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REVIEW PAPER

Alien plant invasion in the Indian Himalayan Region: state of knowledge and research priorities

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Abstract

Invasion by alien species is a global problem and forms one of the major drivers of global change. The researches on plant invasion have grown rapidly across the globe since the mid-twentieth century. However, in the Indian Himalayan Region (IHR) such studies are inadequate and have not been systematically conducted. Lack of empirical evidences on various described aspects of plant invasion in IHR are likely to aggravate the issue of invasion management in the region. This scenario would become more worst under changing climate. This study analyzed the results of an extensive review of the available information generated through Web of Science and Google scholar. A total of 297 naturalized alien plant species belongs to 65 families in the IHR are reported. Of the total 297 naturalized alien plant species in IHR, maximum species occur in Himachal Pradesh (232; 78.1%) followed by Jammu & Kashmir (192; 64.6%) and Uttarakhand (181; 60.90%). Among various invasive species, *Lantana camara, Ageratina adenophora, Parthenium hysterophorus* and *Ageratum conyzoides* have been reported from most of the IHR states and proliferated over larger area. Evidences available in the published studies are indicative that with tourism promotion and increasing roads networks, that passes through forests, many of the alien species in the IHR have started invading forests and even in alpine ecosystems. This study observed expansion of *Ageratina adenophora* up to 2900 m, which is higher than its reported elevation range (300–2800 m) in west Himalaya. These evidences suggest possible encroachment by alien species in hitherto invasion resilient higher Himalaya, particularly with emerging trends of increasing temperature and human disturbances. The present study also provides a multistage framework for investment on invasion researches in IHR. This will allow developing appropriate management strategies and policy planning for addressing issues pertaining to plant invasions across the IHR states.

Keywords Invasion · Naturalized alien plant species · Anthropogenic disturbance · Management strategies · Eradication · Climate change · Indian Himalayan Region

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Introduction

Biological invasions are widespread and significant component of global environmental change, which lead to the loss of biodiversity and ecosystem services through altering native biodiversity, community structure, composition and functions (Vitousek et al. 1996; Tilman 1999; Ehrenfeld 2003; Yurkonis et al. 2005). Invasion by alien species has already been reported as a global problem and considered among the important drivers of global change. Invasion has been reported amongst five major drivers of biodiversity loss (Millennium Ecosystem Assessment 2005). It has impacted various natural ecosystems worldwide, both aquatic and terrestrial (Sharma et al. 2005; Dawson et al. 2017). Among terrestrial ecosystems, mountain ecosystems (especially high mountains) are often been considered at low risk of invasions (Pauchard et al. 2009). This is attributed to various ecological filters (Alexander et al. 2011; McDougall et al. 2011) faced by alien plants as they move up towards the higher mountains. However, the risk is inevitable (Pauchard et al. 2009). Whenever, an alien species manages to establish itself in mountains, it quickly proliferates and becomes difficult to control and manage due to rough and steppe mountain terrains (McDougall et al. 2011). Climate is one of the important determinants of vegetation patterns globally and has significant influence on the ecology of forests (Kirschbaum 2000). Global climate change has been reported to favor the proliferation of invasive alien species (Tilman 1999; Ziska 2003; Walther et al. 2009; Pandey and Sharma 2013). This increase in cover of invasive species in combination with climate change is reported to cause significant and irreversible species loss (Myers 1993; Hulme 2003, 2009).

Invasive alien species also get opportunities to expand in their habitat ranges due to anthropogenic perturbations (Myers 1993). Over the years they replace slow growing native species that require more stable conditions. Alien invasive plants often proliferate faster by both, vegetative means as well as reproductive means and are usually more responsive to increasing atmospheric CO_2 concentrations (Rogers et al. 2008; Bradley et al. 2010). This advantage under elevated CO_2 conditions helps invasive alien species to out-compete the local species in migration to higher ranges. Considering these facts, it has been reported that most alien biota, which originally remains confined to the lower elevations is likely to ascend to higher elevations under increasing human disturbance and global climate change scenario (Simberloff 2000; Ziska 2003).

The Himalaya has been recognized as one of the 36 global biodiversity hotspots for its unique and rich biodiversity that is under severe threats (Palni and Rawal 2013; Sharma et al. 2016). The Indian Himalayan Region (IHR) contributes a large proportion of this hotspot. This region is provider of goods and range of ecosystem services to sustain life of millions of people within and well beyond its physical boundaries. Value of diverse forest ecosystem of IHR is well known (Singh 2014), especially because they provide vital support to the agro-ecosystems of the region through transfer of biomass and energy, and biomass for cooking energy (Negi et al. 2018a, b). The Indian National Action Plan on Climate Change (NAPCC) has recognized Himalayan region vital for ecological security of the country. However, NAPCC also underlines the intense vulnerability of the region due to anthropogenic activities and environmental perturbations, including climate change and biological invasion (Adhikari et al. 2015; Negi et al. 2019).

Globally, the research on plant invasion has grown rapidly since the mid-twentieth century (Lowry et al. 2013a, b). However, studies in IHR have remained limited in scope and extent. Few researches (Khuroo et al. 2012a, b; Sekar 2012; Sekar et al. 2012) in recent decade, however, have made this subject popular in the region. However, most of these studies do not provide a comprehensive account of invasion research in IHR. The present study, therefore, was conceptualized to (i) review the status of research on invasive alien plant species in the IHR, (ii) analyze distribution of invasive alien plant species across IHR and assess distribution of dominant invasive alien plant species by provinces, (iii) document the process and causes of invasion in the region, and (iv) depict the likely impacts of invasion and suggest way forward for management planning for invasive plant species in the IHR.

Materials and methods

Study area

The Indian Himalayan Region (IHR), with geographical coverage of over 5.3 lakh Km^2, comprises of the vast mountain ranges extending over 2500 km in length between the Indus and the Brahmaputra river systems. Vertically, these mountains rise from low-lying plains to over 8000 m above sea level. As being young (30–40 million years old) and still rising mountain, Himalaya is vulnerable to landslips and landslides, and deposits of debris from broken, fractured and shattered rocks (Singh 2014). Administratively, IHR (Fig. 1) consists of ten Indian states fully (Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram, Tripura) and two states partially (i.e. West Bengal hills and Assam hills). Bio-physical diversity of the region is further reflected in its bio-geographic divisions. The region consists of three biogeographic zones (out of 10 in India) viz., the trans Himalaya, the Himalaya and the North-East India; and 9 biogeographic provinces of the total 27 in India (Palni and Rawal 2013).

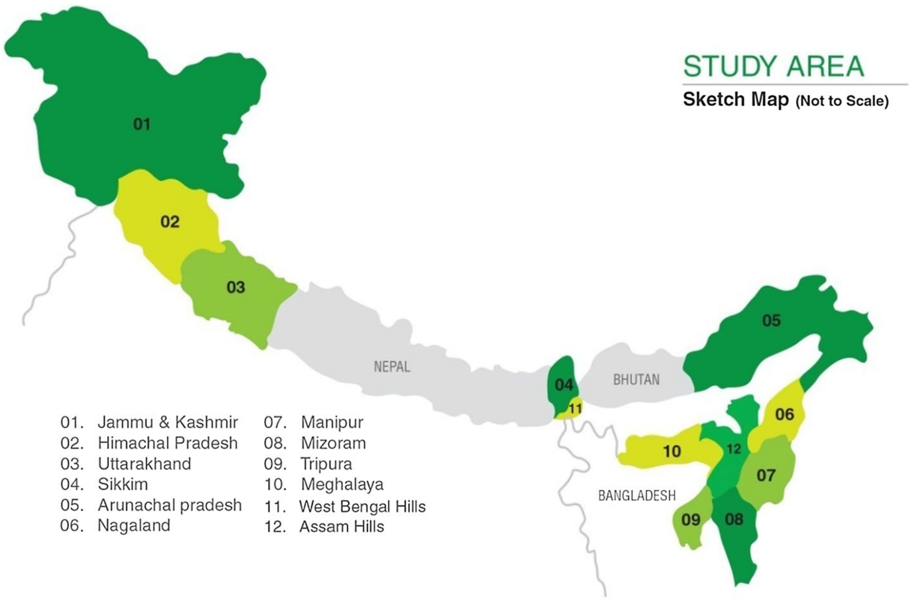

Fig. 1 Extent of the Indian Himalayan Region (IHR) with different states

This region is important for its high forest cover (>41.5% of its geographical area) that represents one-third of the total forest cover of India (FSI 2017). It is pertinent to mention that the Himalayan forests, in their structure and function, differ considerably from forests generally described in global literature (Zobel and Singh 1997; Singh 2014). Further, forest structure and distribution are variously modified in the region by anthropogenic and natural disturbances (Singh 2014). The sustenance of indigenous communities in the IHR has traditionally been dependent on diverse bioresources. More than 80% of the IHR population is involved in agriculture, animal husbandry, forestry and other biodiversity dependent occupations (Palni and Rawal 2013). The IHR constitutes a large portion of the Himalayan Biodiversity Hotspot and, therefore, contributes greatly to richness and representativeness of its biodiversity components at all level i.e. genes, species and ecosystems (Palni and Rawal 2013). As per an estimate (Singh and Hajra 1996), floristic diversity of IHR consists of nearly 8000 species of Angiosperms (40% endemic), 44 species of Gymnosperms (16% endemic), 600 species of Pteridophytes (25% endemic), 1737 species of Bryophytes (33% endemic), 1159 species of lichens (11% endemic) and 6900 species of fungi (27% endemic). The high degree of endemism in plant groups implies occurrence of various special habitats across the region. The diversity of species in high value plant groups is yet another important feature. For instance, among known plants from the region over 1748 (Samant et al. 1998) have been reported to have medicinal properties and over 675 are known as wild edible plants (Samant and Dhar 1997).

Among others, the region is recognized as highly sensitive to changing climate. Evidences suggest, the Himalaya is warming at higher rate than average global rate and warming increases with altitude (Singh et al. 2011a, b, Singh 2014). Also, the IHR, in recent decades, has registered a significant increase in urbanization. As per the census of 2011, the decadal growth rate (2001–2011) for urban population in IHR was 48.4% compared to national average of 31.8%. During the same period rural population increased with a rate of 10.5% per decade. This unprecedented growth of urbanization has brought the entire region in rapid transformations which have significant implications for land use and land cover scenario in the region. Both these factors (i.e. climate change sensitivity and demographic transformation) are expected to create suitable conditions for proliferation of alien invasive species in IHR.

Method

An extensive review of the available information and literature (research articles, reviews, inventories, books, articles, e-link) was conducted using Web of Science and Google scholar. Towards assessing the number of studies conducted on plant invasions, 'Web of Science' a scientific citation indexing service was followed using the terms invasive, alien, non-native, invasion. The search was made in February 2019. We employed the following search string to identify relevant papers by topic (i.e., using key words): Topic = (invasive × OR alien OR non-native OR invasion) AND topic = (plant OR Himalaya). Thereafter, we limited our database to relevant fields of study by using the "refine" function in the Web of Science to include relevant subjects i.e. Ecology and Evolution, Plant sciences and Biodiversity conservation. The outcome was again refined for the country i.e. India. A total of 395 studies thus resulted on plant invasion from India. Thereafter studies pertaining to plant invasion in Indian Himalayan states/Indian Himalayan Region were filtered, which yielded a total of 48 studies.

