Effects of Invasive Alien Plant Species (IAPS) on Native Plant Species in Three Different Altitudinal Range: A Case Study of Five Community Forests of Jajarkot District

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Abstract

Invasive Alien Plant Species (IAPS) pose significant threats to biodiversity and ecosystem services, particularly in ecologically sensitive regions like Nepal. This study investigates the distribution and ecological impacts of IAPS across altitudinal gradients in the Jajarkot district, with a focus on forest ecosystems and agricultural landscapes. Field surveys employing quadrat plots identified four dominant IAPS, notably *Ageratina adenophora* and *Bidens pilosa*, which were more distributed across altitudes. Biodiversity indices, such as the Shannon-Weiner index, indicated impact of IAPS in distribution of native species. The Importance Value Index (IVI) revealed IAPS dominance at lower altitudes, contributing to reduce in frequency of native species and ecosystem destabilisation. The spread of IAPS was closely linked to human disturbances, decreased canopy cover and increased IAPS cover suggesting that these factors may facilitate, their upward expansion under changing environmental conditions. Our study had uneven plot distribution and a research focus on community forest as a limitations. The findings underscore the urgent need for integrated IAPS management. Strategies should prioritise targeted interventions, including community engagement, sustainable forest management practices, and policy reforms, to mitigate IAPS spread and safeguard biodiversity along altitudinal gradients.

Keywords: Invasive alien plant species, biodiversity, altitudinal gradient, community forest, forest management

INTRODUCTION

Invasive Alien Plant Species (IAPS) represent a significant ecological challenge globally, threatening biodiversity hotspots and impacting various ecosystems, particularly in regions such as Asia, Africa, South and Central America, and Europe (IBPES 2019). This threat is exacerbated by human activities, including global trade, increased travel, and climate change, which facilitate the spread of invasive species, disrupting natural habitats and ecological balance (Shrestha *et al.* 2017). Species from the Asteraceae family, such as *Ageratina adenophora, Eupatorium adenophorum,* and *Ageratina riparia*, have emerged as aggressive invaders, causing habitat alteration and biodiversity loss in tropical and subtropical regions (Mccary *et al.* 2016).

In Nepal, a country heavily reliant on resource-based livelihoods, the impact of IAPS on ecosystems and agricultural productivity is particularly pronounced (Shrestha *et al.* 2017). Nepal is home to 29 IAPS (Sharma *et al.* 2020; Shrestha and Shrestha 2021; Shrestha *et al.* 2021). Four species (*Chromolaena odorata, Pontederia crassipes, Lantana camara and Mikania micrantha*) from the listed IAPS are among the 100 worst invasive species in the world (GoN 2019). Native species which was only imported a century ago and had time to evolve and adapt in the local climate more than IAPS as a result of human activity and impact of IAPS are seen less in numbers (Zhang *et al.* 2015). IAPS are seen to migrate upwards to higher altitude from lower altitude in response to the climate change, trade, tourism and anthropogenic disturbances altering both native floral and faunal species composition (Cramer *et al.* 2014). It has been critical to track their potential response along the changing environment (Cramer *et al.* 2014 ; Thapa *et al.* 2018).

Climate change, coupled with anthropogenic disturbances, further exacerbates the problem, particularly in mountainous regions where controlling invasive species presents unique challenges (Thapa *et al.* 2018). Human influence often makes them more susceptible to invasion, facilitating many alien plants by freeing nutrients, and by changing natural disturbance regimes (Davis and Thompson 2000). Pathak *et al.* (2021) has also concluded that urban areas provides suitable microhabitats for the establishment of IAPS that subsequently disseminate their propagules for wider spread into the surrounding landscapes. In case of climate change, they cause a decrease in forms and fitness which are expressed at different levels, and have effects on individuals, populations, species, ecological networks and ecosystems (Bellard *et al.* 2016). The ability of an exotic species to overcome invasion-limiting barriers may be facilitated and increased by a high propagule pressure, which is defined as a composite measure of introduction events and number of released propagules, enabling them to be prone to invasion at higher altitude (Holle and Simberloff 2005).

