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Patterns of invasion by crofton weed (*Ageratina adenophora*) in Kailash sacred landscape region of western Himalaya (India)

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Abstract

Invasion of alien species in high altitude ecosystems is a potent threat to the species diversity as well as it can cause severe environmental and economic issues. The invasion of alien plant species can be facilitated by many eco-climatic factors. The present study was conducted to assess patterns and trends of invasion by *Ageratina adenophora* in major land use and land cover types; in Gokerneshwergad watershed of Kailash Sacred Landscape (KSL) in western Himalaya. Extensive surveys were conducted to map the species in each season and habitat type. Sites with high biotic pressure and open forest canopy were the most suitable habitats for its growth. A negative correlation was found between distribution and altitude. The highest invasion was recorded in between 1700 – 1800m elevation gradient, between 20° and 30° slope positions and at North (33.33%), whereas, the lowest invasion was recorded between 700 – 800m in South-East directions (3.70%). Several other parameters such as distance from the disturbance site such as road, villages or settlements, drainage and soil texture were also found to be affecting the distribution pattern of this species. Interestingly results reveal that the alien plants also start competing among themselves after reaching their threshold level.

Key Words: ***Invasive alien species, watershed, Kailash Sacred Landscape, biodiversity, Himalaya***

Introduction

Invasive alien species are those which become established in natural or semi-natural ecosystems or habitats, an agent of change and threaten native biological diversity (IUCN, Guidelines for the prevention of biodiversity loss caused by alien invasive species, 2000). Invasive plant species can cause important economic, environmental and social losses, either introduced deliberately or accidentally to different parts of the world (Anderson, 2005). Plant diversity around the world is facing various threats and is reducing very rapidly (Dogra *et al.,* 2009). Local studies have shown that invasive plant species can directly or indirectly affect the food security of residents. In areas where they spread, invasive can destroy natural pasture, displace native trees, and reduce the grazing potential of rangelands (Admasu, 2008). After the habitat loss, the invasion of alien plant species has become the second-highest threat to plant diversity (Hobbs and Humphries, 1995) in the new regimes. It may be due to invasive species have many important adaptation techniques as compared to native plants as faster rates of growth and biomass production compared to native species, high reproductive efficiency including production of a large number of seeds, higher efficient dispersal, competitive ability, rapid establishment, vegetative reproduction, and several other factors that help them adapt to new habitats (Sharma *et al.,* 2005; Simberloff *et al.,* 2005) and broader range of tolerance (Walther, *et al.,* 2009; IUCN, 2013). Preventing or tackling biological invasions at a very early stage is considered as the most efficient and cost-effective approach (Brunel, *et al.,* 2013). This demand awareness of the threats they pose, preventive measures to stop new invasions and control of those species that have already invaded the ecosystems. Some of the widely spread and documented invasive plant species all over the world are *Ageratina adenophora, Lantana camara, Parthenium hysterophorus* and *Bidens pilosa*. Himalaya being the youngest mountains on earth are very well known for their vast biodiversity due to which they become one of the best sites for the study of climate change on the earth. It has been observed that species of higher elevations are projected to shift higher, due to which few invasive alien plant species which were earlier limited to the lower areas are now shifting towards the higher

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altitudinal areas of Himalaya (Telwala *et al.,* 2013). About 50% of the alien species are intentionally introduced in the Himalaya (Sekar and Manikandan, 2012) and others came through trade and gain imports. In India the studies on invasive plants and their invasions is still missing, except a few studies, mainly on the specific locations listing (Myers *et al.,* 2000; Reddy, 2008; Singh *et al.,* 2010; Sekar and Manikandan, 2012) ecological status (Jaryan and Singh, 2013; Sharma *et al.,* 2012; Adhikari and Tiwary, 2015; Saxena, 1993; Bhatt *et al.,* 1994; Negi and Hajra, 2007) comprehensive studies on invasive species and plant invasions are still missing except a few studies (Singh *et al.,* 2008; Myers *et al.,* 2000).

Climate change may increase the opportunities for introduction and spread of alien invasive plants (Kriticos *et al.,* 2010; IUCN, 2017). Despite the recognition of the impacts caused by invasive plants worldwide (Mooney and Hobbs, 2000), there are still many regions in the world where basic information on naturalized plant taxa and plant invasions is only superficial or completely lacking like Asia and neighbouring regions (Corlett, 1988; Enomotto, 1999). Therefore, an urgent need was felt to study implications of climate and environmental change on distribution and abundance of major invasive alien species in the Himalayan region along with the impact assessment and management of such species.

Study area

The study was carried out in Gokerneshwergad watershed, a part of Kailash Sacred Landscape (KSL) in Pithoragarh district of Uttarakhand state, India (**Fig. 01**). The topography of the study area is hilly with an interspersion of different type of forests, agricultural fields; fallow land ranging from 600 to 2200m. The climate is mild and generally warm. The summers have much more rainfall when compared with winter. The average temperature is 25 °C. The rainfall here averages 1263 mm. (USIDCL 2012). The total area of the watershed under study was calculated using Arc GIS and was found to be 31.93 Km^2.