Since much literature was not found using Web of Science, the study is largely focused on synthesis of the literature available for IHR, from search results of Google scholar, as well as books and reports. In addition, few case studies on invasion, based on primary data from the western Himalayan region of IHR, have also been considered.

Status and distribution

The first ever inventory on invasive alien plant species of India was compiled by Reddy (2008). Khuroo et al. (2012a, b) published an account of 1599 alien plant species of India, and provided information on the invasion status, native ranges and their distribution in different families. Specifically for the IHR, very few studies have attempted inventorying alien plant species (Khuroo et al. 2007; Sekar et al. 2012; Jaryan et al. 2013; Sekar et al. 2015). Among these, Khuroo et al. (2007) and Jaryan et al. (2013) have provided the invasion status of the listed species. The status of studies conducted on invasive plant species in the IHR has been analyzed (Table 1). The information on invasion status of species listed in inventories is now gaining attention. For instance, Debnath and Debnath (2017) provided a complete list of alien species of Tripura along with invasive status, life form, habit, habitat and mode of introduction of the listed alien plant species. This type of studies that provide updates on invasion status would be very useful in management planning. The information on distribution of alien species is important for analyzing the range of shift of species, while comparing at varied time scale. For example, recently Inderjit et al. (2018) reported 471 naturalized alien species from India as against the 257 species reported earlier (Khuroo et al. 2012a, b). Following the information provided by Inderjit et al. (2018), a total of 297 naturalized alien plant species (65 families) are present in the IHR (please see Supplementary Table 1). Family Asteraceae with 19% naturalized alien plant species is the most alien species rich, followed by Leguminosae (11%), Poaceae (7%) and Euphorbiaceae (6%—Fig. 2). While comparing the IHR states, Himachal Pradesh (232; 78.1%) tops the list in having naturalized alien species followed by Jammu & Kashmir (192; 64.6%) and Uttarakhand (181; 60.9%, Fig. 3). Table 2, gives an account of major alien plants that have been investigated in IHR. Among these, despite been investigated, *Anthemis cotula* and *Sapium sebiferum* have not been included in the inventory given by Inderjit et al. (2018). Although, several new studies have given a better insight on the naturalized alien flora of IHR, the inventories of naturalized alien species needs more information to describe invasiveness of such species (using parameters like abundance, density, frequency and ground cover) needs to be done. Recent studies (Khuroo et al. 2008, 2012a, b) have recommended that inventorization of alien flora of India, including IHR should be carried out following biogeographic approach rather than using political units (state-wise).

Climatic and habitat conditions are known to affect the altitudinal distribution of alien species in mountainous regions (Haider et al. 2010), and with the changing climatic conditions the distribution of these species to new area might be possible. The knowledge on distribution pattern of alien species can help in prediction of their probable distribution under the changing climate scenarios. For example, Lamsal et al. (2018) using the MaxEnt ecological niche modeling software studied the dynamics of five well established Invasive Alien Plant Species (IAPS) of the Himalayan region. The study predicted that *Ageratum conyzoides* and *Parthenium hysterophorus* will lose overall suitable area from the Himalaya by 2070, while *Ageratina adenophora*, *Chromolaena odorata* and *Lantana camara* are expected to expand in more suitable areas. Based on the model predictions, distribution of

Table 1 Available inventories on alien plant species of IHR and future opportunities

S. no.	State	Available inventories	Category of inventory (alien/invasive)	Remarks/issues with the available Inventories	Opportunity
1	Jammu and Kashmir	Khuroo et al. (2007)	Alien flora	Only for Kashmir Himalaya	A combined inventory can be made for Jammu and Kashmir
		Kaur et al. (2014)	Invasive alien flora	Only for Jammu	
2	Himachal Pradesh	Jaryan et al. (2013)	Alien flora	–	Assessment of invasive species can be done for better management
		Sekar et al. (2015)	Invasive alien flora	–	
3	Uttarakhand	Negi and Hajra (2007)	Alien flora	Only for doon valley	Stage based classification can be adopted to make inventory more comprehensive and attempt can be made to form a state level inventory
		Sekar et al. (2012)	Invasive alien flora	Only invasive plants are listed	
4	Sikkim	Not available	–	–	Stage based classification can be adopted to make inventory more comprehensive and attempt can be made to form a state level inventory
5	Assam	Das and Duarah (2013)	Invasive alien flora	Invasive of a single district is listed	
6	West Bengal	Maiti and Bakshi (1981)	Alien flora	–	Need to update the inventory
7	Arunachal Pradesh	Not available	–	–	
8	Manipur	Singh et al. (2015)	Alien/invasive flora	–	Stage based classification can be adopted to make inventory more comprehensive and attempt can be made to form a state level inventory
9	Nagaland	Not available	–	–	
10	Meghalaya	Not available	–	–	
11	Mizoram	Not available	–	–	
12	Tripura	Debnath and Debnath (2017)	Alien flora	–	Assessment of invasive species can be done for better management

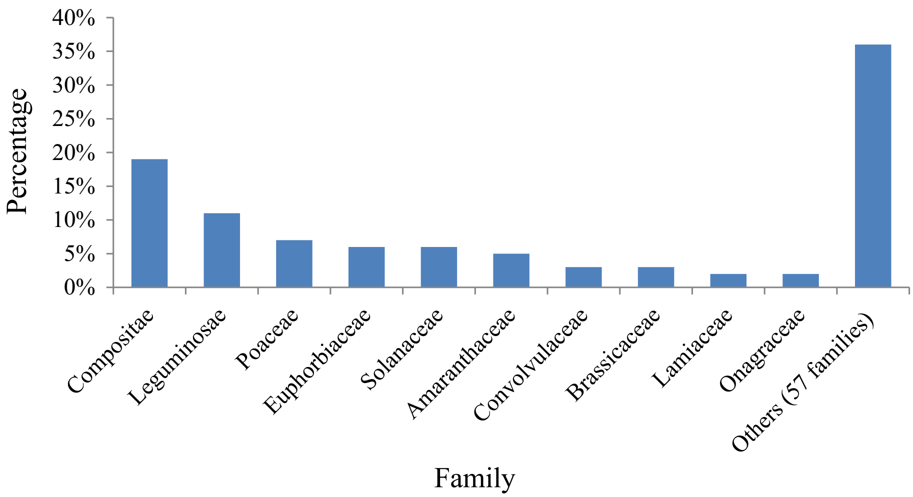

Fig. 2 Proportion of naturalized alien plant species in IHR across families

Fig. 3 Richness of naturalized alien plant species in different states of IHR

most of these invasive plants is expected to expand under future climatic scenarios, which might pose a serious threat to the native ecosystems through competition for resources. It is predicted that native scrublands and subtropical needle-leaved forests will be the most affected ecosystems with the expansion of these IAPS (Thapa et al. 2018). The study further predicted that habitat suitability for all the five species will decrease with increasing elevation. Such studies by predicting the invasion risks of the alien species are thus expected to help in formulating present and future response strategies in the Himalayan region.

Table 2 Most investigated alien plant species in IHR

S. no.	Species	Type of studies conducted	Reference
1	*Lantana camara*	Impact, spread, distribution and invasion success, management	Kandwal et al. (2009), Love et al. (2009), Dobhal et al. (2010), Singh et al. (2014)
2	*Sapium sebiferum*	Spread, distribution and invasion success	Jaryan et al. (2007, 2013, 2014, 2016)
3	*Chromolaena odorata*	Spread, distribution and invasion success	Mandal and Joshi (2014b)
4	*Anthemis cotula*	Spread, distribution and invasion success, biology and association	Rashid and Reshi (2010), Shah and Reshi (2007)
5	*Euphorbia geniculata*	Spread, distribution and invasion success, biology and association	Araf et al. (2010)
6	*Ageratina adenophora*	Impact, antioxidant activity, anti-inflammatory properties	Tripathi et al. (1981), Bughani and Rajwar (2005), Chakravarty et al. (2011), Bhardwaj et al. (2014)
7	*Parthenium hysterophorous*	Impact; spread, distribution and invasion success, Management	Dogra et al. (2011), Dogra and Sood (2012)
8	*Chenopodium murale*	Impact	Batish et al. (2007)
9	*Ageratum conyzoides*	Impact	Batish et al. (2009), Katoch et al. (2012)

Most proliferative alien plant species by states in IHR have been presented (Table 3). The results revealed that *Parthenium hysterophorous, Lantana camara, Ageratina adenophora* and *Ageratum conyzoides* are the naturalized alien species that have proliferated and impacting biodiversity in most of the Indian Himalayan states. The species like *Anthemis cotula, Rubus neivus, Argemone mexicana* and *Sapium sebiferum* remain confined and proliferative in western Himalayan states. Whereas, *Chromolaena odorata, Mikania micrantha, Eclipta prostrate, Mimosa pudica* and *Ageratum houstonianum* proliferate in eastern Himalayan states (Table 3). Thus, focus needs to be given not only to established alien species, but also on the alien species which are not yet well established to prevent them from becoming invasive to the areas. Some species are specific to a particular state as well, for instance *Anthemis cotula* is reported to be proliferative only in Kashmir Himalaya (Khuroo et al. 2008), *Sapium sebiferum* is reported to be proliferative only in Himachal Pradesh (Jaryan et al. 2013).

Mechanism of plant invasion

Plants have been dispersed by humans, deliberately and accidently far from their native ranges, through transport and commerce over the last thousand years (Mack et al. 2000). Invasion success of any alien plant species depends on various factors, i.e. availability of resources (light, nutrients, etc.), reproduction biology and invisibility of the recipient habitat that helps in the spread and establishment of these species (Rejmanek 1989; Daneshgar and Jose 2008). However, it is not necessary that each introduced species will become naturalized. Various mechanisms of plant invasion (Fig. 4) have been studied in IHR (Kala 2004; Arshid and Wani 2012), and most of them are species-specific (Jaryan et al. 2007; Mandal and Joshi 2014a, b).

Invasion by plants is not a novel phenomenon for the region, but studies on plant invasion are novel in this region. Most of the studies (Khuroo et al. 2010; Shah et al. 2011; Shah and Reshi 2014) have focused on characterization, distribution patterns and mechanisms of plant invasion are from Kashmir Himalaya. Few studies (Dogra et al. 2011; Priyanka and Joshi 2013; Jaryan et al. 2016; Datta et al. 2017) are from other region of the IHR i.e. Western Himalaya and Eastern Himalaya (Tripathi et al. 1981; Kosaka et al. 2010; Mao and Gogoi 2010). The process of biological invasion is most often facilitated by disturbances, which may result in loss of native diversity (Hobbs and Huenneke 1992; Pyšek and Richardson 2006). Initially the alien invasive species acts as the 'passengers' of deforestation and disturbances, but very soon change into 'drivers' by disrupting forest regeneration process (Bhuju et al. 2013). Among others, climate change and localized species adaptation is expected to expand the range of current invaders into undisturbed areas over the time (Dietz and Edwards 2006; Pyšek et al. 2010).