Under the difficult conditions, like the upper and lower elevation range boundaries, plant fitness is severely diminished, and range-edge populations frequently serve as demographic sink (Seipel *et al.* 2016). The area with the largest canopy cover is the one that is least affected by invasive species. While forest regions with closed canopy cover act as physical barriers to dispersal paths, common light and moisture conditions act as environmental obstacles for the establishment of alien plant species (Mavimbela *et al.* 2018).

According to De Poorter *et al.* (2007), there are 106 countries where protected areas have been reported to have invasive alien species as a threat or effect. Invading alien species are seriously damaging the ecology of India's natural areas by speeding up the extinction of native and vulnerable species and decreasing the carrying capacity of pastures (Reddy 2008). About 40 per cent of India's flora is made up of foreign species, 25 per cent of which are invasive (Kavita Gupta; National Bureau of Plant Genetic Resources) (Barceloux 2008). Given China's speedy economic growth and the country's expanding travel, tourism, and business sectors, it is feasible that the country may face serious invasive species problems in the future (Xu *et al.* 2012).

Agro-ecosystems, wetlands, protected areas, and forest ecosystems in Nepal have already been devastated by invasive species, putting both biodiversity and human livelihoods at peril (MFSC 2014). In Nepal, the biological invasion has emerged as a fresh barrier to maintaining ecosystem services, protecting biodiversity, and increasing agricultural productivity (Shrestha 2016). IAPS have also infiltrated the buffer zone of Chitwan National Park- one of the oldest National Parks (NP) (Shrestha 2016), whereas in Parsa National Park the effect of IAPS on the process of tree regeneration was seen closer to populated areas (Shrestha and Shrestha 2019).The majority of research on invasive species in Nepal focuses on specific regions, overlooking context-specific invasion phenomena and delaying control measures in sensitive habitats (Bellard *et al.* 2016). In the high mountainous district of Jajarkot, where there is rich non-timber forest products (NTFP), there is lack of research on the influence of invasive species on biodiversity, despite local people observations. To address this lack of existing research on the presence and influence of invasive species on native species in different altitudinal range in Jajarkot, the study aims to answer the following research questions:

1. Are invasive species affecting native species in Jajarkot, as observed by the local population?
2. How do invasive species impact the biodiversity of native species across different altitudinal gradients in Jajarkot?

MATERIAL AND METHODS

Study area

Jajarkot is a mountainous district in Nepal, divided into three zones: High Mountain, Mountain, and Riverine flat land. It covers 2,230 km^2 and is divided into forestland (54.9%), agricultural land (15.8%), rangeland (11.8%), shrub-land (11.7%), and other lands (4.8%). According to DFO/Jajarkot (2020) and GoN (2014), the forest of Jajarkot can be divided into the following types (based on climate):

a. **Tropical (<1,000m)**: Major tree species found are *Shorea robusta* (Sal), *Acacia catechu* (Khaer), *Terminalia elliptica* (Asna), *Dalbergia Sissoo* (Sishoo), *Pinus roxburghii* (Khote Sallo) etc.

b. **Sub-tropical (1,000 m to 1,500 m)**: Major tree species are *Shorea robusta* (Sal), *Pinus roxburghii* (Khote Sallo), *Terminalia elliptica* (Asna), *Adina cordifolia* (Karma), *Toona ciliata* (Tooni), *Alnus nepalensis* (Uttis), *Acacia catechu* (Khaer), and major NTFP species are *Zanthoxylum armatum* (Timur), *Swertia chirayita* (Chiraito), *Terminalia bellirica* (Barro), *Phyllanthus emblica* (Amala), *Bergenia ciliata* (Pakhanbed), *Urtica dioica* (Sisnoo), *Persea spp.*(Kaulo), *Sapindus mukorossi* (Rittha), *Cinnamomum tamala* (Tejpat), etc.

