
86	*Fuirena ciliaris* (L.) Roxb.	Cyperaceae	Tropical America
87	*Galinosoga parviflora* Cav.	Asteraceae	Tropical America
88	*Galinsoga quadriradiata* Ruiz & Pavon	Asteraceae	Mexico
89	*Glossocardia bosvallea* (L.f.) DC.	Asteraceae	East Indies
90	*Gnaphalium coarctatum* Willd	Asteraceae	Tropical America
91	*Gnaphalium pensylvanicum* Willd.	Asteraceae	Tropical America
92	*Gnaphalium polycaulon* Pers.	Asteraceae	Tropical America
93	*Gomphrena celosioides* Martius	Amaranthaceae	South America
94	*Gomphrena serrata* L.	Amaranthaceae	Tropical America
95	*Grangea maderaspatana* (L.) Poir.	Asteraceae	South America
96	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	Tropical America
97	*Impatiens balsamina* L.	Balsaminaceae	Tropical America
98	*Imperata cylindrica* (L.) Raeusch.	Poaceae	Tropical America
99	*Indigofera astragalina* DC.	Fabaceae	Tropical America
100	*Indigofera glandulosa* Roxb. ex Willd.	Fabaceae	Tropical America
101	*Indigofera linifolia* (L.f.) Retz.	Fabaceae	South America
102	*Indigofera linnaei* Ali	Fabaceae	Tropical America
103	*Indigofera trita* L.f.	Fabaceae	Tropical America
104	*Ipomoea carnea* Jacq.	Convolvulaceae	Tropical America
105	*Ipomoea eriocarpa* R.Br.	Convolvulaceae	Tropical America
106	*Ipomoea hederifolia* L.	Convolvulaceae	Tropical America
107	*Ipomoea muricata* (L.) Jacquin	Convolvulaceae	Tropical America
108	*Ipomoea nil* (L.) Roth	Convolvulaceae	North America
109	*Ipomoea obscura* (L.) Ker.Gawal.	Convolvulaceae	Tropical Africa