With the changing climate scenario, opportunity for invasive alien species to widen their distribution is likely to increase due to their adaptability to disturbance (Stachowicz et al. 2002; Lake and Leishman 2004). Although, mountain ecosystems at higher elevations has been considered at low risk of plant invasions as compared to other ecosystems (Millennium Ecosystem Assessment 2003; Baret et al. 2006; Pauchard et al. 2009), theincreased tourism in mountainous regions might facilitate distribution of alien species, which is currently limited to foothills and mid-elevations of IHR. An increase in cover of invasive species aided to climate change may cause significant and irreversible species loss (Myers 1993). Alien invasive plants often proliferate faster by vegetative means and are usually

Table 3 Most proliferative invasive alien plant species in different states of the IHR

S. no.	State	Proliferated invasive species	References
1	Jammu & Kashmir	*Pathenium hysterophorous*	Khuroo et al. (2012a, b)
		Lantana camara	
		Anthemis cotula	
		Ageratum conyzoides	Khuroo et al. (2007)
		Argemone mexicana	Shah and Reshi (2007)
		Cassia tora	Singh and Dangwal (2014)
2	Himachal Pradesh	*Parthenium hysterophorous*	Kohli et al. (2004), Sekar et al. (2015), Jaryan et al. (2013)
		Ageratum conyzoides	
		Lantana camara	
		Sapium sebiferum	
3	Uttarakhand	*Ageratina adenophora*	Bughani and Rajwar (2005), Dobhal et al. (2011), Khanduri et al. (2017)
		Lantana camara	
		Parthenium hysterophorus	
		Ageratum conyzoides	
		Rubus neivus	
4	Sikkim	*Lantana camara*	Tripathi and Yadav (1982), Tripathi et al. (2006), Sikkim Biodiversity action plan (2011), Sikkim State Action Plan on Climate Change (2015)
		Ageratina adenophora	
		Eupatorium riparium	
		Chromolaena odorata	
		Mikania micrantha	
		Rumex nepalensis	
5	Darjelling Hills	*Ageratina adenophora*	Moktan and Das (2013)
		Ageratum houstonianum	
6	Assam hills	*Mikania micrantha*	Mainu Devi (2017)
		Ludwigia peruviana	Barua et al. (2017)

Table 3 (continued)

S. no.	State	Proliferated invasive species	References
7	Arunachal Pradesh	*Ageratum conyzoides*	Kosaka et al. (2010), Tripathi (2013)
		Chromolaena odorata	
		Mikania micrantha	
		Bidens pilosa	
8	Meghalaya	*Ageratina adenophora*	Shankar et al. (2011), Tripathi (2013), Singh et al. (2011a, b)
		Chromolaena odorata	
		Imperata cylendrica	
		Artemesia nilagirica	
		Lantana camara	
		Ligustrum lobustum	
		Ageratum conyzoides	
9	Manipur	*Ageratina adenophora*	Tripathi (2013), Singh et al. (2015)
		Ageratum conyzoides	
		Ageratum houstonianum	
		Mikania micrantha	
		Lantana camara	
		Chromolaena odorata	
10	Nagaland	*Parthenium hysterophorous*	Naithani (1987), Tripathi (2013)
		Lantana camara	
		Chromolaena odorata	

Table 3 (continued)

S. no.	State	Proliferated invasive species	References
11	Mizoram	*Mikania micrantha* *Eupatorium serotinumm* *Ageratum conyzoides* *Lantana camara* *Musa sp. (Wild Banana)*	State Action Plan on Climate Change-Mizoram (2012–2017), Rai and Singh (2015), Rai (2015)
12	Tripura	*Chromolaena odorata* *Ageratum conyzoides* *Parthenium hysterophorous* *Lantana camara* *Alternanthera philoxeroides* *Mikania micrantha* *Mimosa pudica* *Eclipta prostrate*	Debnath et al. (2015a), (b), Debnath and Debnath (2017)

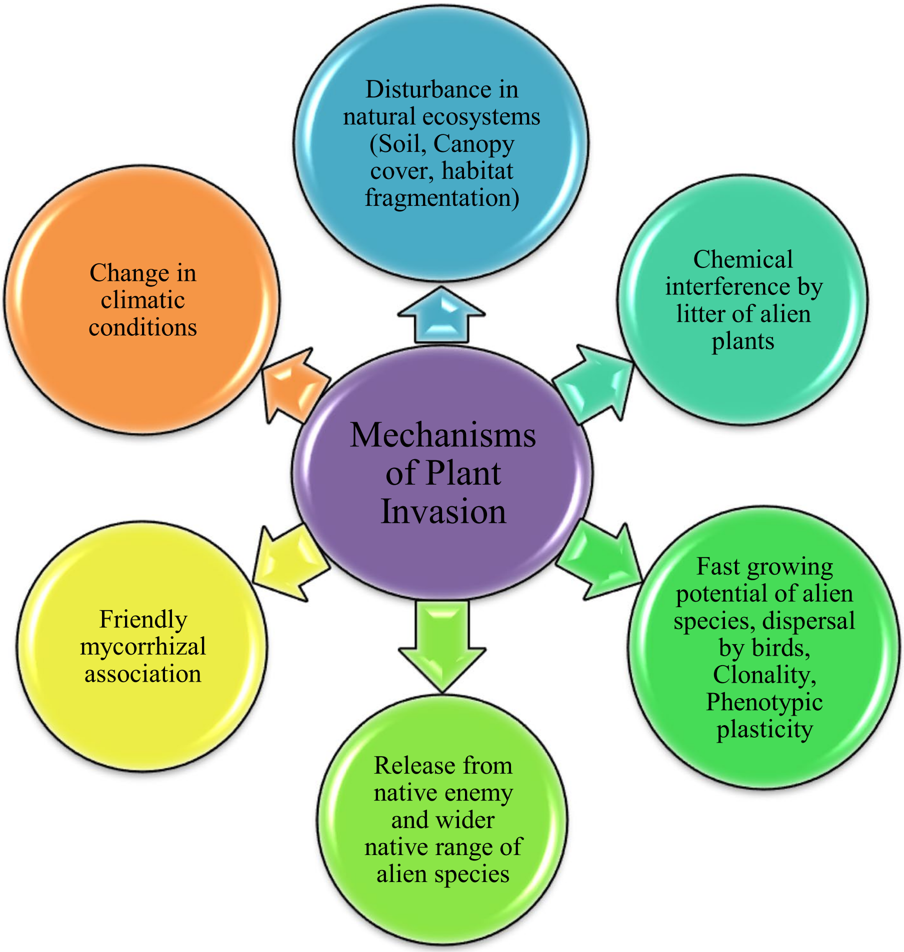

Fig. 4 Mechanisms of plant invasion that have been studied in IHR

more responsive to increase in atmospheric CO_2 concentrations (Rogers et al. 2008). Invasive alien species may have the advantage in elevated CO_2 conditions due to climate warming, and out-compete the local species in migration to higher ranges. According to Sekar (2012), 18 species namely, *Ageratum conyzoides*, *Cassia alata*, *Catharanthus pusillus*, *Celosia argentea*, *Chenopodium album*, *Eichhornia crassipes*, *Impatiens balsamina*, *Ipomoea eriocarpa*, *I. quamoclit*, *Lantana camara*, *Leucaena latisiliqua*, *L. leucocephala*, *Melilotus alba*, *Mirabilis jalapa*, *Passiflora foetida*, *Pennisetum purpureum*, *Portulaca oleracea* and *Prosopis juliflora* have been introduced intentionally, while the remaining species got established unintentionally through trade routes in the IHR.

In IHR, specifically in west Himalaya, *Ageratina adenophora*,, an aggressive alien species (Zheng et al. 2009), was earlier confined to foothills and middle elevations, is now showing upward movement (Sekar et al. 2012). In a recent field survey, *Ageratina adenophora* was observed with few individuals along roadsides between 2800 and 3000 m in western Himalaya (Fig. 5). The alpine meadows of the region are rich repository of unique

Fig. 5 Proliferation of *Ageratina adenophora* at high elevation (2842 m) of Tungnath region, Uttarakhand

element of plant diversity including high value medicinal plants, and the likely proliferation of *A. adenophora* in high elevation areas may be seen as potential threat in near future. Because of its wide ecological amplitude, *A. adenophora* might increase its elevational range, which is alarming and calls for immediate management and planning concerns. The success and spread of this species in western Himalaya depends on its varied stages of life cycle at varied elevations that are mostly controlled by abiotic conditions (Datta et al. 2017). The wide elevational distribution range (300–2800 m asl) of *A. adenophora* suggest for likely spread of this species in near future towards more higher reaches in western Himalaya.

Daneshgar and Jose (2008) proposed six major hypotheses of plant invasion mechanism i.e. invasion meltdown, enemy release, novel weapons, biotic resistance, island susceptibility and ten's rule. According to Jeschke et al. (2012), the hypotheses that considers interactions of exotic invaders with their new environments (invasion meltdown, enemy release and novel weapons) are better supported by empirical evidence than other three hypotheses (biotic resistance, island susceptibility, tens rule). Recognizing this fact, there is a need to conduct more intensive studies in different ecosystems, on different invasive alien species and at different spatial scales to understand the mechanism of plant invasions in the IHR. Beside review and field based exercises, there is a need to perform empirical studies to test the validity and generalization of these hypotheses for biological invasions in IHR.

Impact of alien plant species

Invasion by alien plant species causes wide range of impacts on native species richness, species diversity (Wilcove et al. 1998), soil nutrient composition, loss of productivity of invaded ecosystems, ecosystem services, etc. (Bhatt et al. 1994; Dukes and Mooney 2004; Mckee et al. 2004; Reshi et al. 2008; Vilà et al. 2010; Huddle et al. 2011). Alien plant proliferation may even cause genetic variations in native populations via hybridization (Vilà et al. 2000) and often hinders plant-pollinator interactions (Schweiger et al. 2010). Such evidences suggest simultaneous assessment of the role of species traits in invasion context when attempting to predict impacts of invasive plants. Global studies on invasion have revealed low abundance and diversity of native plants in the invaded sites, whereas primary production has increased in those sites (Vilà et al. 2000). In Indian subcontinent, for instance, *Parthenium hysterophorous* has invaded most of the parts and the infested area by the species is estimated to be 5 million acres (Kohli et al. 2006). Earlier, alien plant species were reported to proliferate mostly along roadsides, open canopy areas and forest edges in IHR (Kosaka et al. 2010). However, in recent decades, with faster construction of roads through forest areas most of alien species have started invading forest and alpine ecosystems. Alien plants are reported to pose various impacts on native diversity, like: (i) reduction in density, frequency and diversity of native species (Tripathi et al. 1981; Kandwal et al. 2009), (ii) replacement of fodder grasses and other medicinal plants (Bughani and Rajwar 2005), (iii) favoring other alien species over endemic species (Dobhal et al. 2011), (iv) Inhibition of seed germination (Bhardwaj et al. 2014), (v) decrease in nutrient content of the soil (Bhatt et al. 1994) and (vi) homogenization of natural habitats (Dar and Reshi 2015). There are very few studies on impacts are on natural ecosystems, while others have focused on agricultural ecosystems (Batish et al. 2007, 2009; Katoch et al. 2012). A summary of reported major impacts of alien invasive species in IHR have been presented (Table 4).