c. **Temperate (1,500 m to 2,500 m):** Major tree species are *Pinus wallichiana* (Gobre Salla), *Quercus leucotrichophora* (Banjh), *Quercus semicordata* (Khasru), *Tsuga dumosa* (Thingure Salla), *Taxus baccata* (Lauth Salla), and NTFP species are *Valeriana jatamansi* (Sugandawal), *Nardostachys grandiflora* (Jatamansi), *Allium wallichii* (Banlasun), *Paris polyphylla* (Satuwa), *Ipomea spp.* (Kala dana), *Lycopodium spp.* (Jhyau), etc.

d. **Alpine forest (above 2,500 m):** Major tree species are *Pinus wallichiana* (Gobre salla), *Tsuga dumosa* (Thingure Salla), *Rhododendron arboreum* (Laliguras), *Betula utilis* (Bhojpatra) and *Cedrus deodara* (Debdar), etc.

The IAPS found in the area are *Lantana camara, Ageratina adenophora, Bidens pilosa and Ageratum conyzoides.* While the Community Forest (CF) of Bheri and Nalgadh municipality were chosen as the study area. The CFs sampled in the study area were Shyaulapakha Kalegaun CF, Bhagwati CF, Pragati CF, Thulokhola Kimuchaur CF and Haanschamakhola CF.