110	*Ipomoea pestigridis* L.	Convolvulaceae	Tropical East Africa
111	*Ipomoea purpurea* (L.) Roth	Convolvulaceae	South America
112	*Ipomoea quamoclit* L.	Convolvulaceae	Tropical America
113	*Ipomoea staphylina* Roem. & Schult.	Convolvulaceae	Tropical Africa
114	*Lagascea mollis* Cav.	Asteraceae	Central America
115	*Lantana camara* L.	Verbenaceae	Tropical America
116	*Leonotis nepetiifolia* (L.)R. Br.	Lamiaceae	Tropical Africa
117	*Leucaena latisiliqua* (L.) Gilli.	Mimosaceae	Tropical America
118	*Ludwigia adscendens* (L.) Hara	Onagraceae	Tropical America
119	*Ludwigia octovalvis* (Jacq.) Raven	Onagraceae	Tropical Africa
120	*Ludwigia perennis* L.	Onagraceae	Tropical Africa
121	*Macroptilium atropurpureum* (Mocino & Sesse et DC) Urb.	Fabaceae	Tropical America
122	*Macroptilium lathyroides* (L.) Urb.	Fabaceae	South and tropical America
123	*Malachra capitata* (L.) L.	Malvaceae	Tropical America
124	*Malvastrum coromandelianum* (L.) Garcke	Malvaceae	Tropical America
125	*Martynia annua* L.	Pedaliaceae	Tropical America
126	*Mecardonia procumbens* (Mill.) Small	Scrophulariaceae	Tropical north America
127	*Melilotus alba* Medik. ex Desr.	Fabaceae	Europe
128	*Melochia corchorifolia* L.	Sterculiaceae	Tropical America
129	*Merremia aegyptia* (L.) Urb.	Convolvulaceae	Tropical America
130	*Mimosa pudica* L.	Mimosaceae	Brazil
131	*Mirabilis jalapa* L.	Nyctaginaceae	Peru
132	*Monochoria vaginalis* (Burm.f.) C. Presl.	Pontederiaceae	Tropical America
133	*Nicotiana plumbaginifolia* Viv.	Solanaceae	Tropical America
134	Ocimum americanum L.	Lamiaceae	Tropical America
135	*Opuntia elatior* Miller	Cactaceae	South America
136	*Opuntia stricta* Haw. Var. dillenii (Ker Gawl.) Benson	Cactaceae	Tropical America
137	*Opuntia vulgaris* Miller	Cactaceae	South America
138	*Oxalis corniculata* L.	Oxalidaceae	Europe
139	*Parthenium hysterophorus* L.	Asteraceae	North America
140	*Passiflora foetida* L.	Passifloraceae	South America
141	*Pedalium murex* L.	Pedaliaceae	Tropical America
142	*Pennisetum purpureum* Schum.	Poaceae	Tropical America
143	*Peperomia pellucida* (L.) Kunth	Piperaceae	South America
144	*Peristrophe paniculata* (Forssk.) Brummit	Acanthaceae	Tropical America
145	*Physalis angulata* L.	Solanaceae	Tropical America
146	*Physalis heterophylla* Nees	Solanaceae	Peru
147	*Physalis minima* L.	Solanaceae	Tropical America
148	*Physalis peruviana* L	Solanaceae	Peru
149	*Pilea microphylla* (L.) Liebm.	Urticaceae	South America
150	*Pistia stratiotes* L.	Araceae	Tropical America
151	*Portulaca oleracea* L.	Portulacaceae	South America
152	*Portulaca quadrifida* L.	Portulacaceae	Tropical America
153	*Prosopis juliflora* (Sw.) DC.	Mimosaceae	Mexico
154	*Rhynchelytrum repens* (Willd.) C. E. Hubb.	Poaceae	Tropical America
156	*Rorippa dubia* (Pers.) Hara	Brassicaceae	Tropical America
157	*Rubus ellipticus* Smith	Rosaceae	Tropical America
158	*Ruellia tuberosa* L.	Acanthaceae	Tropical America
159	*Scoparia dulcis* L.	Scrophulariaceae	Tropical America
160	*Senna absus* L	Caesalpiniaceae	Tropical America
161	*Senna alata* L.	Caesalpiniaceae	West Indies
162	*Senna hirsuta* L	Caesalpiniaceae	Tropical America
163	*Senna obtusifolia* L.	Caesalpiniaceae	Tropical America
164	*Senna occidentalis* L.	Caesalpiniaceae	Tropical South America
165	*Senna pumila* Lam.	Caesalpiniaceae	Tropical America
166	*Senna rotundifolia* Pers.	Caesalpiniaceae	Tropical South America
167	*Senna tora* L.	Caesalpiniaceae	Tropical South America
168	*Senna uniflora* Miller	Caesalpiniaceae	Tropical South America
169	*Synedrella nodiflora* (L.) Gaertn.	Asteraceae	West Indies
170	*Torenia fournieri* Linden ex E. Fourn.	Scrophulariaceae	Australia
171	*Tribulus terrestris* L	Zygophyllaceae	Tropical America
172	*Tridax procumbens* L.	Asteraceae	Central America
173	*Triumfetta rhomboidea* Jacq.	Tiliaceae	Tropical America
174	*Typha angustifolia* L.	Typhaceae	Tropical America
175	*Waltheria indica* L.	Sterculiaceae	Tropical America
176	*Xanthium strumarium* L. P. P.	Asteraceae	Tropical America
177	*Youngia japonica* (L.) DC.	Asteraceae	South America
178	*Zinnia elegans* Jacq.	Asteraceae	Mexico