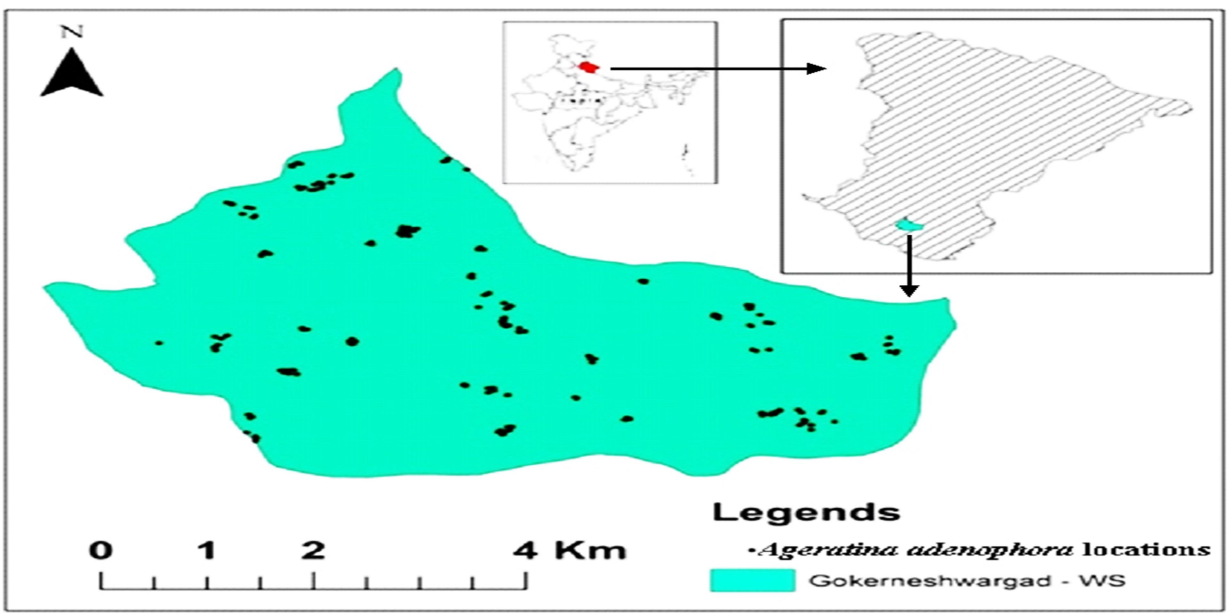

Fig 1. Study area and distribution map of *Ageratina adenophora at* Gokerneshwergad watershed of KSL-India

Materials and method

Site selection was conducted based on the intensive reconnaissance survey of the Gokerneshwer gad watershed depending on the availability of the alien plant species, i.e. *Ageratina adenophora* (Syn. *Eupatorium adenophorum*). Intensive field surveys were conducted during January to April 2016 to record the maximum patches of invasion by

Ageratina adenophora in adjoining areas of 20 villages in Gokerneshwer gad watershed covering forests, fallow lands, agricultural lands and grasslands.

The invasion of *Ageratina adenophora* was also discussed with the local communities and based on the group discussions patches in each village were identified and classified based on the population intensity of selected species such as dense, moderate or sparse. Following the participatory mapping of species-specific, a rapid ecological assessment was carried out in 41 different patches. 229 random quadrates of 1x1m^2 were laid in the identified patches in the watershed. The number of individual of *Ageratina adenophora* and its clumps were recorded in each plot. The density of *Ageratina adenophora* was calculated following the method proposed by Misra (Misra, 1968).

Results and Discussion

Elevation, aspect, and slope are considered the three main topographic factors responsible for the distribution and patterns of vegetation in mountain areas (Titshall, O'Connor and Morris, 2000). Therefore, these topographic factors (aspect, elevation and slope) of the region were created from a digital elevation model. Euclidean distance from road and water source was prepared in Arc GIS-L1, and cover types, important geological layers such as soil textures were also prepared. Several other parameters such as distance from the disturbance site and watershed and land cover type were also found to be important that control the distribution and pattern of *Ageratina adenophora*. The results of the current study are illustrated as follows:

The area of invasion was least in Godiyagaon (485 m^2) followed by Bhurmuni village (613 m^2) whereas, the maximum invasion was recorded in Dhyuree (5370 m^2). The maximum density of *Ageratina adenophora* was recorded in Jajroli (203/m^2) followed by Mostmanu (230.83/m^2), and the lowest value (62.25/m^2) was recorded in Bhurmuni (Fig 2). Out of 41 patches surveyed; maximum patches were recorded in the boundaries of Bichcot, Jagtar and Naini villages (04) whereas, the lowest number of patches were recorded in Malliseem, Sinchora, Sintoli, Dhooga Bhool, Bhurmuni, Mostmanu, Sanghar, Jajroli, Godiya Gaon (01 each).