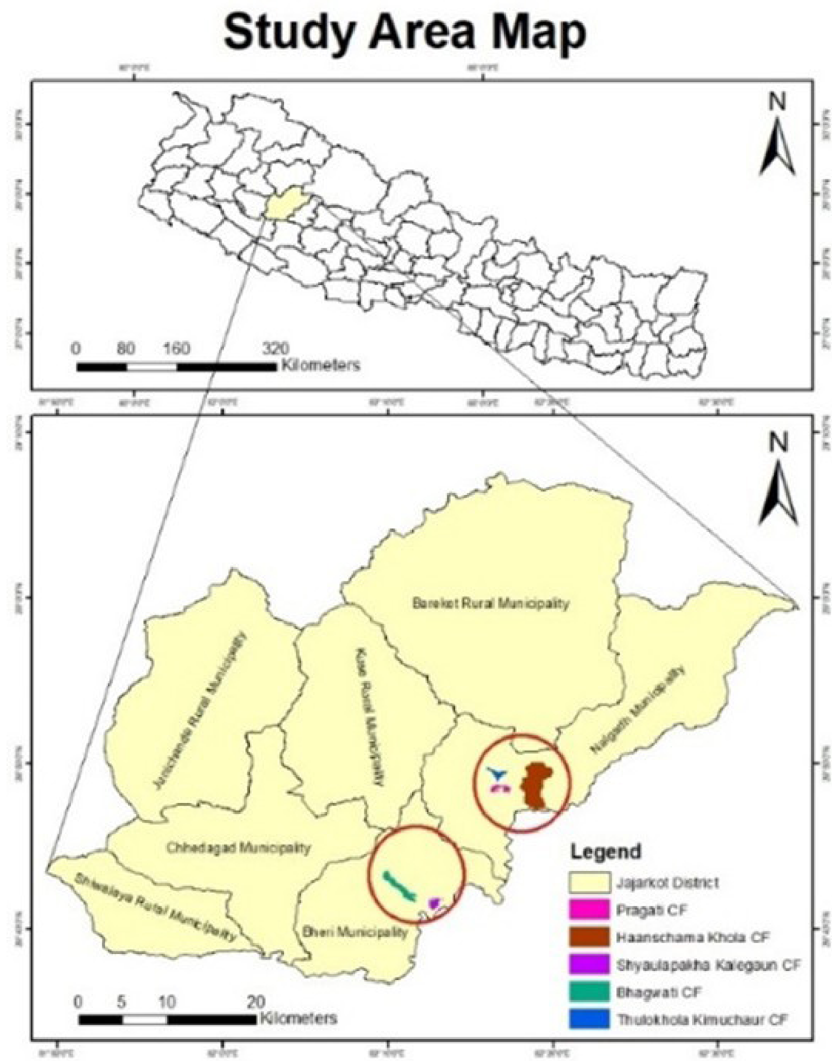


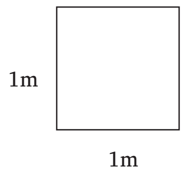
Figure 1: Map of the study area

Data collection

Field reconnaissance surveys were conducted following preliminary visits to selected CF across varying altitudinal ranges identified in consultation with local forestry authorities and Community Forest Users Groups (CFUG). The abundance categories of plant species in each plot were recorded using Garmin GPS, with local inhabitants aiding in species identification. Native and invasive species were counted, and cover assessments were conducted using densitometers. Specimens were cross-referenced with plant identification applications and submitted to the National Herbarium and Plant Laboratories (NHPL) for verification. Secondary data were obtained through the review of existing documents, including research papers, thesis, and articles.

Sampling method

The participatory mapping of areas affected by invasive species involved consultations with the CFUG and Key Informant Interviews (KII) (n=40). A sketch map was created, aiding in the purposive selection of CFs impacted by invasive species. Three altitudinal ranges (<1000m, 1000-2000m, and >2000m) were chosen based on initial surveys revealing varying distributions of IAPS with altitude. Total 120 plots were established in 3 altitudinal range- 31 plots in <1000m, 74 plots in 1000-2000m and 15 plots > 2000m. Equal plots could not be taken in all altitudinal range due to difficult terrain. Each 1x1 quadrat plot (Paclibar and Tadiosa 2019) was assessed along with invasive species, grass, regeneration of woody species including trees and shrubs . The percentage cover of IAPS was recorded as very abundant (>75%), abundant (75-50%), frequent (50-25%), and rare (<25%).



Data Analysis

Vegetative Analysis

Analysis of each quadrat having different level of abundance of invasive species vegetation were done, and all the plants present were sampled, where the relative importance of the species was determined through IVI (Mueller-Dombois and Ellenberg 1974). The importance value index for both grass species and IAPS was also calculated.

Importance Value Index, IVI= Relative Frequency + Relative Cover + Relative density

Where,

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of one species}}{\text{sum of frequency of all species}} \times 100$$

$$\text{Relative Dominance (RCo)} = \frac{\text{Cover of one species}}{\text{sum of cover of all species}} \times 100$$

$$\text{Relative density (RDe)} = \frac{\text{density of one species}}{\text{Sum of density of all species}} \times 100$$

Plant diversity was determined using Shannon Weiner's Index, Simpson's Dominance Index, and Equitability of Evenness Index.

Shannon Weiner's Index,

$$H' = H' = \sum_{i=1}^{s} (pi)(\ln pi)$$

Where,

H= Shannon Wiener Diversity index

pi = fraction of the entire population made up of species I (total number of species / no. of individual of species)

S= number of species encountered

Occurrence mapping and hotspot mapping

IAPS distribution map was prepared by using the presence point of IAPS species in the study area. The boundary map of the municipality and Jajarkot district were obtained from https://www.dos.gov.np/. The altitude of the plot taken was also noted through GPS. We conducted a hotspot analysis to identify the regions potentially suitable for the maximum number of IAPs using the number of IAPS and the elevation they were present at (Shrestha and Shrestha 2019). We aggregated niches for all species to generate species diversity (cells with a higher value indicating high species diversity) and extent maps (cells occupied by at least a single species). We calculated changes in the areas of both diversity and extent of potentially suitable regions. Then the hotspot map was created in ArcGIS 10.5 following Kernel density method and reclassification method.

RESULTS

Distribution of invasive species, grass and regeneration of woody species in different altitudinal range

A total of 31 plant species (grass, invasive and regeneration of woody species) were recorded in different altitudinal ranges. Among them *Ageratina adenophora* and *Bidens pilosa* were found in all altitude (Table 1). There were a total of 20 regeneration of woody species, seven grass species and four IAPS in different altitudinal range of the study area in Jajarkot district (Table 1). Lower elevation holds very abundant category, with highest invasion followed by high elevation with abundant category of invasive species (Figure 2).