Allelochemicals as a marker of Invasive establishment

Invasive plant species are potent sources of many toxic compounds that affect plants in various ways. They release diverse phytochemicals that include essential oils, phenolics, and terpenes inciting defense for local communities' establishment. Invasive plants pollinated by wind have added advantages realized by Pyšek *et al.* (2012) that defend neighbouring plants. *Parthenium hysterophorus* is a noxious invasive plant of widespread distribution. The higher amount of seed production, fast-spreading ability, and allelopathy effect inducted strong interaction on neighboring plants. The most detrimental effects were seen in pollination impairment and soil microbe interactions. Kaul and Bansal (2002) found allelopathic inhibition of *Ageratina adenophora* plant litter in survival and growth of Lantana camara cuttings [25]. Among the highly invasive exotic herb, *Parthenium hysterophorus* allele-chemicals are highly phytotoxic that inhibit plant growth by amending soil physio-chemical properties [26]. Allelopathic effects of *Lantana camara* was established in many crops, including *Zea mays*, *Eragrostis tef* and *Eleusine coracana* [27]. Mishra (2015) and Sousa *et al.*(2012) reviewed the allelopathic effects of Lantana with mention to diverse chemical constituents on it [28,29] (Table 3).

Table 3: Major Phytochemicals released by some nuisance invasive plants.

Invasive plant species	Phytochemicals group	Major chemical entities found to be associated with phytochemicals activities	Reference
Parthenium sp.	Essential oils	α-Pinene, Camphene, Sabinene, α-Phelandrene, trans-β-Ocimene, Borneol acetate, β-Caryophylene, Germacrene D	[30]
	Phenolic compound	caffeic, p-coumaric, gallic, p-hydroxybenzoic, anisic, vanillic and Ferulic acid, Gallic acid	[31]
	Sequineterpine lactone	Parthenin, coronopilin, hymenin	[32]
Lantana sp.	Essential oils	p-cymene, a-phellandrene, a-pinene, diterpene, c-terpinene, caryophyllene, cardinene, cineole, linalool, geraniol, a-terpinol, citral, phellandral	[33]
	Phenolic compound	Protocatechuic acid, Gentisic acid, p-hydroxybenzoic acid, Vanillic acid, Caffeic acid, Syringic acid, Vanillin, p-coumaric acid, m -coumaric acid, Ferulic acid, Salicylic acid, o -coumaric acid, t-cinnamic acid, Methyl coumarin	[34]
	Terpenoids	Lantadene A and B	[35]
Ageratum sp.	Essential oils	Precocene I and II, b-caryophyllene, a-bisabolene, a-cubebene, a-farnesene, b-farnesene, b-cubebene, germacrene, eupatoriochromene, fenchyl acetate, sesquiterpene hydrocarbon, nerolidal, caryophyllene oxide, bornyl formate, b-gurijunene, copane, camphene, b-elemene, methanezulene, tricycoundecane, a-muurolene, demethoxyencecalin, audorenececalinol p-coumaric,	[30]
	Phenolic compound	Gallic acid, Coumalic acid, Protocatechuic acid, Catechin, p-Hydroxybenzoic acid, p-Coumaric acid, Sinapic acid, Benzoic acid	[36]

Progression and regression of invasion

The invasiveness of a species is significantly attributed by associated native plant species and the growth forms. It may be difficult for an IAHS to adapt vigorously in tropical forests where shrubs and trees are the predominant flora. On the contrary, it may be opportunistic if shrub or tree invader crusade a grassland ecosystem. In the earlier case, a regression of invasion can be seen as much negative pressure on the exotic establishment. In the latter case, a progressive establishment can happen where the native herbaceous species have to defend for own rescue.

Table 4: Enumeration of some obnoxious herbaceous species found most detrimental in the Indian subcontinent.

Plant species	Nativity	Detrimental roles in native plant species	Reference(s)
Parthenium hysterophorus	Tropical America	Noxious weed with aggressive colonizer of degraded areas including wastelands, roadsides and overgrazed pastures; detrimental for germination and seedling growth in native species besides physio-chemical properties of soil	[24, 26, 37, 38]
Mikania micrantha	Neotropical origin	Detrimental for the loss of native biodiversity, prevention of forest regeneration and crop yield	[23, 39, 40]
Lantana camara	Tropical and subtropical America	An obnoxious shrub with fast-growing pattern performs allelopathy activities against associated plants, adversely affect crop production, forest regeneration, disturb vegetation distribution	[23, 37, 41, 42]
Ageratum conyzoides	South America	fast growth, production of large numbers of seeds enable rapid spread in its territory; significantly affect crop production, seed germination and species richness	37,38,43,44 [37, 38, 43, 44]
Ageratina adenophora	Tropical America	Reduced crop production, seed germination, replace grassland vegetation	[39, 44, 45, 46]
Prosopis juliflora	Mexico	Major hurdles in forest ecosystems with non-palatable plant parts occupy massive areas	[47, 48, 49]
Cuscuta spp.	Mediterranean	A serious hindrance to agro ecosystems including rice cultivation	[21]
Eichornia crassipes	South America	impediment in navigation, clogs irrigation systems, dominant resource acquisition of water bodies	[50]
Salvinia molesta	Brazil	Clogs aquatic ecosystems with fast vegetative growth, hinder in navigation	[10]
Ipomoea carnea	Tropical America	Dominant in freshwater bodies, choke navigation and water channels	[10, 15]

