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Distribution Pattern of Dominant Invasive Alien Plants in Forests of Kumaon Region in West Himalaya

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ABSTRACT

Present study is an attempt to understand the distribution pattern of five dominant invasive alien plants in forests of the Hat-Kalika watershed in Pithoragarh district of Uttarakhand, Kumaon Himalaya. The results of the study revealed that among selected five invasive alien plants, only *Ageratina adenophora* was present in all studied forests with its highest relative density (48%) and relative abundance (22%) in Banj-oak dominated forest. *Lantana camara* was present in lower elevation forests i.e. Sal and Sal-Pine dominated forest in the region, with maximum relative density (51%) in Sal forest. *Bidens pilosa*, *Erigeron karvinskianus*, and *Oxalis corniculata* showed their highest relative density in Sal-Pine dominated, Banj-Oak, and Mixed broadleaved & conifer forest, respectively. All the species preferred high and medium level of disturbance in the studied forests. The results of the study concludes that *A. adenophora,* which formed dense populations in all studied forests should be given special attention, to control further infestation of the species in natural forests of the region. Study found that many native plant species have density close to that of invasive alien species. Therefore, these native species should be used to restore the degraded forest areas after attempting eradication of invasive alien plant species, for better forest management.

Keywords: Alien plants, Disturbance, Invasive plants, Kumaon Himalaya, Plant invasion.

INTRODUCTION

Invasive alien plant species have been seen as one of the greatest threat to the native diversity worldwide. Their increasing proliferation in new ranges has been a matter of concern for policy makers and land managers. With their capability to impart both ecological and economic losses, their management is urgently required (Early et al. 2016). The first and foremost thing, which helps in formulating management strategy for any invasive alien plant is to understand their distribution pattern in their introduced ranges (Pathak et al. 2019). Studies across various gradients like elevation and disturbance with reference to invasion of alien species can be of great importance for understanding their patterns to contribute in their management strategies or planning (Rahbek 2005). It is also well established that disturbance influences the patterns and community structure of a forest (Negi et al. 2018, Pathak et al. 2021). Assessing distribution patterns of invasive alien plant species and the level of disturbances across such gradients, thus becomes important to contribute in their management.

A lot of studies (Seipel et al. 2012, Averett et al. 2016) has been conducted all over the globe on plant invasion patterns along various gradients in mountain forests, but only few studies (which are based on secondary databases) are from the forested area of Indian Himalayan Region (Dar et al. 2018, Ahmad et al. 2018). The Himalaya, one of the global hotspot, is recognized for its ecological and economic value. More importantly, the dependence of up-land and down-stream communities on goods and services of the Himalaya make this region important candidate for action, both for maintenance and sustainable use of biological diversity (Rawal et al. 2013). Indian Himalayan region (IHR) contributes a large propotion of Himalayan Biodiversity Hotspot. The wealth of biodiversity in this region supports peoples' livelihood directly and indirectly through a range of ecosystem goods and services. Despite being one of

the biodiversity rich region, IHR lacks comprehensive understanding on biological invasion and its consequences on native biodiversity. The empirical evidences are poorly available from many parts of the region and, therefore, the management prescriptions are not available. This scenario calls for undertaking systematic investigations on biological invasions and analyzing its impact on ecology of the region.

Considering the above, the present study is an attempt to understand the pattern of alien species in the region. Considering the rich ecosystem services that the forests in the region provide and the impact that the invasion of alien species might impart on these forests, the present study aims to assess the distribution pattern of five most common invasive alien plants i.e., *Ageratina adenophora, Lantana camara, Bidens pilosa, Erigeron karvinskianus* and *Oxalis corniculata*, along elevation gradient in the forests of Kumaon region of west Himalaya. The outcome of this study are, therefore, likely to build better understanding on the impacts of plant invasion and suggesting possible management measures in the region in particular and in the IHR in general.