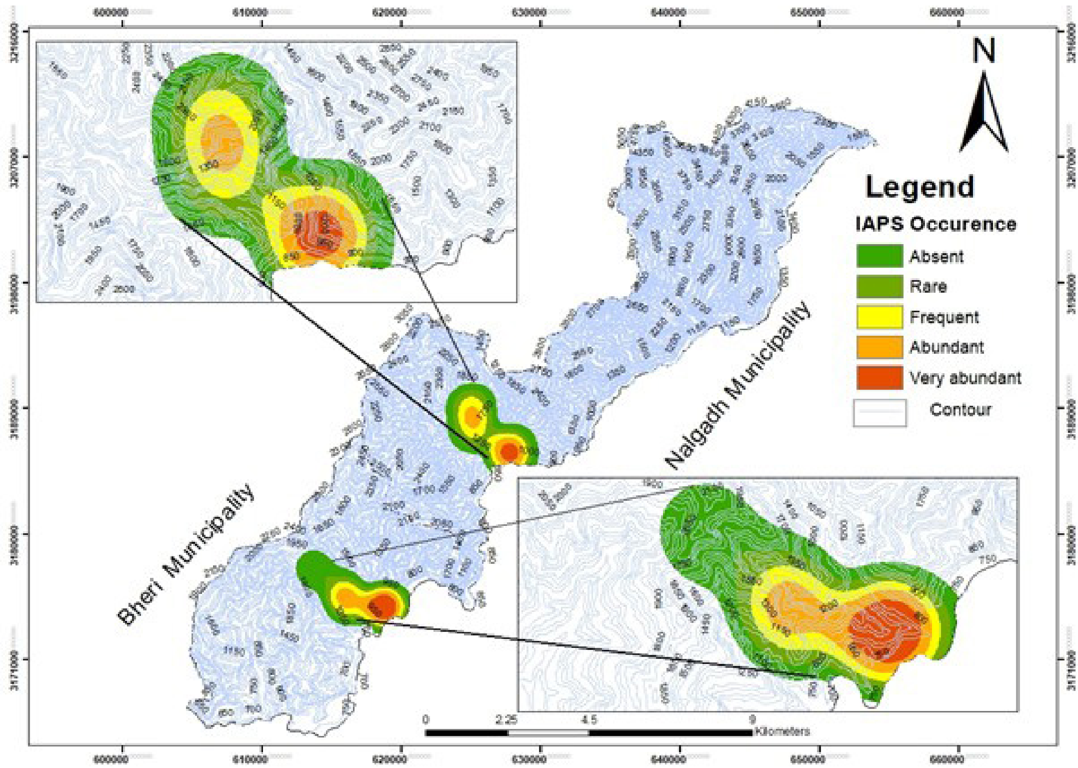


Figure 2: Hotspot mapping of IAPS in different altitudinal ranges

Table 1: Distribution of invasive, grass and regeneration of woody species in different altitudinal range

S.N	Name of species	Local/Common Name	<1000	1000-2000	>2000
Grass Species					
1	*Pogonatherum Species*	Muse khar	*	*	*
2	*Bothriochloapertusa*	PiryeKhar/Athikre	*	*	*
3	*Seteria pumila*	Bale BaleBanso	*	*	*
4	*Sachharum spontaneum*	Kansh	*	*	
5	*Eulaliopsis binate*	Babiyo	*	*	
6	*Miscellaneous*	Pula Khari	*	*	*
7	*Salvia mexicana*	Nilkanthi	*		
Invasive Species					
1	*Ageratina adenophora*	Maobadhi Jhar/ Kalo Banmara	*	*	*
2	*Lantana camara*	Dhungeful	*	*	
3	*Ageratum conyzoides*	Hanuman Jhar	*	*	
4	*Bidens pilosa*	Kuro	*	*	*
Regeneration of woody species					
1	*Shorea robusta*	Sal	*	*	
2	*Grewia optiva*	Bhimal		*	
3	*Pinus roxburghii*	Khote Salla	*	*	
4	*Aesendra butyraceae*	Chiuri	*	*	
5	*Mallotus philippensis*	Sindure	*	*	
6	*Lucaena lucocephala*	Ipil-Ipil	*	*	
7	*Terminalia chebula*	Harro	*	*	
8	*Holarrhena pubescens*	Khirro		*	
9	*Terminalia elliptica*	Sajh	*	*	
10	*Syzygium cumini*	Jamun		*	
11	*Dalbergia Sissoo*	Sissoo	*	*	
12	*Rhododendron arboreum*	Gurans		*	*
13	*Macaranga denticulata*	Maleto		*	
14	*Myrica esculenta*	Kafal		*	*
15	Miscellaneous	Miscellaneous regeneration		*	
16	*Woodfordiaf ruticosa*	Dhaero	*		
17	*Quercus leucotrichophora*	Banjh			*
18	*Melastoma Malabathricum*	Ayar/Angeri			*
19	*Berberis aristata*	Chutro			*
20	*Pyrus species.*	Mel			*