The density of *Ageratina adenophora* was also calculated in different ecosystems of the study area. As per our study, the maximum density of *Ageratina adenophora* in the fallow land was recorded in GodiyaGaon (248/m^2), whereas, the minimum density was recorded in Bichcot village, which was 95.87/m^2. In case of invasion of agriculture land, the maximum density was recorded in Chera village (196.75/m^2), whereas, the minimum was recorded from Jagtar village (70.5/m^2). Chera village has a maximum invasion of *Ageratina adenophora* (200.7/m^2) in terms of density in forest whereas; minimum (62.7/m^2) was recorded in Bhurmuni village (Fig 3).

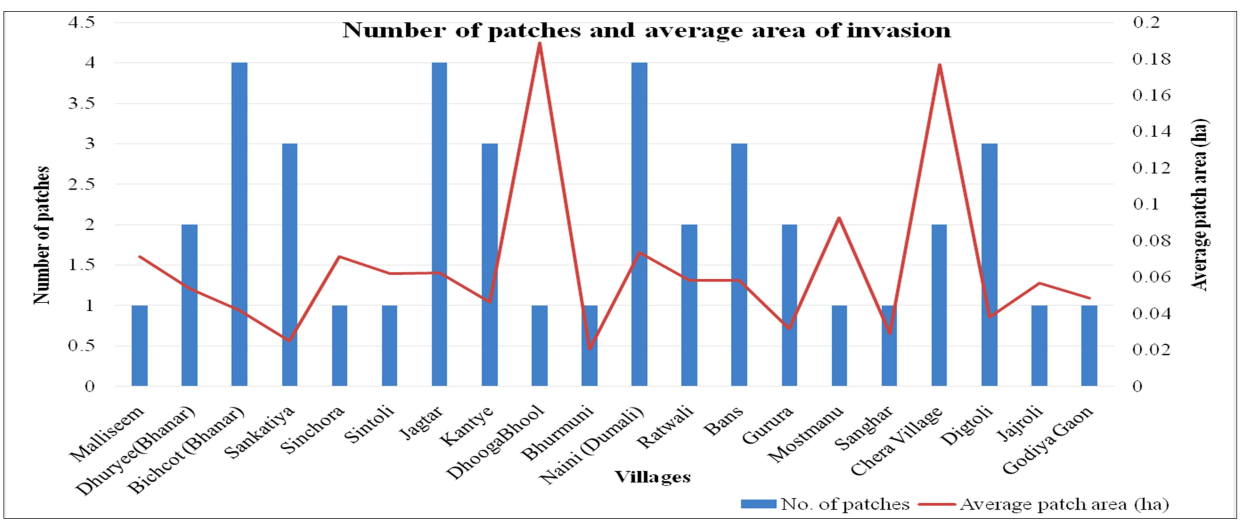

Fig 2. *Ageratina adenophora* invasion in different villages of Gokerneshwer-gad watershed

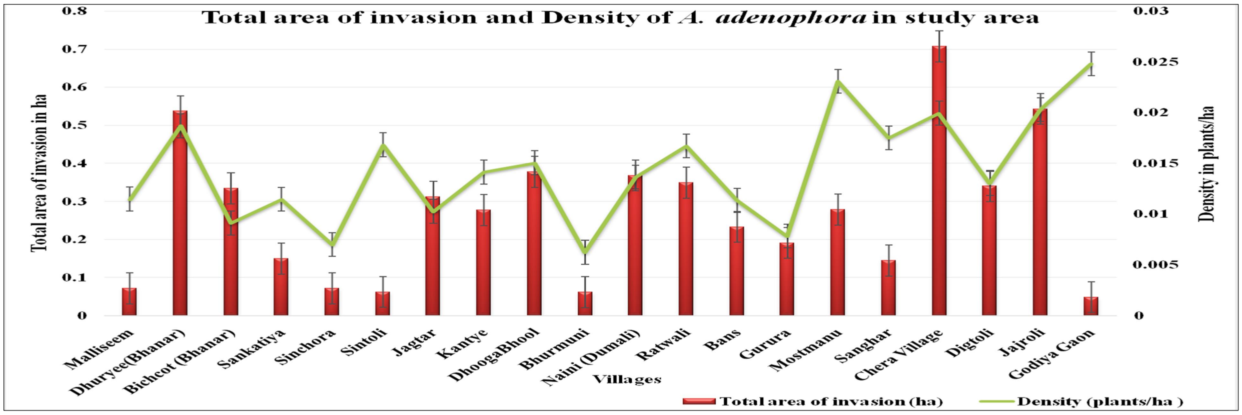

Fig 3. Density of *Ageratina adenophora* in different ecosystem (village wise) of Gokerneshwer-gad watershed

In terms of area, fallow lands had a maximum area of invasion followed by Agricultural land and grassland whereas, highest patch density was observed in most of the grasslands and agricultural lands of Gokerneshwer-gad watershed. The various ecological parameters which affected the distribution of *Ageratina adenophora* were as follows:

1. **Slope:** Slopes of landforms control the amount of rainwater accumulation. Within this region, the maximum presence of *Ageratina adenophora* was observed between 20°and 30° slope positions (Fig 4) as it requires moderate slope steepness for more stability. Slope (Titshall *et al.,* 2000) has also been reported to be one of the important parameters for invasive species distribution.
2. **Distance from road:** The results suggest that the distance from the road was inversely proportional to the growth of Ageratina adenophora invasion in the study area as the highest invasion (41.39%) was observed at roadsides (Fig 5). Similar patterns were also observed by various other workers in other ecosystems (Tyser and Worley, 1992; Parendes and Jones, 2000; Watkins *et al.,* 2003). Our results were also in line with (Kosaka, *et al.,* 2010) and (Bhattarai *et al.,* 2014), who reported that plant invasion in mountainous regions of India and Nepal was facilitated by road construction and the distribution varied with altitude.
3. Land use cover type: The maximum occurrence of Ageratina adenophora (Fig 6) was recorded in the fallow land (69.97%) followed by grassland (18.67%), agriculture (9.10%) and forest (2.26%). The success of invasive alien plants is due to their opportunistic exploitation of anthropogenic disturbances, the absence of natural enemies, and frequently, higher dispersal rate and competitive ability, (Kunwar, 2003; Simberloff *et al.,* 2005; Sharma *et al.,* 2005; Simberloff *et al.,* 2005; Simberloff *et al.,* 2005).
4. **Distance from water source**: Invasive plants have a major impact on catchment hydrology, (Geldenhuys, 1986) reported 30-70% lower water runoff from watershed areas with dense stands of alien species this was also supported by our results (Fig 7) as maximum presence of *Ageratina adenophora* (82%) was recorded near the water bodies (secondary and tertiary tributaries).
5. **Aspect:** A community strongly affected by aspect and this appears in the species distribution at special aspects. *Ageratina adenophora* was recorded highest at North (33.33%) followed by North-West (24.53%), South-West (11.57%), South (9.25%), West (8.79%), East (4.62%), North-East (4.16%) and lowest invasion was recorded in South-East (3.70%). Most of *Ageratina adenophora* was concentrated on the North and North-West direction, which gives the species more sheltered conditions (Fig 8).

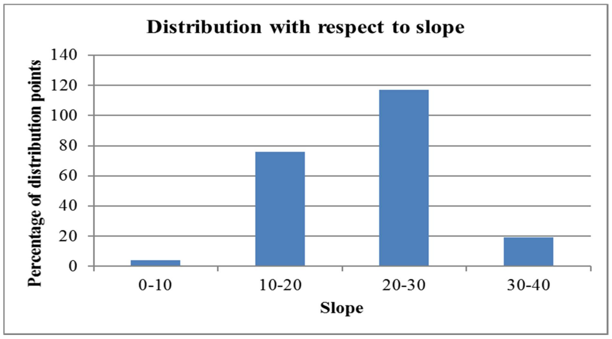

Fig 4. *Ageratina adenophora* distribution with respect to slope.

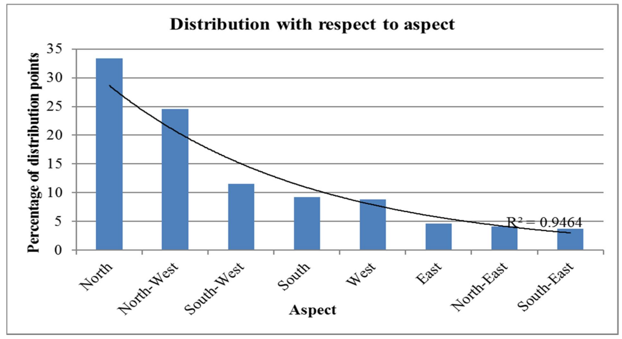

Fig 8. *Ageratina adenophora* distribution with respect to the aspect.

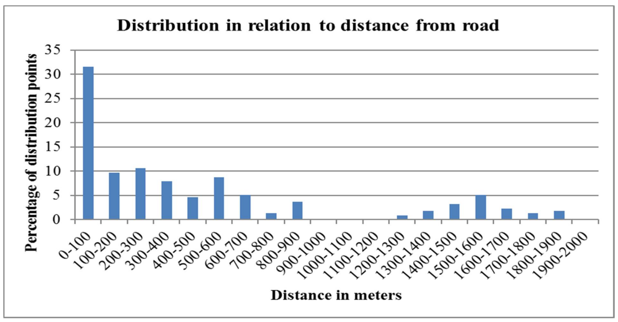

Fig 5. *Ageratina adenophora* distribution with respect to distance from the road.