MATERIAL AND METHODS

Study Area

The present study area lies in the Gangolihat area of Pithoragarh district in Uttarakhand, which is a part of Kumaon Himalaya, which is rich in biophysical and socio-cultural diversity and forms a part of Kailash Sacred Landscape. The intensive study sites were selected in a representative watershed namely, Hat-Kalika, that encompasses various forest types, representative to this region. The watershed, with a total of 45 villages, covers an approximate area of 37 km^2. The forest vegetation in the study area ranges from subtropical Sal (*Shorea robusta*) to temperate Banj-oak (*Quercus leucotrichophora*) forests with a number of intermixing types of forests in between. Major canopy forming species in the watershed are *S. robusta, Pinus roxburghii, Q. glauca* (in some patches), *Q. leucotrichophora* and *Cedrus deodara*. Also, open grazing, collection of fodder and removal of fuelwood from forests, persistently make these forests prone to disturbance and invasion by alien species (Joshi and Negi 2011).

Vegetation Sampling

Based on the preliminary study conducted at 135 locations in the study area, five most common invasive alien plants i.e., *Ageratina adenophora, Bidens pilosa, Erigeron karvinskianus, Lantana camara,* and *Oxalis corniculata* were selected for the study based on occurrence of these species in forests of the watershed. Towards intensive investigation, study was conducted during 2017-2018 in peak growing season (June-August). Forest sites were selected at every 200 m asl difference in the study area. Six forest sites were selected along the identified gradient (900-1900 m; Table 1). At any given elevational point, one village was selected, and the forest around the village was considered for detailed analysis.

Intensity of disturbance was determined on the basis of cut stumps intensity, lopping intensity, grazing intensity in each plot following Rawal et al. (2012), Murali et al. (1996), and Saxena and Singh (1984). Based on these parameters disturbance intensity was calculated following Rawat (2013) and disturbance gradients were categorized as High (when disturbance intensity is > 60%), Medium (when disturbance intensity is 31-60 %), and Low

Table 1. Geo-coordinates and major vegetation type in the selected study sites

S. No.	Site name	Latitude	Longitude	Elevation (m asl)	Dominant species	Distance from road (km)
1	Bursam	29.624465	80.104263	900	*Shorea robusta*	2.0
2	Kanara	29.628624	80. 096222	1100	*Shorea robusta* and *Pinus roxburghii*	1.5
3	Jarmal Gaon	29.631479	80.086078	1300	*Pinus roxburghii*	0.5
4	Bhandari Gaon	29.630545	80.077783	1500	*Quercus leucotrichophora*	1
5	Hat-Kalika	29.658441	80.046886	1700	*Quercus leucotrichophora* and *Cedrus deodara*	0.5
6	Guptadi	29.687670	80.055345	1900	*Quercus leucotrichophora*	0.1

(when disturbance intensity is < 30%). At each forest three plots of 50 X 50 m were laid (one at each disturbance gradient) and within each plot five 10 X 10 m quadrat were laid for trees and sapling, four 2 X 2 m quadrat for shrub and seedlings, and ten 1 X 1 m for herbs. Data was analyzed for obtaining density, Abundance and their relative values following Misra (1968) and Muller-Dombois and Ellenberg (1974). Nativity of a species is in terms of native of Himalayan region. For determining the nativity of a species Samant et al (1998) was followed. Species distribution was calculated by calculating abundance (A) and frequency (F) ratio for each selected species following Cottam and Curtis (1956); regular when A/F ratio is < 0.025, random when A/F ratio is 0.025-0.05, and contagious when A/F ratio is >0.05.

RESULTS AND DISCUSSION

Floristic diversity

The total plants recorded from the study area were 76, representing 38 families and 68 genera across the entire annual cycle. Asteracea was the dominant family with most number of species (13 no.) followed by Rosaceae (7), Fabaceae (6) and Lamiaceae (6). Out of total species, 39 species were native and 37 species were non-native to Himalayan region. Total species richness across the annual cycle ranged between 22 – 42, and was highest (42) at Mixed broadleaved and conifer forest (1900 m asl) and was recorded lowest (22 each) for Sal forest and Sal- Pine forest at 900 and 1100 m asl, respectively. Tree species richness ranged between 1 – 9 and was recorded maximum (9) in Mixed broadleaved and conifer forest, with *Quercus leucotrichophora* and *Cedrus deodara* as the dominant trees and lowest (1) in Chir-Pine forest, where only *Pinus roxburghii* was found. Shrub species richness ranged between 5 – 14 and was maximum (11) for Mixed broadleaved and conifer forest and lowest (5) for Chir-Pine forest and Sal-Pine forest. Herb species richness ranged between 11 – 21 and was found highest (21) in Banj-Oak- Deodar forest (1700 m asl) and lowest (11) for Sal forest.