Conclusion

The introduction of invasive species to India is historically long and wide across the globe. The suitability of the climate, edaphic factors, and geographical uniqueness is so fascinating that most invasive introductions to India are stable. The alien flora invades the terrestrial, swamplands, disturbed lands, riparian areas, ecotones all the habitats. Herbaceous species in most of these habitats are devastating for nutrients acquisition and resources portioning that negatively influence local plant species.

Native plant species are abruptly facing challenges posed by invasion of alien plants that inculcate the regional habitats in most parts of the Indian subcontinent [38]. Terrestrial and aquatic ecosystems of disturbed and static lands are widely malfunctioned by exotic invasion. Various reports and inventories from time to time by several research groups indicated an alarming situation for the native plant species in India. The authors enlisted the herbaceous plants in terrestrial and aquatic habitats that confront detrimental effects on the regional floral communities associated with the invasive plants. The trauma caused by invasive plant's allelochemicals in microbial communities and associated plant species is inductive to generate negative pressure in local plants. The habitat loss and range of distribution of so many Indian plants are strictly regulated by most obnoxious invasive plants including *Parthenium* sp., *Lantana* sp., *Mikania* sp., *Ipomoea* sp., *Eichhornia* sp., *Ageratum* sp. The occupancy and adaptation of *Parthenium* sp., *Lantana* sp., *Eichhornia* sp., *Ageratum* sp. in the most disturbed habitats are highly intriguing. The accessible mode of seed dispersal, numerous seeds, non-palatable nature for grazing animals, and secretions of defensive phytochemicals made them more aggressive to influence India's regional flora.

Future studies and opportunities

There are tremendous opportunities for exploitations in plant invasion studies. Because plant invasion is of utmost necessity to determine the status of invasion, causes of invasion and response of native species, invasion distribution, effects of invasion on yield in an agri-horticultural crop, aggression in forest plant species and their interaction for habitat occupancy. Plant invasion is a considerable burden for regional species. And many more collaborative efforts in various fields of biology and forest management are needed to mitigate the problems of charge of exotic plants in future.

Conflict of Interest

The authors do not have any conflict of interest.