Effects of invasive species on native species in different altitudinal range

The Shannon-Weiner index for IAPS was highest in the altitudinal range of <1000m (1.25), and it gradually decreased with increasing altitude, with values of 1.09 in the 1000-2000m range and 0.40 in the >2000m range (Table 2). Regarding regeneration, the Shannon-Weiner index was highest in the <1000m range, while grasses had the highest index in the 1000-2000m range (Table 2). Both categories showed the lowest values in the >2000m altitude range.

Important Value Index

Lantana camera had the highest IVI value (57.32) followed by *Pogonatherum* species (43.93), *Ageratum adenophora* (35.63) and *Bothriochloa pertusa* (25.82). *Terminalia elliptica* stood last with the 1.46 IVI value in altitudinal range below 1000m (Figure 3). Here, Invasive species posed 41.97 per cent of total IVI than other species.

Table 2: Biodiversity indices of invasive species, grass and regeneration of woody species

Altitudinal Range (m)	Category	Shannon-Weiner index
<1000	Invasive	1.25
	Grass	1.35
	Regeneration	1.81
1000-2000	Invasive	1.09
	Grass	1.51
	Regeneration	1.75
>2000	Invasive	0.40
	Grass	1.08
	Regeneration	1.64

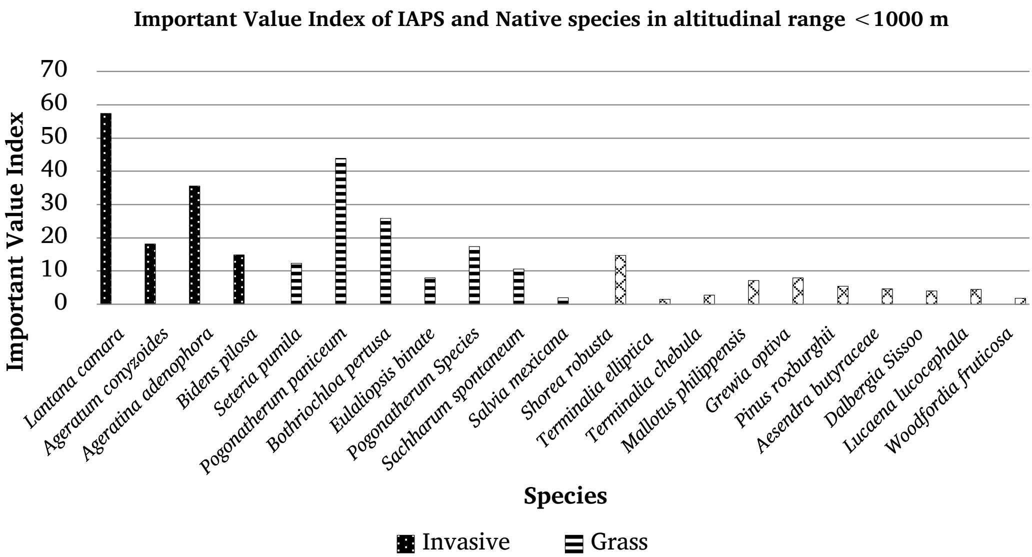


Figure 3: Important Value Index of IAPS and Native species in altitudinal range <1000m

Ageratina adenophora had the highest IVI value (59.33) followed by *Pogonatherum paniceum* (43.11), *Bothriochloa pertusa* (33.78) and *Shorea robusta* (24.81). *Myrica esculenta* had the least IVI value of 1.02 value at an altitudinal range below 1000-2000m asl (Figure 4). Here, Invasive species posed 35.98 per cent of total IVI than other species.