Distribution pattern of invasive alien plant species along elevation gradient

Ageratina adenophora

In the study area, the species was found to be present in all forests with its maximum relative abundance (22 %) and relative density (48 %) in Banj-Oak

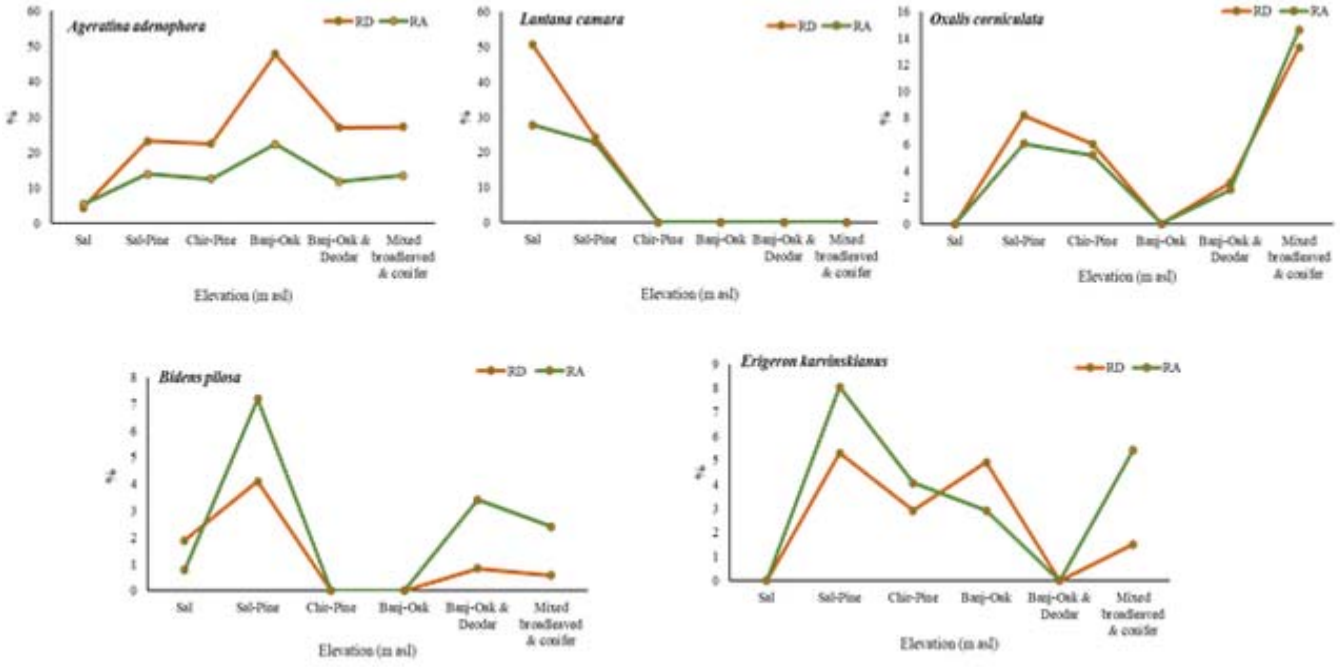

Figure 1. Relative Density (RD) and Relative Abundance (RA) of selected invasive alien plants in forests of the study area.