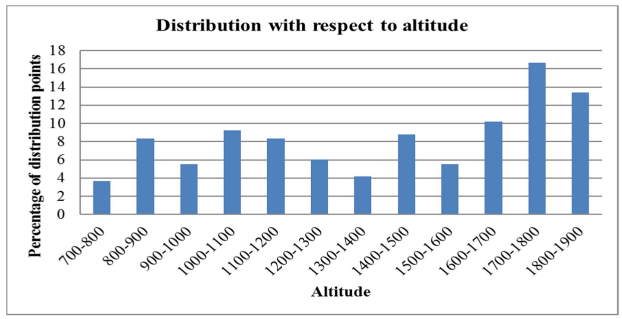

Fig 9. *Ageratina adenophora* distribution with respect to altitude.

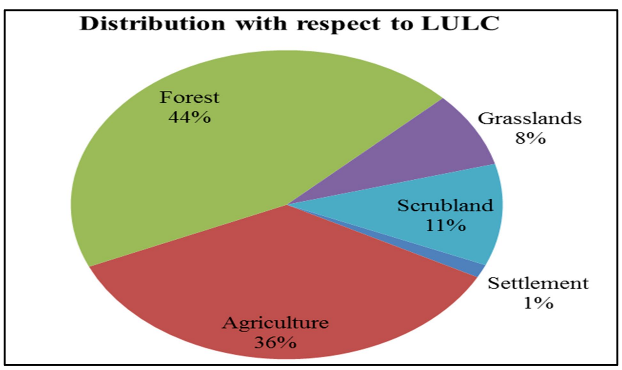

Fig 6. Distribution of *Ageratina adenophora* with respect to *LULC.*

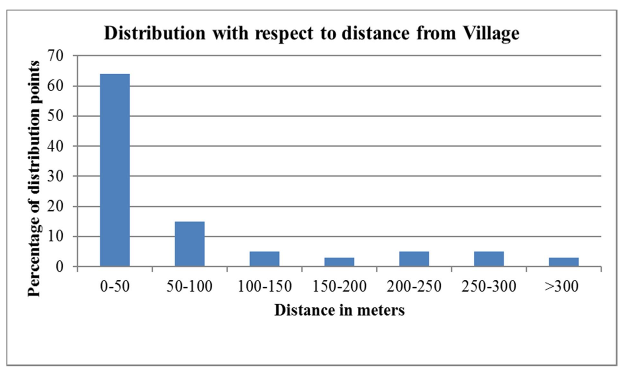

Fig 10. *Ageratina adenophora* distribution with respect to distance from the village

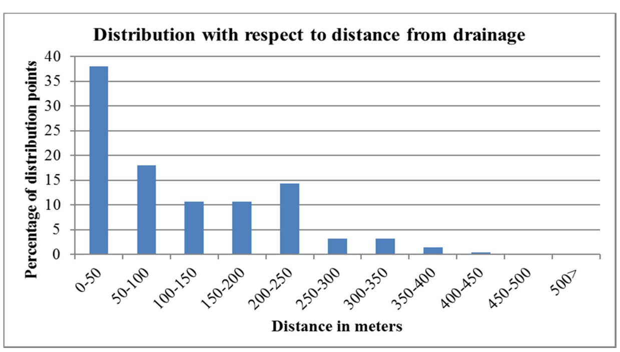

Fig 7. Distribution of *Ageratina adenophora* with respect to distance from the water source.

6. **Elevation:** A elevation determines the microclimate of an area; thus, it also determines the large-scale spatial distribution and patterns of vegetation (Busing *et al.,* 1992). The relationship was further confirmed when the distribution and altitude maps were superimposed by GIS. It was observed that the highest *Ageratina adenophora* invasion (16.66%) was in between 1700 – 1800m elevation gradient and the lowest presence (3.70%) detected between 700 – 800m (Fig 9).

7. **Distance from the village:** During the study, it was noticed that the abundance and occurrence of Ageratina adenophora were inversely proportional to the distance from the village or disturbance site. As we moved away from the villages, less density and abundance of Ageratina adenophora was recorded (Fig. 10). Both natural and direct anthropogenic disturbances are known to promote invasion of exotic species (Hobbs and Huenneke, 1992) (Lozon and MacIsaac, 1997); (D'Antonio *et al.,* 1999). Thus it could be concluded that the disturbance or anthropogenic activities are favourable for the distribution of Ageratina adenophora.

The number of clumps of Ageratina adenophora was found to be negatively correlated with the digital elevation (DEM) thus altitude plays an important role in distribution of this alien plant species and number of clumps was negatively correlated with mean number of plants per clump indicating that more the density of clumps lesser is the number of plants per clump in an area. Thus it may also be said that after acquiring an area, the species is competing to itself. A very interesting correlation was found between the environmental and ecological variables with the total clumps, total plants and mean number plants per clump of Ageratina adenophora in the study area (Table 1).