Among various alien invasive species in IHR, *Lantana camara, Ageratina adenophora, Parthenium hysterophorus* and *Ageratum* conyzoides with their spread over a larger area in the IHR arenegatively impacting the plant diversity and the biological integrity of Himalayan ecosystems (Dobhal et al. 2011). According to Kohli et al. (2006), *Parthenium hysterophorus* is the most noxious weed, which is replacing the native vegetation and causing a number of human health problems in the region. Similarly, *Lantana camara* is reported to encroach upon large areas of land, especially the Himalayan foothill forests, where it has virtually replaced the forest floor vegetation and reduced tree growth (Kohli et al. 2006; Negi et al. 2013). *Ageratina adenophora* mostly spreads in moist areas along road and forests in IHR and is impacting the plant diversity by increasing its competitive advantage through allelopathic action and by altering soil microbial communities (Dhyani 1978). *Ageratum conyzoides* has invaded agricultural fields in most of the states of IHR and causes yield reductions of major staple crops. Amongst alien plant species recorded from IHR (Sekar et al. 2012), *Ageratina adenophora* has been reported as an invasive species largely in Eastern Himalaya (Tripathi and Yadav 1982).

Most of the studies on impacts of alien species on native plants and or the crops have been conducted in laboratory conditions in IHR. Therefore, there is a need to study the impact of the alien invasive species in field situations using standardized methods (Hejda et al. 2009; Barney et al. 2015) to better understand the pattern, cause and mechanism of impact.

Management perspective

Persistence of funding limitations is considered to be costly and labor-intensive for invasive species management (Larson et al. 2011), which have been a hindrance in invasive species management. With changing climatic conditions, which are expected to increase invasion rates in upcoming years (Hellmann et al. 2008), greater efforts are required for better management. Developing management strategies needs proper examination and prediction of

Table 4 Impacts of dominant alien species in different ecosystems of IHR

S. no.	Alien species	Impacts	References
1	*Lantana camara*	Poor forest regeneration and crop production; significant loss of species richness and diversity in invaded localities. A 28.4% decrease in species richness of invaded localities and nearly 63% loss of basal area of vegetation in the invaded localities compared to non- invaded ones; negative effect of structure and function of vegetation	Kohli et al. (2004), Kohli et al. (2006), Love et al. (2009), Dobhal et al. (2010)
2	*Mikania micrantha*	Reduced crop production	Kohli et al. (2006), Kosaka et al. (2010)
3	*Ageratina adenophora*	Reduced crop production by reducing seed germination, allergy from seeds to humans; replacement of native grasses from grasslands	Bughani and Rajwar (2005), Kosaka et al. (2010), Katoch et al. (2012), Datta et al. (2017)
4	*Ageratum conyzoides*	Reduced crop production by reducing seed germination; altering soil properties; reduction in species richness in infested areas	Kohli et al. (2004), Batish et al. (2009), Dogra et al. (2009), Katoch et al. (2012)
5	*Parthenium hysterophorous*	Change in physico-chemical properties of soil; adversely affect the germination and the subsequent seedling growth of native plants (*Acacia catechu*, *Achyranthes aspera* and *Cassia tora;* reduction in species richness in infested areas	Kohli et al. (2004), Dogra et al. (2009), Dogra and Sood (2012)

the invasion potential, which can be done through a reliable screening system that requires answering a series of questions on attributes of invasive species, such as life-history, biogeography, habitat and weed history (Daehler and Carino 2000), that permits a species to be classified as likely to be invasive or unlikely to be invasive (Sharma et al. 2005). Among various management possibilities, a few have been listed below:

Eradication of IAPs

Management of plant invasions has largely been ad hoc in Himalayas and is mostly directed towards, agriculture, horticulture and freshwater lakes (McDougall et al. 2011). Eradication of the invasive species is considered to be successful only if it is done at early stage of proliferation (Zanden et al. 2010; Khuroo et al. 2010). Eradication of well-established invasive species may cause release of another previously suppressed non-native species to invade the area (Caut et al. 2009). Therefore, regular monitoring of these areas is necessary to prevent further invasion.

Once a new invasive alien is reported from any region, establishing a response decision becomes necessary step in eradication process. In short term, eradication of an IAPS can be costly, but can serve as a cost-effective option, if the invader is completely eliminated (Zanden et al. 2010). Decision making on whether or not to attempt eradication, needs to weigh several factors e.g. costs of eradication, likelihood of success (Zanden et al. 2010) and in case of failure what further impact the invader can pose to an area (i.e. re-invasion by the species, facilitation to other invasive species). For that, traditional cost–benefit analysis can be used to decide whether to eradicate a new invader or not (Naylor 2000).

In Indian Himalaya, the eradication has been successfully done in Corbett National Park, Uttarakhand, India by using cut root stock method along with manual removal of *Lantana camara,* a well established invasive alien species in the region (Love et al. 2009). To prevent re-invasion or secondary invasion by other invasive species, restoration of the area with native grass species was done and the results were fruitful (Babu et al. 2009). In some areas, burning of the invaded locality has been adopted as a management practice, but it might not serve as a good practice as the target invasive species itself can grow more after burning of infested localities (Dobhal et al. 2009). Addition of carbon to soil can be considered as a method for controlling invasive alien plants (Rashid and Reshi 2010). Thus there is a need to conduct systematic research on ecological role of dominated invaders before eradication is attempted. Studies on bio-control agents of invasive plant species can be conducted for better management and control of invasive weeds. Long-term monitoring along with management and phased enlargement of managed sites for long-established invasive plant species needs to be done for effective management (Ramaswami et al. 2014).

Biological control

Invasive alien plants have an advantage over the natives because of the escape from their natural enemies of their native ranges. Thus, biological control of invasive species using co-evolved natural enemies has long been considered a safe, environmentally sound and cost effective management tool (Messing and Wright 2006). It is one method that is used either alone or in combination with other management options. Furthermore, it is often extremely successful and highly cost effective (Moran et al. 2005). About 365 species of invertebrates and fungi has been deliberately released for control of 133 weed species in 75 countries during last 150 years till 1996 (Julien and Griffiths 1998; McEvoy and Coombs

1999). However, the extent of negative impacts of the imported natural enemies on populations of non-target/native species is of greater concern (Louda et al. 2005; Zimmermann et al. 2000). Having known the benefits and possible risks of introduction of biocontrol species, management strategies should be formulated in a more comprehensive way to address the risk.

Biological control measures for three major IAPs found in IHR are shown in Table 5, which have been taken into account in many parts of the world, but not in India except for *Lantana camara*. The attempts to control infestation of *Lantana camara* biologically by introduction of pest of the species was initiated in India in 1916 (Muniappan and Viraktamath 1986). Since then various studies (Khan 1944; Muniappan and Viraktamath 1986) have been conducted to control the species by various pests (*Lantanophaga pusillidactyla, Orthezia insignis, Ophiomyia lantanae*, *Teleonemia scrupulosa* etc.), whose host is *Lantana camara.* Kumar (2015) found that *Teleonemia scrupulosa,* which was introduced to control infestation of *Lantana camara,* is yet to kill the *Lantana* in spite of good defoliation during rainy season. This is because of the fact that the eggs of this bug face heavy parasitism (up to 85%) by *Erythmelus teleonemiae* which impaired the population build up of *T. scrupulosa*.

Harnessing the potential of IAPs

While the outcomes of efforts of eradication and biological control have succeeded in limited context, various invasive species have been used by the local peoples traditionally in different purposes, including medicines to cure various ailments (Kosaka et al. 2010; Das and Duarah 2013; Sekar et al. 2015). For example, *Ageratina adenophora* is being used for the treatment of cough and cold and has been reported as an ethnomedicinal plant in 18 reports (Singh et al. 2017). Leaves of *Lantana* are rich in various active constituents that have excellent antimicrobial, fungicidal, insecticidal, nematicidal and biocidal activity, therefore useful in the preparation of various ethno-medicine (Sharma et al. 1988; Ghisalberti 2000; Saxena 2000; Sharma et al. 2007). Many invasive species are being used in various other ways. For example, stems of *Lantana camara* widely used to make furniture, decorative items and walls of houses in Uttarakhand (Chatterjee 2015). Various tribal artesian of South India are indigenously utilizing *L. Camera* for manufacturing furniture, toys and artifacts of household utility (Kannan et al. 2008; Perrings et al. 2010). Few studies (Sharma et al. 1988; Inada et al. 1997; Varshney et al. 2006) also reported use of *L. camara* in the production of commercially valuable ethanol. Therefore, a strategy for harnessing the potential of this species would establish it as an income generating source for the local people. This can be an effective way of managing the species not as a weed but a resource.

Avani, a non-governmental organization working in the Kumaon Himalaya have been using *Ageratina adenophora* for extraction of a natural dye used for colouring of traditional textile products. By way of using this plant as a dyeing agent, Avani have created financial incentives for the local communities to manage this plant. Thus the use value of these species needs to be harnessed properly which can act as an effective tool for control and management of these species. *Cannabis sativa*, also known as Hemp is an invasive plant (Sekar et al. 2012) to the IHR. Cannabis plants have been cultivated and used for thousands of years for herbal use and medications, as well as for its euphoric mood-altering effects (Maule 2015). It is a good fibre yielding plant in which fibers are contained within the tissues of the stem which help to hold it erect. The high strength and stiffness of hemp fibers makes them a useful material to be used as reinforcement in composite materials. There

Table 5 Suggested management practices for selected invasive alien plants in IHR

Target species	Management practices	References
Ageratina adenophora	Biological control; Using the species in compost combinations, using the species in preparation of dye; manual eradication	Bess and Haramoto (1959)
Parthenium hysterophorous	Biological control; manual eradication; Integrated weed management of Parthenium weed involves the combination of all available methods for its management and is considered to be the most effective approach to its long-term control	Dhileepan (2007), Adkins and Shabbir (2014)
Lantana camara	Biological control; manual eradication; chemical pesticide; preparation of furniture	Muniappan and Viraktamath (1986), Babu et al. (2009)

has been an exponential increase in the use of hemp for various applications in recent years (Shahzad 2012). The species is also used in making bio-fuel (Keller 2013). Through literature search, herbarium consultation and through local people perception it was found that several invasive species are being used for different purposes (Sekar 2012). For example, the stem of *Malvastrum coromande-lianum*, *Sesbania bispinosa*, *Sida acuta*, and *Cannabis sativa* are being used in making fibres, and *Borassus flabellifer* is being used for making Hand-held fan. Kosaka et al. (2010) found that *Ageratum conyzoides* and *Solanum carolinense* are being used in traditional medicine system, *Galinsoga quadriradiata* is used as a vegetable, and *Eichhornia crassipes* is used to improve fish growth in aquaculture in Arunachal Pradesh. Singh et al. (2016) while studying the Carbon exchange in three invasive species namely *Lantana camara, Ageratum conyzoides* and *Bidens biternata* in the Himalayan foothills found that these species together absorbed comparatively equal or even more carbon than that of mature forests. These evidences suggest that managing these species by way of harnessing their use potential can serve as a better management option in the Indian Himalayan Region.