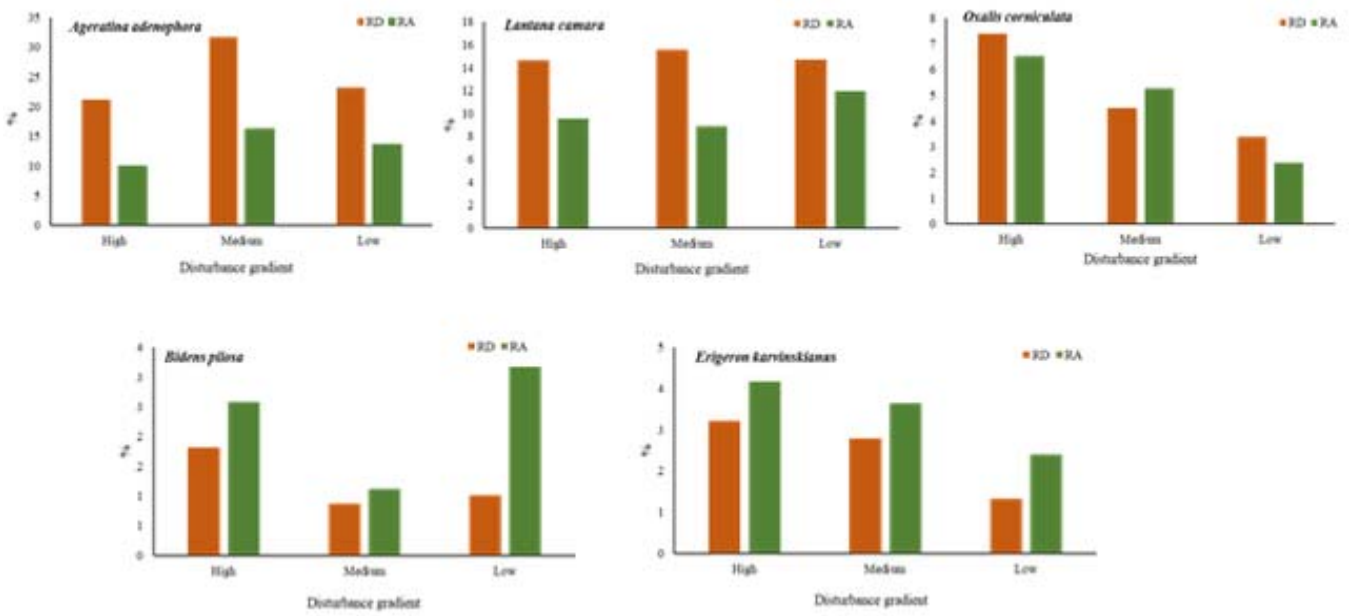

Figure 2. Relative Density (RD) and Relative Abundance (RA) of selected invasive alien plants along the disturbance gradient in the study area.

forest. The species has its lowest relative abundance (5%) and relative density (4 %) in Sal dominated forest. The relative density and relative abundance of the species was found to be highest (32 % and 16 %, respectively) at medium disturbance gradient (Fig 1 & 2). In all forests the average density of the species ranged between 756 and 36933 individual/hectare (ind/ha), with its highest density recorded from Banj-Oak forest and lowest from Sal forest. The species showed contagious distribution in all the elevations, which shows that the species is present in patches all along the study area.

Lantana camara

In the watershed, the species is limited to lower elevations in the forested ecosystem, however, it is present along roadsides upto 1600 m. The species has its highest relative abundance (27.72 %) and relative density (50.65 %) in Sal forest, where it dominates the shrub layer. The species preferred middle and low disturbance area in the study site with its high relative density and relative abundance, respectively (Figs. 1 & 2). The species was not recorded from Chir-Pine, Banj-Oak, Banj-Oak & Deodar, and Mixed broadleaved & conifer forests in the study site, however, its highest density (3167 ind/ha) was recorded in Sal forest. The species showed contagious distribution in Sal forest and random distribution in Sal-Pine dominated forest.

Oxalis corniculata

Oxalis corniculata in the study region was distributed in higher and lower elevations, and was not recorded from middle elevation sites. The species has its relative density and relative abundance highest (15.20 % and 13.60 %) in Mixed broadleaved & conifer forest. The species has its highest relative density and abundance in the high disturbance areas in the study transect. The values for RD and RA of the species decreased with decreasing level of disturbance (Figs. 1 & 2). The density of the species ranged from 0 ind/ha in Sal forest and Banj-Oak forest to 10167 ind/ha in Mixed broadleaved & conifer forest. The species showed random distribution at in Sal-Pine dominated, Chir-Pine, and Banj-Oak & Deodar dominated forest, while in Mixed broadleaved & conifer forest, it showed contagious distribution.