The PCA shows a negative correlation between the clumps of *Ageratina adenophora* and altitude, indicating that the number of clumps of *Ageratina adenophora* decreases with increase in altitude whereas it also decreases with increase in distance from drainage and soil texture (Fig 11). A negative correlation of clumps to mean number of plants per clump was also found suggesting that as the number of clumps increase in an area, the mean number of plants per clump decreases which further indicates that after reaching a threshold level the alien plants start competing among themselves. Similarly, a positive correlation was found between total clumps and total *Ageratina adenophora* plants in the study area. On the other hand, a positive correlation was also found between the mean number of plants per clump and distance from road and village/settlements suggesting that this plant species prefer to remain in clumps as it moves away from the disturbance sites. The total number of clumps also increased with the decline in distance from the drainage suggesting that this species prefer habitats which are moist to dry habitats. Thus availability of water source is also one of the important factors in distribution of this alien plant species although it does not require more fertile land to grow as a negative correlation was found between total number of clumps of this plant species and soil texture.

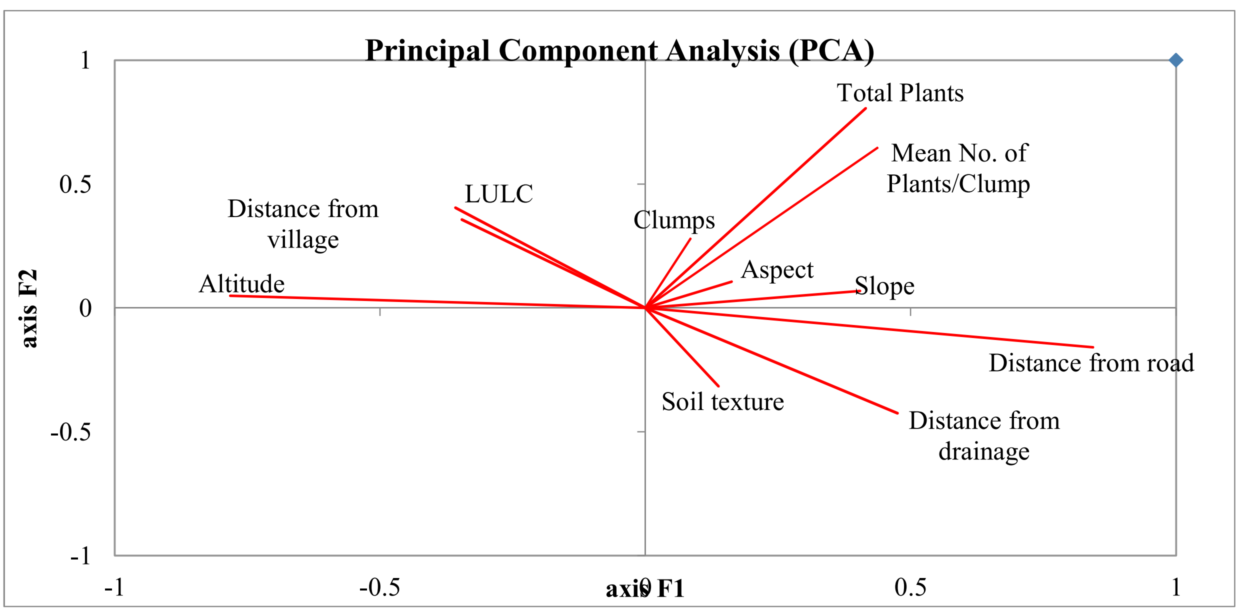

Fig 11. Factors responsible for distribution and invasion of *Ageratina adenophora*

Table 1.Correlation between various factors and variables responsible for the distribution of *Ageratina adenophora*

	slope	**Altitude**	**Distance from village**	**Distance from road**	**Aspect**	**Distance from drainage**	**Soil texture**	**LULC**	**Clumps**	**Total Plants**	**Mean No. of Plants/Clump**
Slope	1	**-0.345**	0.120	**0.238**	**0.176**	0.074	0.044	-0.020	0.081	0.061	0.041
Altitude	**-0.345**	1	**0.343**	**-0.674**	**-0.178**	**-0.187**	**0.152**	0.102	**-0.165**	-0.133	-0.107
Distance from village	0.120	**0.343**	1	-0.080	0.003	-0.112	**-0.209**	**0.294**	0.011	0.001	-0.005
Distance from road	**0.238**	**-0.674**	-0.080	1	0.121	**0.495**	0.094	**-0.250**	0.004	**0.146**	**0.208**
Aspect	**0.176**	**-0.178**	0.003	0.121	1	-0.057	-0.047	**0.134**	0.058	0.010	-0.035
Distance from Drainage	0.074	**-0.187**	-0.112	**0.495**	-0.057	1	0.097	**-0.157**	**-0.156**	-0.098	0.035
Soil texture	0.044	**0.152**	**-0.209**	0.094	-0.047	0.097	1	**-0.262**	**-0.140**	0.009	0.036
LULC	-0.020	0.102	**0.294**	**-0.250**	**0.134**	**-0.157**	**-0.262**	1	-0.028	0.012	-0.012
Clumps	0.081	**-0.165**	0.011	0.004	0.058	**-0.156**	**-0.140**	-0.028	1	**0.320**	**-0.237**
Total Plants	0.061	-0.133	0.001	**0.146**	0.010	-0.098	0.009	0.012	**0.320**	1	**0.779**
Mean No. of Plants/Clump	0.041	-0.107	-0.005	**0.208**	-0.035	0.035	0.036	-0.012	**-0.237**	**0.779**	1