Removal of invasive alien species on time is less risky than later interventions (Simberloff et al. 2013). Therefore, early detection of the invasive species is very crucial as it provides opportunity to implement cost-effective management. For this, a management strategy proposed by Khuroo et al. (2008) can be used and considered for Indian Himalayan region. The basic requisite for management of any alien species or the habitat they invade is (i) pridiction, which acts as an effective first line of defense, (ii) prevention of the introduced alien species to restrict them from establishment, (iii) prescription, that involves control measures that ultimately aim at mitigation of the harmful impacts of the established alien species and (iv) public awareness that includes public education and awareness campaigns, prioritization efforts and restoration plans. This framework is only found suitable, if it is implemented when the alien species of a region of interest is characterized in terms of stages of invasion as suggested by Colautti and MacIsaac (2004). Species at different stages of invasion needs different management strategy. For species that are at stage I, II and III, Prediction can be used as an effective management strategy. Prevention can be practiced when the species are in stage III & IVb. Prescription strategy can be implemented for species that are at IVa, IVb and V stage. Public awareness is a prerequisite for management of species of all stages of invasion. So, following the stage of invasion, best management strategies can be adopted to reduce the infestation by these species in natural habitats.

Research gaps

The review revealed various research gaps that need to be addressed by conducting empirical studies and opportunities that are required to be taken up by researchers to address the problem of plant invasion in the IHR under changing climate scenarios (Fig. 6). The literature search through Web of Science resulted in only 48 studies from IHR that are related to plant invasion/invasive alien plant species. This highlights the need for studies that can address the issues related to plant invasion in the region. As the stage based classification provides better insight towards prioritizing species for management, inventorization of alien flora based on their stage of invasion is a much needed research topic to be taken up for formulating better management strategies towards prevention and control of proliferation by invasive alien plants.

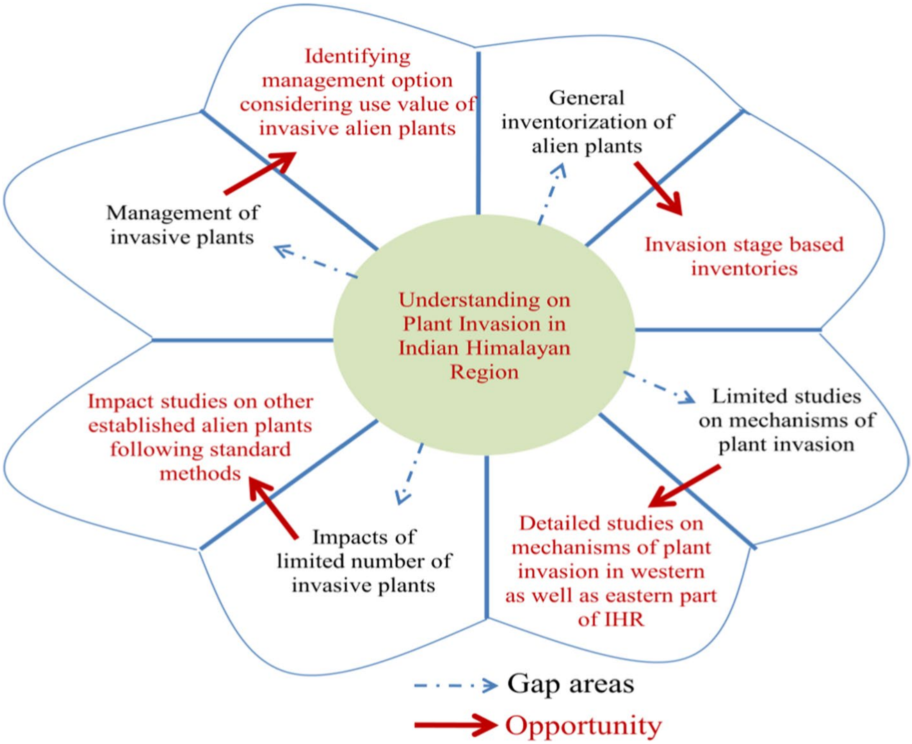

Fig. 6 Research gaps and opportunities regarding plant invasion in IHR

Pathways and mechanism of plant invasion is required to understand the nature of any invasive flora. Therefore, in-depth research on such mechanisms becomes a priority in different ecosystems and habitats. Impacts posed by invasive species on the native biodiversity and systems needs to explored more intensively using standardized methods more in natural conditions. Already established alien species requires proper management interventions by means of various strategies adopted worldwide. Towards achieving this, various species might require alternate management options. For instance, harnessing the use potential of some of these species can be adopted in future researches, so that management option can also become a mean for generating alternate livelihood for the people in the IHR.

Way forward

Considering the increasing context of 'Plant invasion' in the IHR and realizing the lack of empirical evidences on the subject from the region, there exists an opportunity to invest on empirical studies so as formulate some worthy generalizations. As > 30% of vascular plants are endemic in the Himalaya, invasion by alien species might pose a significant threat to such species and ecosystem services in IHR. The diversity and abundance of endemics and native species increases with elevation in IHR (Dhar et al. 1997; Negi et al. 2018a, b), and under changing climate proliferation of non-natives and alien invasive species is likely

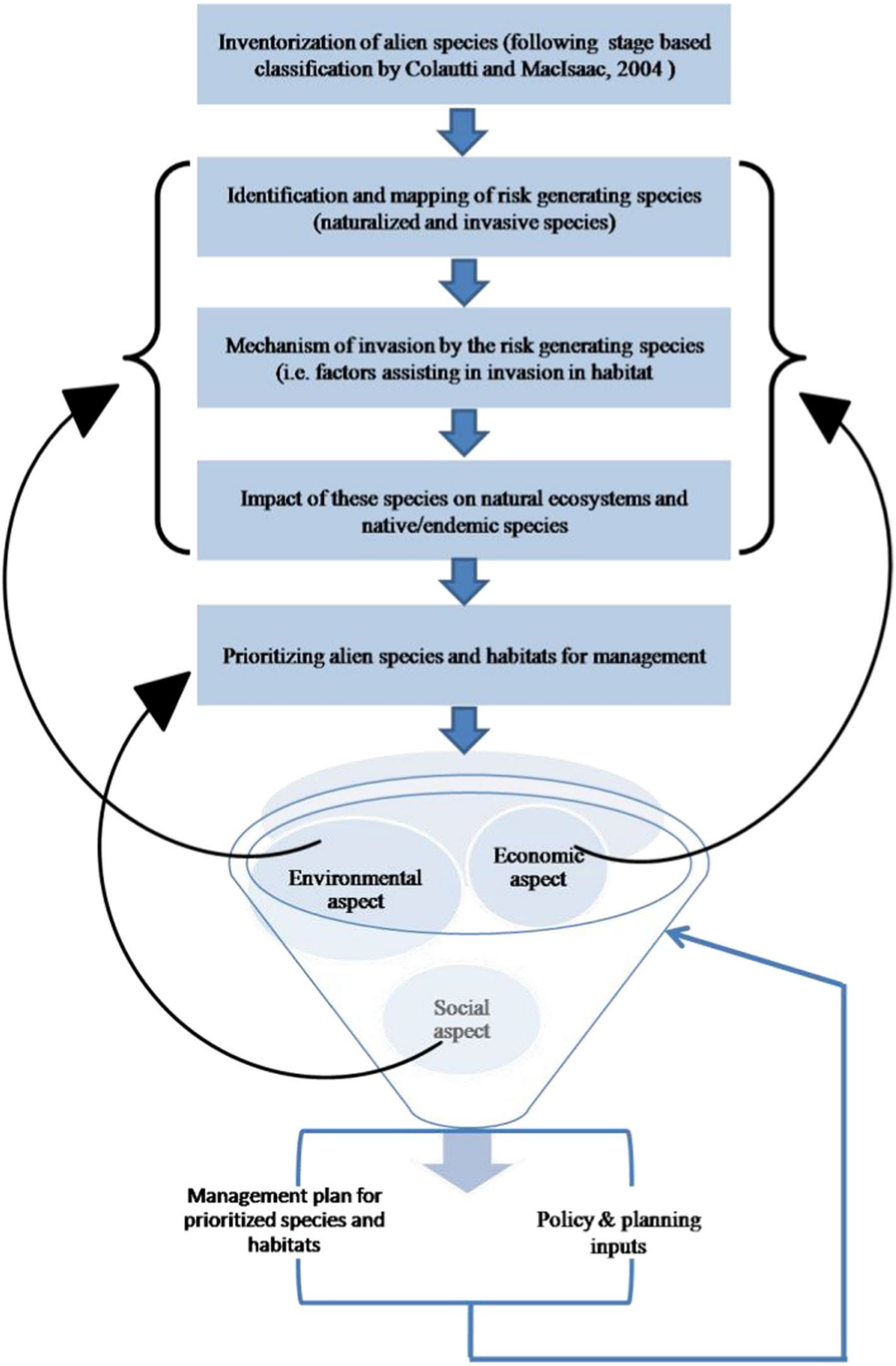

Fig. 7 Framework for conducting studies on plant invasion in IHR

to increase towards higher elevation. Therefore, it would be essential to understand pathways of invasion and likely impacts on native and endemics in higher Himalaya. Based on the review and analysis of existing knowledge, this study proposes a multistep framework (Fig. 7), for better output from the research activities on plant invasion in IHR. The first step is to make a comprehensive inventory of the alien plant species present in the region, using field based studies, consultation of herbarium, and published records from the region. This can be followed by identification of risk generating species (naturalized alien species). A detailed information, such as biology of species, mode of introduction, mechanism of spread and possible impacts can thus follow. This approach will provide better understanding about their behavior and invasion pattern, which may be useful to develop suitable strategies and management practices for particular species, area and region. The framework will also be helpful in documenting knowledge gaps and developing management planning for invasive alien species in IHR.

Conclusion

The study concludes the following: (i) in spite of the fact that IHR is having rich and unique biodiversity elements, which face severe threats under proliferation of alien species, the region is least investigated with respect to alien invasive species, (ii) the inventories available on naturalized alien plant species in IHR are grossly incomplete and lack most of the important information pertaining to status, distribution and proliferation rate; (iii) *Parthenium hysterophorus, Lantana camara, Ageratina adenophora* and *Ageratum conyzoides* are widely distributed and more rapidly proliferating alien plant species in IHR, (iv) evidences are there to suggest that alien plant species are moving upwards in higher elevations, (v) among various possible ways of management of alien invasive plant species in the region, the study emphasizes on managing such species by linking them with alternate livelihood opportunities, and (vi) a multistep framework of studies on alien invasive species in the IHR has been suggested for investment of researches in this subject across the IHR.