Bidens pilosa

The species in the study site was distributed in all forests, except for in Chir-Pine and Banj-Oak forest, with its highest relative density (4 %) and relative abundance (7 %) in Sal-Pine dominated forest. The species was mostly recorded from the high and mid disturbance gradient, with maximum RD and RA in

high disturbance gradient and low disturbance respectively (Figs. 1 & 2). The density of the species ranges from 0 ind/ha in Chir-Pine forest and Banj-Oak forest to 1367 ind/ha in Sal-Pine dominated forest. The distribution of the species was regular in Sal forest and contagious in Sal-Pine, Banj-Oak & Deodar, and Mixed broadleaved and conifer forest.

Erigeron karvinskianus

The species was mostly present in high and medium disturbance region, except in Sal-Pine dominated forest, where it was present in low disturbance gradient. The species has its highest RD and RA at high disturbance gradient (3 % and 4%, respectively). The values of RD and RA were highest at Sal-Pine dominated forest and was absent in Sal forest and Deodara forest in the study transect (Figs. 1 & 2). The density of the species ranged from 0 ind/ha in Sal forest and Banj-Oak & Deodar forest to 5534 ind/ha in Banj-Oak forest. The species showed random distribution in Banj-Oak forest and contagious distribution in Sal-Pine dominated, Chir-Pine, and Mixed broadleaved & conifer forest.

Invasive alien plants have created serious threats to the native biodiversity all over the globe, whether it is aquatic, island or terrestrial ecosystems (Vilà et al. 2011). In the IHR, various species are known to be proliferating at a great pace and are imparting threats to the native plants, crops and species composition and forest dynamics as whole (Dobhal et al. 2010, Lodhiyal et al. 2016). But, most of these species are not those that invade forested landscapes. Therefore, present study focused on the distribution pattern of invasive alien plants invaded in forest ecosystems. *Ageratina adenophora* is one of the most aggressive invasive alien species proliferating in south Asia, east Asia, south-east Asia, South Africa and eastern coast of Australia (Muniappan et al. 2009). The species attributed to its wide elevational distribution, is successful in invading varied habitats (Datta et al. 2017). The elevational range of this species varies from 300 – 2900 m asl in the Himalayan region (Sekar 2012), with high probability of occurrence of the species between 1000-1600 m asl (Datta et al. 2017). In the present study, the species was found in all the elevations along elevational gradients with its highest RD and RA at 1500 m asl (Banj-Oak forest). The species preferred medium disturbance areas. In a recent study, Thapa et al (2020) have found that canopy disturbance (low canopy cover) promotes the cover of the species, i.e., lower the canopy cover, higher would be the cover of *Ageratina adenophora*. If we see the overall distribution, the species shows an increasing trend of RD and RA with increasing elevation. Our finding is consistent with the findings of Chaudhary et al. (2019), which reported similar trends along elevation for the species with higher invasion at 1700-1900 m asl. Higher values of relative density and abundance of the species in Banj-Oak might be the species prefers moist and mild climate for its optimum growth (CABI 2021).

Lantana camara is one of the most widely distributed invasive alien species in the world and is still widening its range. The species has become key threat to the western Himalayan forest, thus biodiversity over the past few years. The distribution of the species depends on the level of disturbance in a particular forest (Mandal and Joshi 2014, Mungi et al. 2018); the species generally is limited to 2000 m asl elevation (Sekar et al. 2012). *Lantana camara* prefers tropical and subtropical open areas, riverine areas, forest edges and degraded forests for proliferation (Thapa et al. 2018). In the study transects, the species was present only in the lower elevation forests i.e., Sal and Sal-Pine mixed, which were most disturbed. The species preferred all kinds of disturbance classes; however had its high RD and RA at medium and low level of disturbance respectively in the present study.