References

1. Alpert P, Bone E, Holzapfel C. Perspectives in Plant Ecology, Evolution and Systematics Invasiveness, invasibility and the role of environmental stress in the spread of non-native plants. Perspect. Plant Ecol. Evol. Syst,2000:3:52–66.
2. Milanovic M, Knapp S, Pyšek P, Kühn I. Linking traits of invasive plants with ecosystem services and disservices. Ecosyst. Serv,2020:42:1010-1072.
3. Blackburn T M *et al.* A Unified Classification of Alien Species Based on the Magnitude of their Environmental Impacts. PLoS Biol, 2014, 12.
4. Jeschke JM. Defining the impact of non-native species. Conserv. Biol,2014:28:1188-1194.
5. Pyšek P. A global assessment of invasive plant impacts on resident species, communities and ecosystems: The interaction of impact measures, invading species' traits and environment. Glob. Chang. Biol,2012:8:1725-1737.
6. Fine PVA. The invasibility of tropical forests by exotic plants. J. Trop. Ecol,2002:18:687-705.
7. Inderjit. Plant invasions: Habitat invasibility and dominance of invasive plant species. Plant Soil,2005:277:1-5.
8. Vilà M. How well do we understand the impacts of alien species on ecosystem services? Pan European crosstaxa assessment. Front. Ecol. Environ,2010:8:135-144.
9. Jentsch A, Beierkuhnlein C. A new generation of climate-change experiments: events, not trends. Front. Ecol. Environ,2007:5:365-374.
10. Khuroo A A *et al.* Alien flora of India: Taxonomic composition, invasion status and biogeographic affiliations. Biol. Invasions,2012:14:99-113.
11. Sekar KC. Invasive Alien Plants of Indian Himalayan Region—Diversity and Implication. Am. J. Plant Sci,2012:03:177-184.
12. Sekar KC, Manikandan R, Srivastava SK. Invasive alien plants of Uttarakhand Himalaya. Proc. Natl. Acad. Sci. India Sect. B - Biol. Sci,2012:82:375-383.
13. Negi PS, Hajra PK. Alien flora of Doon Valley, Northwest *Himalaya. Curr. Sci,2007:92*:968-978.
14. Khuroo A A, Rashid I, Reshi Z, Dar G H, Wafai B A. The alien flora of Kashmir Himalaya. Biol. Invasions,2007:9:269-292.
15. Jaryan V, Uniyal SK, Gupta RC, Singh RD. Alien Flora of Indian Himalayan state of Himachal Pradesh. Environ. Monit. Assess,2013:185:6129-6153.
16. Reddy C S. Catalogue of invasive alien flora of India. Life Sci. J,2008:5:84-89.
17. Pathak R, Negi VS, Rawal RS, Bhatt ID. Alien plant invasion in the Indian Himalayan Region: state of knowledge and research priorities. Biodivers. Conserv,2019:8:3073-3102.
18. Kaur B, Bhatia S, Sharma KK. Diversity and impact of invasive alien plant species of family Asteraceae in Jammu district (Jammu and Kashmir, India). Int. J. Interdiscip. Multidiscip. Stud,2014:1:51-62.
19. Sekar KC, Aseesh P, Srivastava S, Giri L. Invasive Alien Plants of Himachal Pradesh, India. Indian For,2015:141:520-527.
20. Das K, Duarah P. Invasive Alien Plant Species in the Roadside Areas of Jorhat, Assam : Their Harmful Effects and Beneficial Uses. Int. J. Eng. Res. Appl,2013:3:353-358.
21. Singh TB. Study of Alien and Invasive Flora of Valley District of Manipur and Their Control. Int. J. Innov. Res. Sci. Technol,2015:1:14-16.
22. Debnath A, Debnath B. Diversity, Invasion Status and Usages of Alien Plant Species in Northeastern Hilly State of Tripura : A Confluence of Indo-Barman Hotspot. 2017. doi:10.4236/ajps.2017.82017.
23. Kohli RK, Batish DR, Singh HP, Dogra KS. Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lantana camara* L.) in India. Biol. Invasions,2006:8:1501-1510.