In bold, significant values (except diagonal) at the level of significance alpha=0.050 (two-tailed test)

Conclusion

Plant invasions in the new areas cause huge economic and ecological imbalance by altering native community composition, depletion of species diversity thus affecting the ecosystem process. The increased incidence of invasion in high altitudinal ecosystems possesses a major threat to the indigenous biological diversity of the region. The results indicate that four environmental variables viz. altitude; soil texture, distance from disturbance site such as road and village/settlement as well as a water source as the distance from nearest drainage, play a major role in the distribution and invasion of *Ageratina adenophora*. This species prefers and occupies such habitats which are degraded, disturbed and the habitats where the anthropogenic pressure is much higher than other habitat types in any ecosystem and does not require much fertile land to invade. Some serious mitigation techniques and measures are required to check the further distribution of this alien species in the western Himalayan region as this species was recorded up to an elevation of about 2100 masl. The further distribution of this alien species in the Himalayan region may cause a serious threat to the local biodiversity and a change in ecosystem process of the area causing loss of vital ecosystem services.

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References

Adhikari, D. and Tiwary, R.A. 2015. Modelling Hotspots for Invasive Alien Plants in India. ***PLoS ONE,*** 10(7): 1-20 e0134665. Doi: 10.1371/journal. pone.0134665.

Admasu, D. 2008. Invasive Plants and Food Security: the case of Prosopis juliflora in the Afar region of Ethiopia. *IUCN: Farm Africa*, 1-13.

Anderson, S. 2005. *Spread of the Introduced Tree Species Prosopis juliflora (Sw.) DC in the Lake Baringo Area, Kenya.* Institutionen for Skoglif Vegetationsekologi, SLU (Swedish Agricultural University), UMEA, Sweden.

Bhatt, Y.D., Rawat, Y.S. and and Singh, S.P. 1994. Changes in ecosystem functioning after replacement of forest by Lantana shrubland in Kumaun Himalaya. ***Journal of Vegetation Science***, 5: 67-70.

Bhattarai, K.R., Måren, I.E. and Subedi, S.C. 2014. Biodiversity and invasibility: Distribution patterns of invasive plant species in the Himalaya. ***Nepal J Mt Sci,*** 11: 688-696.

Brunel, S., Galiano, E.F., PieroGenovesi, E., Vernon, H., Heywood, V. H. and Kueffer, C. A. 2011. Invasive alien species: a growing but neglected threat? *In:* ***Late lessons from early warnings: science, precaution, innovation***, 486-508.

Busing, R., White, P.S. and Mac Kende, M. 1992. Gradient analysis of old spruce-fir forest of the Great Smokey Mountains circa 1935. ***Canadian Journal of Botany,*** 71, 951-958.

Corlett, R.T. 1988. The naturalized flora of Singapore. ***Journal of Biogeography, 15***, 657-663.

D'Antonio, C.M., Dudley, T.L. and Mack, M.C. 1999. Disturbance and biological invasions: direct effects and feedbacks in Ecosystems of disturbed ground. ***Elsevier,*** 413-452.

Dogra, K.S., Kohli, R.K. and Sood, S.K. 2009. An assessment and impact of three invasive species in the Shivalik hills of Himachal Pradesh, India. *International* ***Journal of Biodiversity and Conservation,*** 1(1): 4-10.

Enomotto, T. 1999. *Naturalized Weeds from Foreign Countries into Japan.* National Institute of Agro-Environmental Science, Tsukuba, Biological invasion of ecosystem by pests and beneficial organisms, 1-14.

Geldenhuys, C. J. 1986. *Costs and benefits of the Australian Blackwood Acacia melanoxylon in South African forestry.* Cape Town: Oxford University Press, Macdonald IAW, The ecology and management of biological invasions in southern Africa.

Hobbs, R. and Huenneke, L.F. 1992. Disturbance, diversity and invasion: implications for conservation. ***Conservation Biology,*** 6: 324–337.

Hobbs, R. and Humphries, S. 1995. An integrated approach to the ecology and management of plant invasions. ***Conservational Biology,*** 9:761-770.