Oxalis corniculata is one among several largely distributed plants in the world and has been known as the third largely distributed vascular plant (Pysek et al. 2017). The species is constantly been associated with the anthropogenic disturbances, but is not as strong competitor as many other invasive plants (Groom et al. 2019). The results of the study shows that the RD and RA of the species is increasing (not significant) with the elevation, however beyond 2000 m asl the species is known to have decreased values in the IHR (Bisht and Bhat 2013). The species showed higher values of RD and RA in highly disturbed forest stand; similar findings are also reported from Garhwal Himalaya (Kumar et al 2004). *Bidens pilosa* has successfully invaded many parts of the world especially in subtropical tropical and

temperate regions (Bartolome et al 2013). In the Himalayan region, the species is expected to expand upwards by 680 metres from its current elevational range (Thapa et al. 2018). In the study transects, the species was found in the lower elevations and absent in the middle elevations. Highest RD and RA values for the species were recorded from 1100 m asl, which is a Pine and Sal dominated forest. The high values of the above mentioned parameters in these forests might be due to the fact that the species prefers open areas to flourish and Sal and Pine forest in the study area provides the suitable condition for the species with presence of more canopy gap. Disturbance has also played an important role in determining the distribution of the species.

Erigeron karvinskianus is an invasive species, native to Mexico and Central America, now widely distributed all over the world (Shrestha and Shrestha 2019). Tolerating a broad range of environmental condition the species can grow profusely in any open habitat (CABI 2020), and primarily invades agricultural ecosystems in the Himalayan region (Thapa et al 2018). The species is expected to expand its elevational range by 980 m asl upwards from its current elevational range (677 to 2566 m asl), by 2050 (Thapa et al. 2018). In the study area, the species was present abundantly in lower and middle elevation zones, and in all type of disturbance regimes, with dense and abundant population at high disturbance gradient. The higher values of RD and RA of the species at lower elevations and at the highest elevation might be due to high canopy disturbance that created open spaces for the species to flourish well and proliferate.

Across the study sites, various native species were recorded that have densities and relative densities close to that of the invasive alien species. These plants can be used to restore the invaded forests after eradication of these species from the forests. For instance, at lower elevation where *Lantana camara* was more proliferative, species like *Cajanus scarabaeoides*, *Indigofera heterantha*, *Inula cappa*, and *Senecio nudicaulis* can be used to restore the forest after eradication of *L. camara*. At middle and higher elevations, native species like *Ajuga parviflora, Valeriana jatamansi, Pyracantha crenulata, Himalrandia tetrasperma, Galium elegans*, *Thalictrum foliolosum*, and *Urtica parviflora* can be seen as potential plants for restoration after eradication of *Ageratina adenophora*, which is most prevalent in the study area. These identified species are, apart from being native to the region are also useful in many ways especially in form of medicine and wild edible (Bhatt et al. 2017).

CONCLUSIONS

The results of the study conclude that forests habitats in the study region are being invaded by noxious invasive alien plants species. These species are preferring disturbed forest areas, especially highly and moderately disturbed areas due to increased lopping and grazing in these forests. It is required to minimize the disturbances in the forests, so as to check the infestation of invasive alien plants. Native plant species that have densities and relative densities closer to that of the invasive alien plant species should be used to restore the degraded forest areas. This could serve as a better management option for restoring invaded forest habitats in the region. The study suggests that out of the 5 studied species *Ageratina adenophora* is the only species that was widely present in all the study sites. Therefore, it calls for an urgent need to manage the proliferation of this species in particular and other alien species in the biodiversity rich forested ecosystems in the region, through developing appropriate management planning and strategies.

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REFERENCES

Ahmad, M., Uniyal, S.K., and Singh, R.D. 2018. Patterns of alien plant species richness across gradients of altitude: analyses from the Himalayan state of Himachal Pradesh. Tropical Ecology, 59(1), 35-43.

Averett, J.P., McCune, B., Parks, C.G., Naylor, B.J., DelCurto, T. and Mata-González, R. 2016. Non-native plant invasion along elevation and canopy closure gradients in a middle Rocky Mountain ecosystem. PloS one, 11(1), p.e0147826.

Bartolome, A.P., Villaseñor, I.M. and Yang, W.C. 2013. *Bidens pilosa* L.(Asteraceae): botanical properties, traditional uses, phytochemistry, and pharmacology. Evidence-based complementary and alternative medicine, 2013.

Bhatt, I.D., Rawat, S., Badhani, A. and Rawal, R.S. 2017. Nutraceutical potential of selected wild edible fruits of the Indian Himalayan region. Food chemistry, 215, 84-91.