24. Raghubanshi AS, Rai LC, Gaur JP, Singh JS. Invasive alien species and biodiversity in India. Curr. Sci,2005:88:539-540.
25. Kaul S, Bansal GL. Allelopathic effect of *Ageratina adenophora* on growth and development of *Lantana camara*,2002:7:195-197.
26. Kuldip SD. Phytotoxicity of Parthenium hysterophorus residues towards growth of three native plant species (Acacia catechu willd, Achyranthes aspera L. and Cassia tora L.) in Himachal Pradesh, India. Int. J. Plant Physiol. Biochem, 2012, 4.
27. Tadele D. Allelopathic Effects of Lantana (*Lantana camara* L.) leaf extracts on germination and rarly growth of three agricultural crops in Ethiopia,2014:6:111-119.
28. Mishra A. Allelopathic properties of *Lantana camara*. 2015. doi:10.14303/irjbcs.2014.048.
29. Sousa EO, Costa JGM. Genus Lantana : chemical aspects and biological activities,2012:1155–1180.
30. Kong C, Hu F E I, Xu X. Allelopathic potential and chemical constituents of volatiles from *Ageratum conyzoides* under stress,2002:28:1173-1182.
31. Mersie W, Singh M. Effects of Phenolic Acids and Ragweed Parthenium (*Parthenium hysterophorus*) Extracts on Tomato (*Lycopersicon esculentum*) Growth and Nutrient and Chlorophyll Content Author (s): Wondimagegnehu Mersie and Megh Singh Published by : Cambridge University,1988:36:278-281.
32. Fuente JRDe, Uriburu ML, Burton G, Sosa V E. Sesquiterpene lactone variability in Parthenium hysterophorus L,2000:55:769-772.
33. Saleh M. Gas-chromatographic analysis of the essential oils of *Lantana camara* L. varieties. Planta medica,1974, 25.
34. Jain R, Singh M, Dezman DJ. Qualitative and Quantitative Characterization of Phenolic Compounds,2018:37:302-307.
35. Noel K, John A, Sioumisb AA, Suaresa H. New Triterpenes of *Lantana camara*. A Comparative Study of the Constituents of Several Taxa, 1976.
36. Xuan TD, Tawata S, Khanh TD. Assessment of phytotoxic action of *Ageratum conyzoides* L. (billy goat weed) on weeds. 2004. doi:10.1016/j.cropro.2004.02.005.
37. Kohli RK *et al.* Impact of Invasive Plants on the Structure and Composition of Natural Vegetation of Northwestern Indian Himalayas. Weed Technology,2004:18(I):1296-1300.
38. Dogra KS, Kohli RK, Sood SK. An assessment and impact of three invasive species in the Shivalik hills of Himachal Pradesh, India,2009:1:4-10.
39. Kosaka Y. Roadside distribution patterns of invasive alien plants along an altitudinal gradient in Arunachal Himalaya, India. Mt. Res. Dev,2010:30:252-258.
40. Lahkar B P, Talukdar B K, Sarma P. Invasive species in grassland habitat: An ecological threat to the greater one-horned rhino (*Rhinoceros unicornis*). *Pachyderm*,2011:49:33-39.
41. Love A, Babu S, Babu CR. Management of Lantana, an invasive alien weed, in forest ecosystems of India. *Curr. Sci*,2009:97:1421-1429.
42. Parveen KD, Ravinder KK, Daizy RB. Evaluation of the impact of Lantana camara L. invasion, on four major woody shrubs, along Nayar river of Pauri Garhwal, in Uttarakhand Himalaya. Int. J. Biodivers. Conserv.2010:2:155-161.
43. Batish DR, Kaur S, Singh HP, Kohli RK. Role of root-mediated interactions in phytotoxic interference of Ageratum conyzoides with rice (*Oryza sativa*). Flora Morphol. Distrib. Funct. Ecol. Plants,2009:204:388-395.
44. Singh A. Allelopathic influence of dominant weeds of North-Western Himalayan region on common cereal crops. Allelopath. Influ. Domin. weeds North-Western Himal. Reg. common Cereal Crop,2012:3:84-97.
45. Bughani I, Rajwar G S. Primary productivity and the impacts of the exotic weed Eupatorium glandulosum in a montane grassland of Garhwal Himalaya. Environmentalist,2005:25:31-38.
46. Datta A, Kühn I, Ahmad M, Michalski S, Auge H. Processes affecting altitudinal distribution of invasive Ageratina adenophora in western Himalaya: The role of local adaptation and the importance of different life-cycle stages. PLoS One,2017:12:1-18.
47. Dayal V. Social diversity and ecological complexity: How an invasive tree could affect diverse agents in the land of the tiger. Environ. Dev. Econ,2007:12:553-571.
48. Mukherjee A, Velankar AD, Kumara HN. Invasive Prosopis juliflora replacing the Native Floral Community over three decades: a case study of a World Heritage Site, Keoladeo National Park, India. Biodivers. Conserv,2017:26:2839-2856.
49. Kaur R. *et al.* Community Impacts of Prosopis juliflora Invasion: Biogeographic and Congeneric Comparisons. PLoS One, 2012, 7.
50. Villamagna AM, Murphy BR. Ecological and socio-economic impacts of invasive water hyacinth (*Eichhornia crassipes*): A review. Freshw. Biol,2010:55:282-298.