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References

Adhikari D, Tiwary R, Barik SK (2015) Modelling hotspots for invasive alien plants in India. PLoS ONE 10(7):e0134665

Adkins S, Shabbir A (2014) Biology, ecology and management of the invasive parthenium weed (Parthenium hysterophorus L.). Pest Management Science 70(7):1023–1029

Alexander JM, Kueffer C, Daehler CC, Edwards PJ, Pauchard A, Seipel T, Arévalo J, Cavieres L, Dietz H, Jakobs G, McDougall K (2011) Assembly of nonnative floras along elevational gradients explained by directional ecological filtering. Proc Natl Acad Sci USA 108(2):656–661

Araf M, Kumar S, Hamal IA (2010) Ant pollination of an invasive non-native weed, euphorbia geniculata ortega in North West Himalaya (India). The Bioscan 5(1):81–83

Arshid S, Wani AA (2012) Polla level. As being yen biology and stigma receptivity in *Myriophyllum spicatum* L. an invasive species in Kashmir Himalayan aquatic system. Int J Adv Life Sci 3:13–20

Babu S, Love A, Babu CR (2009) Ecological restoration of lantana-invaded landscapes in Corbett Tiger Reserve, India. Ecol Restor 27(4):467–477

Baret S, Rouget M, Richardson DM, Lavergne C, Egoh B, Dupont J, Strasberg D (2006) Current distribution and potential extent of the most invasive alien plant species on La Re´union (Indian Ocean, Mascarene islands). Austral Ecol 31:747–758

Barney JN, Tekiela DR, Barrios-Garcia MN, Dimarco RD, Hufbauer RA, Leipzig-Scott P, Nunez MA, Pauchard A, Pyšek P, Vítková M, Maxwell BD (2015) Global invader impact network (GIIN): toward standardized evaluation of the ecological impacts of invasive plants. Ecol Evol 5(14):2878–2889

Barua IC, Deka J, Devi M, Deka RL, Moran J (2017) Weeds as emerging threat to biodiversity: a consequence of spread of Ludwigia peruviana in Dhansiri and Kopili catchment areas of Assam, North East India. Curr Sci 112(9):1904–1914

Batish DR, Lavanya K, Singh HP, Kohli RK (2007) Phenolic allelo-chemicals released by *Chenopodium murale* affect the growth, nodulation and macromolecule content in chickpea and pea. Plant Growth Regul 51(2):119–128

Batish DR, Kaur S, Singh HP, Kohli RK (2009) Role of root-mediated interactions in phytotoxic interference of Ageratum conyzoides with rice (Oryza sativa). Flora-Morphol Distrib Funct Ecol Plants 204(5):388–395

Bess HA, Haramoto FH (1959) Biological control of pamakani, Eupatorium adenophorum, in Hawaii by a tephritid gall fly, *Procecidochares utilis*. 2. Population studies of the weed, the fly, and the parasites of the fly. Ecology 40(2):244–249

Bhardwaj S, Kapoor KS, Singh HP (2014) Studies on allelopathic effects of ageratina adenophora sprengel (King and Robinson) on some weed plants growing in forest ecosystem. Int J Theor Appl Sci 6(2):1

Bhatt YD, Rawat YS, Singh SP (1994) Changes in ecosystem functioning after replacement of forest by Lantana shrubland in Kumaun Himalaya. J Veg Sci 5(1):67–70

Bhuju DR, Shrestha BB, Niraula RR (2013) Study on invasive alien species (IAPS) as drivers to deforestation and degradation of forests in different physiographic regions of Nepal. BS JV API, Baneshwor-10, Kathmandu, p 60

Bradley BA, Blumenthal DM, Wilcove DS, Ziska LH (2010) Predicting plant invasions in an era of global change. Trends Ecol Evol 25(5):310–318

Bughani I, Rajwar GS (2005) Primary productivity and the impacts of the exotic weed *Eupatorium glandulosum* in a montane grassland of Garhwal Himalaya. Environmentalist 25(1):31–38

Caut S, Angulo E, Courchamp F (2009) Avoiding surprise effects on Surprise Island: alien species control in a multitrophic level perspective. Biol Invasions 11(7):1689–1703

Chakravarty AK, Mazumder T, Chatterjee SN (2011) Anti-inflammatory potential of ethanolic leaf extract of Eupatorium adenophorum Spreng through alteration in production of TNF-α, ROS and expression of certain genes. Evid-Based Complement Altern Med. https://doi.org/10.1093/ecam/neq033

Chatterjee R (2015) Impact of Lantana camara in the Indian society. Int J Environ 4(2):348–354

Colautti RI, MacIsaac HJ (2004) A neutral terminology to define 'invasive'species. Divers Distrib 10(2):135–141

Daehler CC, Carino DA (2000) Predicting invasive plants: pros-pects for general screening system based on current regional mod-els. Biol Invasions 2:93–102

Daneshgar P, Jose S (2008) Mechanisms of plant invasion. In: Kohli RK, Jose S, Singh HP, Batish DR (eds) Invasive plants and forest ecosystems. CRC Press, Taylor & Francis Group, Boca Raton, pp 11–27

Dar PA, Reshi ZA (2015) Do alien plant invasions cause biotic homogenization of terrestrial ecosystems in the Kashmir Valley, India? Trop Ecol 56(1):111–123

Das K, Duarah P (2013) Invasive alien plant species in the roadside areas of Jorhat, Assam: their harmful effects and beneficial uses. J Eng Res Appl 3(5):353–358

Datta A, Kühn I, Ahmad M, Michalski S, Auge H (2017) 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 12(11):e0187708

Dawson W, Moser D, van Kleunen M, Kreft H, Pergl J, Pyšek P, Weigelt P, Winter M, Lenzner B, Blackburn TM, Dyer EE (2017) Global hotspots and correlates of alien species richness across taxonomic groups. Nat Ecol Evol 1(7):0186
Debnath A, Debnath B (2017) Diversity, invasion status and usages of alien plant species in northeastern hilly state of Tripura: a confluence of Indo-Barman hotspot. Am J Plant Sci 8(02):212
Debnath B, Debnath A, Paul C (2015a) Diversity of invasive alien weeds in the major roadside areas of tripura and their effect and uses. J Chem Biol Phys Sci 5:3091–3102
Debnath B, Debnath A, Paul C (2015b) Diversity of invasive plant species in Trishna Wildlife Sanctuary, Tripura, NorthEast India. Life Sci Leafl 70:9–21
Devi M (2017). Invasive species mikania micrantha an environmental threat, its control with reference to ERI silk worm. In: Proceedings of 31st research world international conference, Saint Petersburg, Russia, pp 8–11
Dhar U, Rawal RS, Samant SS (1997) Structural diversity and representativeness of forest vegetation in a protected area of Kumaun Himalaya, India: implications for conservation. Biodivers Conserv 6(8):1045–1062
Dhileepan K (2007) Biological control of parthenium (Parthenium hysterophorus) in Australian rangeland translates to improved grass production. Weed Sci 55(5):497–501
Dhyani SK (1978) Allelopathic potential of Ageratina adenophora on seed germination of Lantana camara var. aculeata. Indian J For 1(4):311
Dietz H, Edwards PJ (2006) Recognition that causal processes change during plant invasion helps explain conflicts in evidence. Ecology 87:1359–1367
Dobhal PK, Batish DR, Kohli RK (2009) Phyto-sociological transformations in burnt Lantana Camara L invaded communities in context of unburnt invaded and non-invaded plant communities. The Ecoscan 3:41–45
Dobhal PK, Kohli RK, Batish DR (2010) 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 2(7):155–161
Dobhal PK, Kohli RK, Batish DR (2011) Impact of Lantana camara L. invasion on riparian vegetation of Nayar region in Garhwal Himalayas (Uttarakhand, India). J Ecol Nat Environ 3(1):11–22
Dogra KS, Sood SK (2012) 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 4(5):105–109
Dogra KS, Kohli RK, Sood SK (2009) An assessment and impact of three invasive species in the Shivalik hills of Himachal Pradesh, India. Int J Biodivers Conserv 1(1):4–10
Dogra KS, Sood SK, Sharma R (2011) Distribution, biology and ecology of *Parthenium hysterophorus* L. (congress grass) an invasive species in the North-Western Indian Himalaya (Himachal Pradesh). Afr J Plant Sci 5(11):682–687
Dukes JS, Mooney HA (2004) Disruption of ecosystem processes in western North America by invasive species. Rev Hist Nat 77(3):411–437
Ehrenfeld JG (2003) Effects of exotic plant invasions on soil nutrient cycling processes. Ecosystems 6(6):503–523
FSI (2017) State of forest report. Forest Survey of India, (Ministry of Environment & Forests), Dehradun
Ghisalberti EL (2000) Lantana camara Linn. (Review). Fitoterapia 71:467–485
Government of Sikkim (2015) Sikkim state action plan on climate change. Government of Sikkim, Gangtok, p 152
Haider S, Alexander J, Dietz H, Trepl L, Edwards PJ, Kueffer C (2010) The role of bioclimatic origin, residence time and habitat context in shaping non-native plant distributions along an altitudinal gradient. Biol Invasions 12(12):4003–4018
Hejda M, Pyšek P, Jarošík V (2009) Impact of invasive plants on the species richness, diversity and composition of invaded communities. J Ecol 97(3):393–403
Hellmann JJ, Byers JE, Bierwagen BG, Dukes JS (2008) five potential consequences of climate change for invasive species. Conserv Biol 22(3):534–543
Hobbs RJ, Huenneke LF (1992) Disturbance, diversity, and invasion: implications for conservation. Conserv Biol 6:324–337
Huddle JA, Awada T, Martin DL, Zhou X, Pegg SE, Josiah SJ (2011) Do invasive riparian woody plants affect hydrology and ecosystem processes? Great Plains Res 21:49–71
Hulme PE (2003) Biological invasions: winning the science battles but losing the conservation war? Oryx 37(02):178–193
Hulme PE (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. J Appl Ecol 46(1):10–18