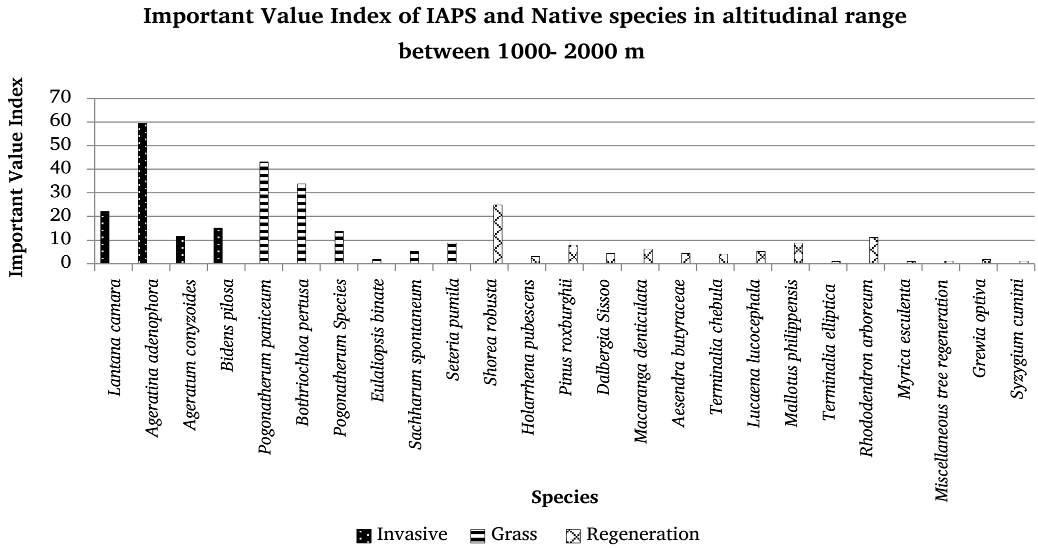


Figure 4: Important Value Index of IAPS and Native species in altitudinal range between 1000- 2000m

Ageratina adenophora had the highest IVI value (55.96) followed by *Bothriochloa pertusa* (53.87), *Pogonatherum paniceum* (45.81) and *Rhododendron arboreum* (24.81). *Melastoma Malabathricum* had least IVI value with 6.60 at an altitudinal range below >2000m asl (Figure 5). Here, Invasive species posed 24.12 per cent of total IVI than other species.