Bisht, A.S. and Bhat, A.B. 2013. Vegetational structure and plant diversity relation in a sub-alpine region of Garhwal Himalaya, Uttarakhand India. African Journal of Plant Science, 7(8), 401-406.

CABI. 2020. Datasheet: *Erigeron karvinskianus*. Centre for Agriculture and Bioscience International. https://www.cabi.org/isc/datasheet/114202. Accessed on 11.10.2020.

CABI. 2021. Invasive species compendium. Datasheet: *Ageratina adenophora*. https://www.cabi.org/isc/datasheet/23243#tosummaryOfInvasiveness. Accessed on 11.08.2021.

Chaudhary, A., Adhikari, B.S., Joshi, N.C. and Rawat, G.S. 2019. Patterns of invasion by crofton weed (*Ageratina adenophora*) in Kailash sacred landscape region of western Himalaya (India). Environment Conservation Journal, 20(3), 9-17.

Cottam, G. and Curtis, J.T. 1956. The use of distance measures in phytosociological sampling. Ecology, 37(3), 451-460.

Dar, P.A., Reshi, Z.A. and Shah, A.B. 2018. Altitudinal distribution of native and alien plant species along roadsides in Kashmir Himalaya, India. Tropical Ecology, 59(1), 45-55.

Datta, A., Kühn, I., Ahmad, M., Michalski, S. and 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), p.e0187708.

Dobhal, P.K., Kohli, R.K. and Batish, D.R. 2010. Evaluation of the impact of *Lantana camara* L. invasion, on four major woody shrubs, along Nayar river of Pauri Garhwal, in Uttarakhand Himalaya. International Journal of Biodiversity and Conservation, 2(7), 155-161.

Early, R., Bradley, B.A., Dukes, J.S., Lawler, J.J., Olden, J.D., Blumenthal, D.M., Gonzalez, P., Grosholz, E.D., Ibañez, I., Miller, L.P. and Sorte, C.J. 2016. Global threats from invasive alien species in the twenty-first century and national response capacities. Nature communications, 7(1), 1-9.

Groom, Q.J., Van der Straeten, J. and Hoste, I. 2019. The origin of *Oxalis corniculata* L. PeerJ, 7, p.e6384.

Joshi, G. and Negi, G.C. 2011. Quantification and valuation of forest ecosystem services in the western Himalayan region of India. International Journal of Biodiversity Science, Ecosystem Services & Management, 7(1), 2-11.

Kumar, M., Rajwar, G.S. and Sharma, C.M. 2004. Disturbance and dynamics in a sub-tropical forest of Garhwal Himalaya. Bulletin of the National Institute of Ecology, 14, 43-50.

Lodhiyal, N., Gupta, S., Lodhiyal, L.S., Kapkoti, B. and Bhakuni, N. 2016. Assessment of ecological parameters of crofton weed along the road-side forests of Kumaun Himalaya. Indian Journal of Weed Science, 48(4), 410-416.

Joshi, S.P. 2014. The Role of Habitat Types and Soil Physicochemical Properties in the Spread of a Non Native Shrub Lantana Camara in the Doon Valley, Western Himalaya, India. Journal of Environmental Geography, 7(3-4), 31-42.

Mishra, R. 1968. Ecology Work Book. Oxford and IBH Publishing Co. New Delhi, 242pp.

Mueller-Dombois, D. and Ellenberg, D. 1974. Aims and methods of vegetation ecology. New York: Wiley, 547pp.

Mungi, N.A., Coops, N.C., Ramesh, K. and Rawat, G.S. 2018. How global climate change and regional disturbance can expand the invasion risk? Case study of *Lantana camara* invasion in the Himalaya. Biological Invasions, 20(7), 1849-1863.

Muniappan, R., Raman, A. and Reddy, G.V. 2009. *Ageratina adenophora* (Sprengel) King and Robinson (Asteraceae). Biological control of tropical weeds using arthropods, pp. 63-73.

Murali, K.S., Shankar, U., Shaanker, R.U., Ganeshaiah, K.N. and Bawa, K.S. 1996. Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India. 2. Impact of NTFP extraction on regeneration, population structure, and species composition. Economic Botany, 50(3), 252-269.