Inada A, Nakanishi T, Tokuda H, Sharma OP (1997) Antitumor activities of lantadenes on mouse skin tumors and mouse hepatic tumors. Plant Med 63:476–478
Inderjit Pergl J, van Kleunen M, Hejda M, Babu CR, Majumdar S, Singh P, Singh SP, Salamma S, Rao BR, Pyšek P (2018) Naturalized alien flora of the Indian states: biogeographic patterns, taxonomic structure and drivers of species richness. Biol Invasions 20(6):1625–1638
Jaryan V, Chopra S, Uniyal SK, Singh RD (2007) Spreading fast yet unnoticed: are we in for another invasion? Curr Sci 93(11):1483
Jaryan V, Uniyal SK, Gupta RC, Singh RD (2013) Alien flora of Indian Himalayan State of Himachal Pradesh. Environ Monit Assess 185(7):6129–6153
Jaryan V, Uniyal SK, Gupta RC, Singh RD (2014) Phenological documentation of an invasive species, *Sapium sebiferum* (L.) Roxb. Environ Monit Assess 186(7):4423–4429
Jaryan V, Uniyal SK, Datta A, Gupta RC (2016) Late fruiting in *Sapium sebiferum*: an effective dispersal strategy. Trop Ecol 57(2):375–379
Jeschke J, Aparicio LG, Haider S, Heger T, Lortie C, Pyšek P, Strayer D (2012) Support for major hypotheses in invasion biology is uneven and declining. NeoBiota 14:1
Julien MH, Griffiths MW (1998) Biological control of weeds. A world catalogue of agents and their target weeds. ACIAR, Canberra
Kala CP (2004) Pastoralism, plant conservation, and conflicts on proliferation of Himalayan knotweed in high altitude protected areas of the Western Himalaya, India. Biodivers Conserv 13(5):985–995
Kandwal R, Jeganathan C, Tolpekin V, Kushwaha SPS (2009) Discriminating the invasive species, ‘Lantana’ using vegetation indices. J Indian Soc Remote Sens 37(2):275
Kannan R, Aravind NA, Joseph G, Ganeshaiah KN, Shaanker RU (2008) Lantana Craft: a weed for a need. Biotech News 3(2):9–11
Katoch R, Singh A, Thakur N (2012) Allelopathic influence of dominant weeds of North-Western Himalayan region on common cereal crops. Intl J Environ Sci 3:84–97
Kaur B, Bhatia S, Sharma KK (2014) Diversity and impact of invasive alien plant species of family Asteraceae in Jammu district (Jammu and Kashmir India). Int J Interdiscipl Multidiscipl Stud 1(8):51–62
Keller NM (2013) The legalization of industrial hemp and what it could mean for Indiana’s biofuel industry. Ind. Int’l & Comp. L. Rev. 23:555
Khan AH (1944) On the lantana bug (Teleonemia scrupulosa Stal). Indian J Entomol 6:149–161
Khanduri A, Biswas S, Vasistha HB, Rathod D, Jha SK (2017) A status of invasive alien species plant diversity in Tehri district forest ecosystem of Garhwal Himalayan Region. Curr World Environ 12(2):377
Khuroo AA, Rashid I, Reshi Z, Dar GH, Wafai BA (2007) The alien flora of Kashmir Himalaya. Biol Invasions 9(3):269–292
Khuroo AA, Reshi Z, Rashid I, Dar GH, Khan ZS (2008) Operational characterization of alien invasive flora and its management implications. Biodivers Conserv 17(13):3181–3194
Khuroo AA, Malik AH, Reshi ZA, Dar GH (2010) From ornamental to detrimental: plant invasion of *Leucanthemum vulgare*(Lan.) (Ox-eye Daizy) in Kashmir Valley, India. Curr Sci 98(5):600–602
Khuroo AA, Reshi ZA, Dar GH, Hamal IA (2012a) Plant invasions in Jammu and Kashmir state India. In: Bhatt et al (eds) Invasive alien plants: an ecological appraisal for the indian subcontinent. CABI, Wallingford, pp 216–226
Khuroo AA, Reshi ZA, Malik AH, Weber E, Rashid I, Dar GH (2012b) Alien flora of India: taxonomic composition, invasion status and biogeographic affiliations. Biol Invasions 14(1):99–113
Kirschbaum MU (2000) Forest growth and species distribution in a changing climate. Tree Physiol 20(5–6):309–322
Kohli RK, Dogra KS, Batish DR, Singh HP (2004) Impact of invasive plants on the structure and composition of natural vegetation of north western Indian Himalayas. Weed Technol 18:1296–1300
Kohli RK, Batish DR, Singh HP, Dogra KS (2006) Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lantana camara* L.) in India. Biol Invasions 8(7):1501–1510
Kosaka Y, Saikia B, Mingki T, Tag H, Riba T, Ando K (2010) Roadside distribution patterns of invasive alien plants along an altitudinal gradient in Arunachal Himalaya, India. Mt Res Dev 30:252–258
Kumar S (2015) History, progress and prospects of classical biological control in India. Indian J Weed Sci 47(3):306–320
Lake J, Leishman MR (2004) Invasion success of exotic plants in natural ecosystems: the role of disturbance, plant attributes and freedom from herbivores. Biol Conserv 117:215–226
Lamsal P, Kumar L, Aryal A, Atreya K (2018) Invasive alien plant species dynamics in the Himalayan region under climate change. Ambio. https://doi.org/10.1007/s13280-018-1017-z

Larson DL, Phillips-Mao L, Quiram G, Sharpe L, Stark R, Sugita S, Weiler A (2011) A framework for sustainable invasive species management: environmental, social, and economic objectives. J Environ Manage 92(1):14–22
Louda SM, Rand TA, Arnett AE, McClay AS, Shea K, McEachern AK (2005) Evaluation of ecological risk to populations of a threatened plant from an invasive biocontrol insect. Ecol Appl 15(1):234–249
Love A, Babu S, Babu CR (2009) Management of Lantana, an invasive alien weed, in forest ecosystems of India. Curr Sci 97(10):1421–1429
Lowry E, Rollinson EJ, Laybourn AJ, Scott TE, Aiello-Lammens ME, Gray SM, Mickley J, Gurevitch J (2013a) Biological invasions: a field synopsis, systematic review, and database of the literature. Ecol Evol 3(1):182–196
Lowry E, Rollinson EJ, Laybourn AJ, Scott TE, Aiello-Lammens ME, Gray SM, Mickley J, Gurevitch J (2013b) Biological invasions: a field synopsis, systematic review, and database of the literature. Ecol Evol 3(1):182–196
Mack RN, Simberloff D, Mark Lonsdale W, Evans H, Clout M, Bazzaz FA (2000) Biotic invasions: causes, epidemiology, global consequences, and control. Ecol Appl 10(3):689–710
Maiti GG, Bakshi DG (1981) Invasion of exotic weeds in West Bengal since 1903: dicotyledones and monocotyledones. J Econ Taxon Bot 2:1–21
Mandal G, Joshi SP (2014a) Changes in physicochemical properties of soil encourage the invasion establishment and carbon dynamics of Lantana camara from Doon Valley, Western Himalaya, India. Aceh Int J Sci Technol 3(2):87–105
Mandal G, Joshi SP (2014b) Invasion establishment and habitat suitability of Chromolaena odorata (L) King and Robinson over time and space in the western Himalayan forests of India. J Asia-Pac Biodivers 7(4):391–400
Mao AA, Gogoi R (2010) Fire-induced invasion of an endemic plant species alters forest structure and diversity: a study from north-east India. Curr Sci 98(4):483–485
Maule WJ (2015) Medical uses of marijuana (Cannabis sativa): fact or fallacy? Br J Biomed Sci 72(2):85–91
McDougall KL, Alexander JM, Haider S, Pauchard A, Walsh NG, Kueffer C (2011) Alien flora of mountains: global comparisons for the development of local preventive measures against plant invasions. Divers Distrib 17(1):103–111
McEvoy PB, Coombs EM (1999) Biological control of plant invaders: regional patterns, field experiments, and structured population models. Ecol Appl 9(2):387–401
McKee JK, Sciulli PW, Fooce CD, Waite TA (2004) Forecasting global biodiversity threats associated with human population growth. Biol Conserv 115:161–164
Messing RH, Wright MG (2006) Biological control of invasive species: solution or pollution? Front Ecol Environ 4(3):132–140
Millennium Ecosystem Assessment (2003) Ecosystems and human well-being: a framework for assessment. Island Press, Washington, DC
Millennium Ecosystem Assessment (2005) Ecosystems and Human well-being: synthesis. Island Press, Washington, DC
Moktan S, Das AP (2013) Diversity and distribution of invasive alien plants along the altitudinal gradient in Darjiling Himalaya, India. Pleione 7(2):305–313
Moran VC, Hoffmann JH, Zimmermann HG (2005) Biological control of invasive alien plants in South Africa: necessity, circumspection, and success. Front Ecol Environ 3(2):71–77
Muniappan R, Viraktamath CA (1986) Status of biological control of the weed, *Lantana camara* in India. Trop Pest Manag 32:40–42
Myers N (1993) Environmental refugees in a globally warmed world. Bioscience 43(11):752–761
Naithani HB (1987) Parthenium hysterophorus a pernicious weed in Arunachal Pradesh and Nagaland. Indian For 113:709–710
Naylor RL (2000) The economics of alien species invasions. Invasive species in a changing world. Island Press, Washington, DC, pp 241–259
Negi PS, Hajra PK (2007) Alien flora of Doon valley, Northwest Himalaya. Curr Sci 92(7):968–978
Negi GCS, Sharma S, Vishvakarma SC, Samant SS, Maikhuri RK, Prasad RC, Palni LMS (2013) *Lantana camara* in India: an ecological review. GBPIHED publication, Almora
Negi VS, Joshi BC, Pathak R, Rawal RS, Sekar KC (2018a) Assessment of fuelwood diversity and consumption patterns in cold desert part of Indian Himalaya: implication for conservation and quality of life. J Clean Prod 196:23–31
Negi VS, Kewlani P, Pathak R, Bhatt D, Bhatt ID, Rawal RS, Sundriyal RC, Nandi SK (2018b) Criteria and indicators for promoting cultivation and conservation of Medicinal and Aromatic Plants in Western Himalaya, India. Ecol Indic 93:434–446

Negi VS, Pathak R, Rawal RS, Bhatt ID, Sharma S (2019) Long-term ecological monitoring on forest ecosystems in Indian Himalayan Region: criteria and indicator approach. Ecol Indic 102:374–381

Palni LMS, Rawal RS (2013) The himalayan biodiversity: richness, representativeness, uniqueness and life-support values. G. B. Pant Institute of Himalayan Environment and Development (GBPIHED), Almora, p 84

Pandey A, Sharma GP (2013) Plant invasion researches in India: how long do we have to wait for appropriate management options? Curr Sci 104(4):408–409

Pauchard A, Kueffer C, Dietz H, Daehler CC, Alexander J, Edwards PJ, Arévalo JR, Cavieres LA, Guisan A, Haider S, Jakobs G, McDougall K, Millar CI, Naylor BJ, Parks CJ, Rew LJ, Seipel T (2009) Ain'tno mountain high enough: plant invasions reaching new elevations. Front Ecol Environ 7(9):479–486

Perrings C, Mooney H, Williamson M (2010) Bio-invasions and globalization: ecology, economics, management, and policy. Oxford University Press, Oxford, pp 1–18

Priyanka N, Joshi PK (2013) Assessment of plant invasion and forest fires linkage-a case study of *Lantana camara*. Int J Technol Enhanc Emerg Eng Res 2(10):40–46