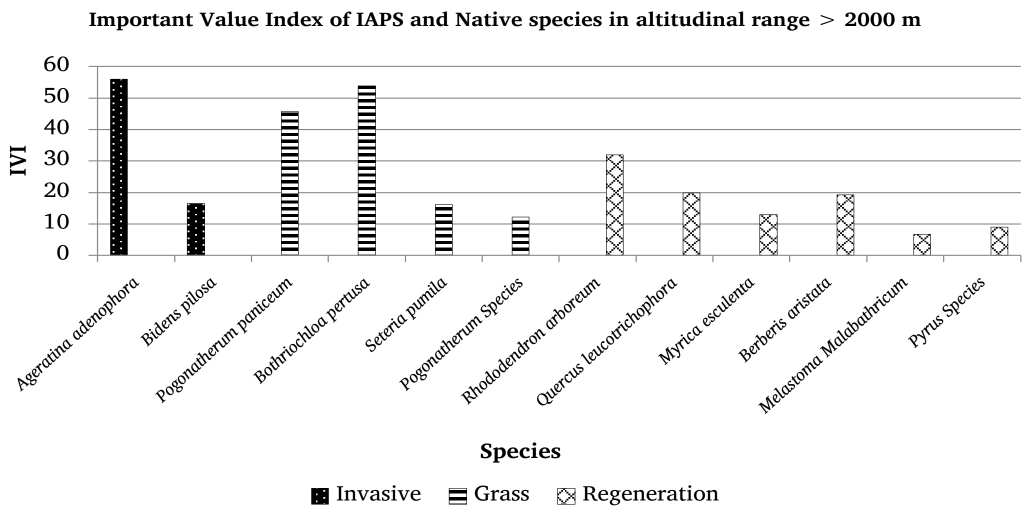


Figure 5: Important Value Index of IAPS and Native species in altitudinal range > 2000m

DISCUSSION

Our study recorded seven grass species, four IAPS, and 20 regenerating woody species. Among the IAPS, *Ageratina adenophora* and *Bidens pilosa* were found to have impact on native species across all altitudinal zones, while *Lantana camara* and *Ageratum conyzoides* were restricted to elevations below 2000 m. A marked decline in IAPS abundance was observed at a higher altitudes (>1000m) while it was dominant in lowland areas. This altitudinal trend was consistent within the study done by Becker *et al.* (2005). Although the diversity of IAPS was lower than that of native species, biodiversity indices from the result showed the gradual impact in native species richness and evenness due to the increasing dominance of IAPS. This dominance was largely attributed to the greater cover and height of invasive species, which suppressed native flora through declining evenness rather than complete elimination. These findings align with Hejda *et al.* (2009), who demonstrated that IAPS suppresses native species through competitive exclusion, with the degree of impact varying based on environmental context and invaders characteristic. Similarly, Baidar *et al.* (2017) used Maxent modelling, reported adverse impacts of IAPS on sapling, shrubs, and grasses in forested and grassland ecosystems.

According to GoN (2014), IAPS like *Ageratina adenophora* has been a major driver of biodiversity loss in the mid- hills. Current ongoing climate change, IAPS are encroaching into higher elevations. Our results from analysing the IVI revealed that IAPS remained dominant and influential on native species across all the elevation zone. Research by Paiaro *et al.* (2011) and Gallardo (2014) has also reported that IAPS with higher IVI values substantially altered the native species distribution. Likewise, the research also showed that IAPS exerted greater negative impact with reduced canopy cover, where their abundance was highest. Pandey *et al.* (2021) and Lawes *et al.* (2004) also stated in their findings that a negative correlation between canopy density and IAPS proliferation. Despite the ecological impact of IAPS across the altitudinal ranges, over data revealed a gradual expansion of IAPS richness. This trend is a mirror observations by Zhang *et al.* (2015), who reported that species richness peaked at lower elevations and declines sharply with increasing altitude. The proliferation of IAPS at lower altitudes is primarily driven by anthropogenic disturbances, such as unplanned road construction, agricultural activities, canopy cover and soil characteristics (Baral *et al.* 2017; Shrestha *et al.* 2017). Overall, our findings highlight the significant impact of IAPS on native species distribution, particularly their upward expansion to higher altitude facilitated by environmental disturbances and increasing distribution of IAPS.

CONCLUSION

This study in the CFs of Jajarkot district highlights the impact of IAPS on the distribution of native species across different altitudinal ranges. IAPS were predominantly concentrated at lower altitudes (<1000m), with their diversity and influence gradually decreasing at higher elevations. However, the findings suggest a potential upward expansion of IAPS, posing significant threats to biodiversity and ecosystem integrity, particularly in areas above 2000 m if effective management is not implemented. The high Importance Value Index (IVI) and diversity of IAPS at lower and mid-altitudes underscore the impact on the native species that needs urgent conservation measures to mitigate their impact. Future research should adopt systematic sampling techniques, include diverse land-use types, and investigate the socio-ecological drivers of IAPS spread. Collaborative approaches involving local communities, policymakers, and conservation stakeholders are essential to safeguard biodiversity and promote ecosystem resilience.

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