Negi, V.S., Joshi, B.C., Pathak, R., Rawal, R.S. and Sekar, K.C. 2018. Assessment of fuelwood diversity and consumption patterns in cold desert part of Indian Himalaya: implication for conservation and quality of life. Journal of Cleaner Production, 196, 23-31.

Pathak, R., Negi, V.S., Rawal, R.S. and Bhatt, I.D. 2019. Alien plant invasion in the Indian Himalayan Region: state of knowledge and research priorities. Biodiversity and Conservation, 28(12), 3073-3102.

Pathak, R., Thakur, S., Negi, V.S., Rawal, R.S., Bahukhandi, A., Durgapal, K., Barola, A., Tewari, D. and Bhatt, I.D. 2021. Ecological condition and management status of Community Forests in Indian western Himalaya. Land Use Policy, 109, 105636.

Pyšek, P., Pergl, J., Essl, F., Lenzner, B., Dawson, W., Kreft, H., Weigelt, P., Winter, M., Kartesz, J., Nishino, M. and Antonova, L.A. 2017. Naturalized alien flora of the world. Preslia., 89(3), 203-274.

Rahbek, C. 2005. The role of spatial scale and the perception of large scale species richness patterns. Ecology letters, 8(2), 224-239.

Rawal, R.S., Bhatt, I.D., Sekar, K.C. and Nandi, S.K. 2013. The Himalayan Biodiversity: Richness, Representativeness, Uniqueness and Life-support Values. GB Pant Institute of Himalayan Environment and Development (GBPIHED), Kosi-Katarmal, Almora, Uttarakhand, India, 84pp.

Rawal, R.S., Gairola, S. and Dhar, U. 2012. Effects of disturbance intensities on vegetation patterns in oak forests of Kumaun, west Himalaya. Journal of Mountain Science, 9(2), 157-165.

Rawat, B.S. 2013. Changes in vegetation diversity and plant response in Nanda Devi Biosphere Reserve over the last two decades. Ph.D. Thesis, Kumaun University, Nainital, India.

Samant, S.S., Dhar, U. and Palni, L.M.S. 1998. Medicinal Plants of Indian Himalaya. Gyanodaya Prakashan, Nainital.

Saxena, A.K. and Singh, J.S. 1984. Tree population structure of certain Himalayan forest associations and implications concerning their future composition. Vegetatio, 58(2), 61-69.

Seipel, T., Kueffer, C., Rew, L.J., Daehler, C.C., Pauchard, A., Naylor, B.J., Alexander, J.M., Edwards, P.J., Parks, C.G., Arevalo, J.R. and Cavieres, L.A. 2012. Processes at multiple scales affect richness and similarity of non native plant species in mountains around the world. Global Ecology and Biogeography, 21(2), 236-246.

Chandra, S. 2012. Invasive alien plants of Indian Himalayan region—diversity and implication. American Journal of Plant Sciences, 3(02), 177-184.

Sekar, K.C., Manikandan, R. and Srivastava, S.K. 2012. Invasive alien plants of Uttarakhand Himalaya. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences, 82(3), 375-383.

Shrestha, U.B. and Shrestha, B.B., 2019. Climate change amplifies plant invasion hotspots in Nepal. Diversity and Distributions, 25(10), 1599-1612.

Thapa, L.B., Kaewchumnong, K., Sinkkonen, A. and Sridith, K. 2020. "Soaked in rainwater" effect of Ageratina adenophora on seedling growth and development of native tree species in Nepal. Flora, 263, 151554.

Thapa, S., Chitale, V., Rijal, S.J., Bisht, N. and Shrestha, B.B. 2018. Understanding the dynamics in distribution of invasive alien plant species under predicted climate change in Western Himalaya. PloS one, 13(4), .e0195752.

Vilà, M., Espinar, J.L., Hejda, M., Hulme, P.E., Jarošík, V., Maron, J.L., Pergl, J., Schaffner, U., Sun, Y. and Pyšek, P. 2011. Ecological impacts of invasive alien plants: a meta analysis of their effects on species, communities and ecosystems. Ecology Letters, 14(7), 702-708.

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