Pyšek P, Richardson DM (2006) The biogeography of naturalization in alien plants. J Biogeogr 33(12):2040–2050

Pyšek P, Jarošík V, Hulme PE, Kühn I, Wild J, Arianoutsou M, Bacher S, Chiron F, Didžiulis V, Essl F, Genovesi P (2010) Disentangling the role of environmental and human pressures on biological invasions across Europe. Proc Natl Acad Sci USA 107(27):12157–12162

Rai PK (2015) Plant invasion ecology of an indo-Burma hot spot region along the disturbance gradient: a case study. Int Res J Environ Sci 4:108–114

Rai PK, Singh MM (2015) Lantana camara invasion in urban forests of an Indo-Burma hotspot region and its ecosustainable management implication through biomonitoring of particulate matter. J Asia-Pac Biodivers 8(4):375–381

Ramaswami G, Prasad S, Westcott D, Subuddhi SP, Sukumar R (2014) Addressing the management of a long-established invasive shrub: the case of *Lantana camara* in Indian forests. Indian For 140(2):129–136

Rashid I, Reshi ZA (2010) Does carbon addition to soil counteract disturbance-promoted alien plant invasions? Trop Ecol 51(2):339–345

Reddy CS (2008) Catalogue of invasive alien flora of India. Life Sci J 5(2):84–89

Rejmanek M (1989) Invasibility of plant communities. In: Drake JA et al (eds) Biological invasions: a global perspective. Wiley, New York, pp 369–388

Reshi Z, Rashid I, Khuroo AA, Wafai BA (2008) Effect of invasion by *Centaurea iberica* on community assembly of a mountain grassland of Kashmir Himalaya, India. Trop Ecol 49:147–156

Rogers HH, Runion GB, Prior SA, Price AJ, Torbert HA, Gjerstad DH (2008) Effects of elevated atmospheric CO_2 on invasive plants: comparison of purple and yellow nut sedge (*Cyperus rotundus* L. and *C. esculentus* L.). J Environ Qual 37(2):395–400

Samant SS, Dhar U (1997) Diversity, endemism and economic potential of wild edible plants of Indian Himalaya. Int J Sustain Dev World Ecol 4(3):179–191

Samant SS, Dhar U, Palni LMS (1998) Medicinal plants of Indian Himalaya. Gyanodaya Prakashan, Nainital

Saxena MK (2000) Aqueous leachate of Lantana camara kills water hyacinth. J Chem Ecol 26(10):2435–2447

Schweiger O, Biesmeijer JC, Bommarco R, Hickler T, Hulme PE, Klotz S, Kühn I, Moora M, Nielsen A, Ohlemüller R, Petanidou T (2010) Multiple stressors on biotic interactions: how climate change and alien species interact to affect pollination. Biol Rev 85(4):777–795

Sekar KC (2012) Invasive alien plants of Indian Himalayan region—diversity and implication. Am J Plant Sci 3(02):177

Sekar KC, Manikandan R, Srivastava SK (2012) Invasive alien plants of Uttarakhand Himalaya. Proc Natl Acad Sci India Sect B 82(3):375–383

Sekar KC, Pandey A, Srivastava SK, Giri L (2015) Invasive alien plants of Himachal Pradesh, India. Indian For 141(5):520–527

Shah MA, Reshi Z (2007) Invasion by alien *Anthemis cotula* L. in a biodiversity hotspot: release from native foes or relief from alien friends? Curr Sci 92(1):21–22

Shah MA, Reshi ZA (2014) Characterization of alien aquatic flora of Kashmir Himalaya: implications for invasion management. Trop Ecol 55(2):143–157

Shah MA, Reshi ZA, Lavoie C (2011) Predicting plant invasiveness from native range size: clues from the Kashmir Himalaya. J Plant Ecol 5(2):167–173

Shahzad A (2012) Hemp fiber and its composites: a review. J Compos Mater 46(8):973–986

Shankar U, Yadav AS, Rai JPN, Tripathi RS (2011) Status of Alien Plant Invasions in the North-eastern Region of India. In: Bhatt JR et al (eds) Invasive alien plants: an ecological appraisal for the Indian subcontinent. CABI, Wallingford

Sharma OP, Makkar HPS, Dawra RK (1988) A review of the noxious plant Lantana camara. Toxicon 26:975–987

Sharma GP, Singh JS, Raghubanshi AS (2005) Plant invasions: emerging trends and future implications. Curr Sci 88(5):726–734

Sharma OP, Sharma S, Pattabhi V, Mahato SB, Sharma PD (2007) A review of the hepatotoxic plant. *Lantana camara*. J Sci Ind Res 37:313–352

Sharma E, Molden D, Wester P, Shrestha RM (2016) The Hindu Kush Himalayan monitoring and assessment programme: action to sustain a global asset. Mt Res Dev 36(2):236–240

Sikkim Biodiversity Action Plan (2011) Sikkim Biodiversity Conservation and Forest Management Project (SBFP) Forest, Environment and Wildlife Management Department Government of Sikkim, p 44

Simberloff D (2000) Global climate change and introduced species in United States forests. Sci Total Environ 262:253–261

Simberloff D, Martin JL, Genovesi P, Maris V, Wardle DA, Aronson J, Courchamp F, Galil B, García-Berthou E, Pascal M, Pyšek P (2013) Impacts of biological invasions: what's what and the way forward. Trends Ecol Evol 28(1):58–66

Singh SP (2014) Attributes of Himalayan forest ecosystems: they are not temperate forests. Proc Indian Natl Sci Acad 80(2):221–233

Singh A, Dangwal LR (2014) Noxious weeds of district Rajouri, Jammu and Kasmir, India. World J Pharm Pharm Sci 3(10):1442–1451

Singh DK, Hajra PK (1996) Floristic diversity. Biodiversity status in the Himalaya. British Council, Delhi, pp 23–38

Singh B, Phukan SJ, Sinha BK, Singh VN, Borthakur SK (2011a) Conservation strategies for Nepenthes Khasiana in the Nokrek Biosphere Reserve of Garo Hills, Northeast, India. Int J Conserv Sci 2(1):55–64

Singh SP, Bassignana-Khadka I, Singh Karky B, Sharma E (2011b) Climate change in the Hindu Kush-Himalayas: the state of current knowledge. International Centre for Integrated Mountain Development (ICIMOD), Lalitpur

Singh HP, Batish DR, Dogra KS, Kaur S, Kohli RK, Negi A (2014) Negative effect of litter of invasive weed Lantana camara on structure and composition of vegetation in the lower Siwalik Hills, northern India. Environ Monit Assess 186(6):3379–3389

Singh TB, Das AK, Singh PK, Singh TB, Das AK, Singh PK (2015) Study of alien and invasive flora of valley district of Manipur and their control. Int J Innov Sci Technol 1:616–626

Singh N, Patel NR, Singh J, Raja P, Soni P, Parihar JS (2016) Carbon exchange in some invasive species in the Himalayan foothills. Trop Ecol 57(2):263–270

Singh A, Nautiyal MC, Kunwar RM, Bussmann RW (2017) Ethnomedicinal plants used by local inhabitants of Jakholi block, Rudraprayag district, western Himalaya, India. J Ethnobiol Ethnomed 13(1):49

Stachowicz JJ, Terwin JR, Whitlatch RB, Osman RW (2002) Linking climate change and biological invasions: ocean warming facilitates nonindigenous species invasions. Proc Natl Acad Sci USA 99(24):15497–15500

State Action Plan on Climate change: Mizoram (2012–2017) Directorate of Science and Technology, Govenrment of Mizoram

Thapa S, Chitale V, Rijal SJ, Bisht N, Shrestha BB (2018) Understanding the dynamics in distribution of invasive alien plant species under predicted climate change in Western Himalaya. PLoS ONE 13(4):e0195752

Tilman D (1999) The ecological consequences of changes in biodiversity: a search for general principles. Ecology 80(5):1455–1474

Tripathi RS (2013) Alien plant invasion and its ecological implications: an Indian perspective with particular reference to biodiversity-rich regions. In: Jose S et al (eds) Invasive plant ecology. CRC Press, Boca Raton, pp 137–146

Tripathi RS, Yadav AS (1982) Population regulation of *Ageratina adenophora* spreng and *E. riparium* regel: effect of population density, soil nitrogen and light intensity. Plant Soil 65(1):35–49

Tripathi RS, Singh RS, Rai JPN (1981) Allelopathic potential of Ageratina adenophora, a dominant ruderal weed of Meghalaya. Proc Indian Acad Sci 47(3):458–465

Tripathi RS, Kushwaha SPS, Yadav A (2006) Ecology of three invasive species of eupatorium: a review. Int J Ecol Environ Sci 32(4):301–326

Vander Zanden MJ, Hansen GJ, Higgins SN, Kornis MS (2010) A pound of prevention, plus a pound of cure: early detection and eradication of invasive species in the Laurentian Great Lakes. J Great Lakes Res 36(1):199–205
Varshney VK, Gupta PK, Naithani S, Khullar R, Bhatt A, Soni PL (2006) Carboxymethylation of a-celluloseisolated from Lantana camara with respect to degree ofsubstitution and rheological behavior. Carbohydr Polym 63:40–45
Vilà M, Weber E, Antonio CM (2000) Conservation implications of invasion by plant hybridization. Biol Invasions 2(3):207–217
Vilà M, Basnou C, Pyšek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE (2010) How well do we understand the impacts of alien species on ecosystem services? A pan-European, cross-taxa assessment. Front Ecol Environ 8(3):135–144
Vitousek PM, D'Antonio CM, Loope LL, Westbrooks R (1996) Biological invasions as global environmental change. Am Sci 84(5):468
Walther GR, Roques A, Hulme PE, Sykes MT, Pyšek P, Kühn I, Zobel M, Bacher S, Botta-Dukat Z, Bugmann H, Czucz B (2009) Alien species in a warmer world: risks and opportunities. Trends Ecol Evol 24(12):686–693
Wilcove DS, Rothstein D, Dubow J, Phillips A, Loso E (1998) Quantifying threats to imperiled species in the United States. Bioscience 48:607–615
Yurkonis KA, Meiners SJ, Wachholder BE (2005) Invasion impacts diversity through altered community dynamics. J Ecol 93(6):1053–1061
Zheng YL, Feng YL, Liu WX, Liao ZY (2009) Growth, biomass allocation, morphology, and photosynthesis of invasive Ageratina adenophora and its native congeners grown at four irradiances. Plant Ecol 203(2):263–271
Zimmermann HG, Moran VC, Hoffmann JH (2000) The renowned cactus moth, *Cactoblastis cactorum*: its natural history and threat to native Opuntia in Mexico and the United States of America. Divers Distrib 6:259–269
Ziska LH (2003) Evaluation of the growth response of six invasive species to past, present and future atmospheric carbon dioxide. J Exp Bot 54(381):395–404
Zobel DB, Singh SP (1997) Forests of Himalaya: their contribution to ecological generalizations. Bioscience 47:735–745

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