IUCN. 2000. *Guidelines for the prevention of biodiversity loss caused by alien invasive species.* Report Prepared by the SSC (Invasive Species Specialist Group) and approved by the 51st meeting of the IUCN council, Gland Switzerland, February, 2000. Retrieved from https://portals.iucn.org/library/efiles/documents/Rep-2000-052.pdf

IUCN. 2013. *Impact Assessment of Invasive Plant Species in Selected Ecosystems of Bhadauretamagi VDC, Kaski. An Ecosystem-based Adaptation in Mountain Ecosystem in Nepal.*

IUCN. 2017. *Invasive alien species and climate change.* Retrieved from Invasive alien species and climate change: https://www.iucn.org/sites/dev/files/ias_and_climate_change_issues_brief_final.pdf

Jaryan, V.U. and Singh, R.D. 2013. Alien flora of Indian Himalayan state of Himachal Pradesh. ***Environ Monit Assess,*** *185*(7): 6129-53doi: 10.1007/s10661-012-3013-2.

Kosaka, Y., Saikia, B., Mingki, T., Tag, H., Riba, T. and and Ando, K. (2010). Roadside distribution patterns of invasive alien plants along an altitudinal gradient in Arunachal Himalaya. ***BioOne, India Mt Res Dev,*** 30:252-258, https://doi.org/10.1659/MRD-JOURNAL-D-10-00036.1.

Kriticos, D.J., Sutherst, R.W., Brown, J.R., Adkins, S.W. and M., A.A. 2003. Climate change and the potential distribution of an invasive alien plant: Acacia niloticassp. indica in Australia. ***Journal of Applied Ecology,*** 40:111-124.

Kunwar, R.M. 2003. Invasive alien plants and Eupatorium: Biodiversity and livelihood. ***Himalayan Journal of Sciences,*** 1(2):129-133.

Lozon, J. D. and MacIsaac, H. J. 1997. Biological invasions: are they dependent on disturbance? ***Environmental Reviews,*** 5: 131–144.

Masters, G. and Norgrove, L. 2010. *Climate change and invasive alien species.*

Misra, R. 1968. *Ecology Work Book.* Calcutta: Oxford and IBS Publishing Company.

Mooney, H.A. and Hobbs, R.J. 2000. The exotic flora of Rajasthan. ***Journal of Economic and Taxonomic Botany,*** 18(1): 105-121.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Fonseca, G. A. and Kent, J. 2000. Biodiversity hotspots for conservation priorities. ***Nature,*** 403:853-858.

Negi, P.S. and and Hajra, P.K. 2007. Alien flora of Doon valley, Northwest Himalaya. ***CurrSci,*** 92 (7), 968-78.

Parendes, L.A., and Jones, J.A. 2000. Role of light availability and dispersal in exotic plant invasion along roads and streams in the H. J. Andrews Experimental Forest, ***Oregon. Conserv. Biol,*** 14: 64 –75.

Reddy, C. 2008. Catalogue of invasive alien flora of India. ***Life Science Journal,*** 5(2): 84-89.

Saxena, S.K. 1993. Ecology of Prosopis juliflora in the arid regions of India. *Proceedings of conference Prosopis Species in the Arid and Semi-Arid Zones of India.* Jodhpur, Rajasthan, India.: Central Arid Zone Research Institute.

Sekar, K. and Manikandan, R.A. 2012. Invasive alien plants of Uttarakhand Himalaya. ***Proc Natl Acad Sci., India - Section B,*** 82: 375-383.

Sharma, G.P. and and Raghubanshi, A.S. 2012. Invasive Species: Ecology and Impact of Lantana camara Invasions. In S. J. Bhatt JR (Ed.), *Invasive alien plants: an ecological appraisal for the Indian subcontinent* (pp. 19-42). CABI Wallingford UK.

Sharma, G.P., Singh, J.S. and Raghubanshi, A.S. 2005. Plant invasions: Emerging trends and future implications. ***Current Science,*** 88: 726-734.

Simberloff, D., Parker, I.M. and Windle, P.M. 2005. Introduced species policy, management and future implications. ***Frontiers in Ecology and environment,*** 3: 12-20.

Singh, K., Shukla, A. and S. J. 2010. State-level inventory of invasive alien plants, their source regions and use potential. ***Current Science,*** 90(1): 107-114.

Telwala, Y., Brook, B.W., Manish, K., and Pandit, M.K. 2013. Climate-Induced Elevational Range Shifts and Increase in Plant Species Richness in a Himalayan Biodiversity Epicentre. ***PLoS ONE,*** (2): 1-8. e57103. doi:10.1371/journal. pone.0057103.

Titshall, L.W., O'Connor, T.G., and Morris, C.D. 2000. Effect of long-term exclusion of fire and herbivory on the soils and vegetation of sour grassland. ***African Journal of Range and Forage Science,*** 17: 70-80.

Tyser, R.W., and Worley, C.A. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana, USA. ***Conserv. Biol.,*** 6: 253-262.

Walther, G., Roques, A., Hulme, P., Sykes, M., Pysûk, P. and Kühn, I. Z. 2009. Alien species in a warmer world: Risks and opportunities. ***Trends in Ecology and Evolution,*** 24(12): 686-693.

Watkins, R.Z., Chen, J.Q., Pickens, J. and Brosofske, K.D. 2003. Effects of forest roads on understory plants in a managed hardwood landscape. ***Conserv. Biol,*** 17: 411-419.