Effects of Invasive Alien Plant Species on Native Plant Species in Three Different Altitudinal Ranges: A Case Study of Five Community Forests in 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 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 on distribution of native species. The Importance Value Index (IVI) revealed IAPS dominance at lower altitudes, contributing to reduction in the 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 forests as 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 were only imported a century ago and had time to evolve and adapt in the local climate more than IAPS as a result of human activities and impact of IAPS, are fewer in number (Zhang *et al.* 2015). IAPS are seen to migrate upwards to higher altitude from lower altitude in response to climate change, trade, tourism and anthropogenic disturbances, altering both native floral and faunal species compositions (Cramer *et al.* 2014). It is essential 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 provide suitable microhabitats for the introduction of IAPS, which 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, making them prone to invasion at higher altitudes (Holle and Simberloff 2005).

Under 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). According to Kavita Gupta of National Bureau of Plant Genetic Resources, about 40 per cent of India's flora is made up of foreign species, 25 per cent of which are invasive (Barceloux 2008). Given China's speedy economic growth and the country's expanding travel, tourism and business sectors, the country may face serious invasive species problems in the future (Xu *et al.* 2012).

Agroecosystems, 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, 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 the Chitwan National Park, one of the oldest national parks in Nepal (Shrestha 2016), whereas, in the Parsa National Park, the effects of IAPS on the process of tree regeneration were seen to be closer to populated areas (Shrestha and Shrestha 2019). Most of the research on invasive species in Nepal focuses on specific regions, overlooking context-specific invasion phenomenon and delaying control measures in sensitive habitats (Bellard *et al.* 2016). Despite local people's observations, there is lack of research on the presence and influence of invasive species on biodiversity in the high mountainous district of Jajarkot, which has rich non-timber forest products (NTFP). To address this lacuna, the study aims to carry out research on the presence and influence of invasive species on native species in different altitudinal ranges in Jajarkot and answer the following 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, a mountainous district in Nepal, is divided into three zones: High Mountain, Mountain and Riverine flatland. It is spread over 2,230 km^2 and is divided into forestland (54.9%), agricultural land (15.8%), rangeland (11.8%), shrubland (11.7%), and other lands (4.8%). According to the District Forest Office (DFO), Jajarkot (2020) and GoN (2014), based on climate, the forests of Jajarkot can be divided into the following types:

1. **Tropical (<1,000 m)**: Major tree species found are *Shorea robusta (Sal), Acacia catechu (Khaer), Terminalia elliptica (Asna), Dalbergia Sissoo (Sishoo),* and *Pinus roxburghii (Khote Sallo).*
2. **Subtropical (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),* and *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),* and *Cinnamomum tamala (Tejpat).*
3. **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),* and *Taxus baccata (Lauth Salla)* and major NTFP species are *Valeriana jatamansi (Sugandawal), Nardostachys grandiflora (Jatamansi), Allium wallichii (Banlasun), Paris polyphylla (Satuwa), Ipomea spp. (Kala dana),* and *Lycopodium spp. (Jhyau).*
4. **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).*

The IAPS found in the area are *Lantana camara, Ageratina adenophora, Bidens pilosa* and *Ageratum conyzoides.* The community forests (CFs) of Bheri and Nalgadh municipalities 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.

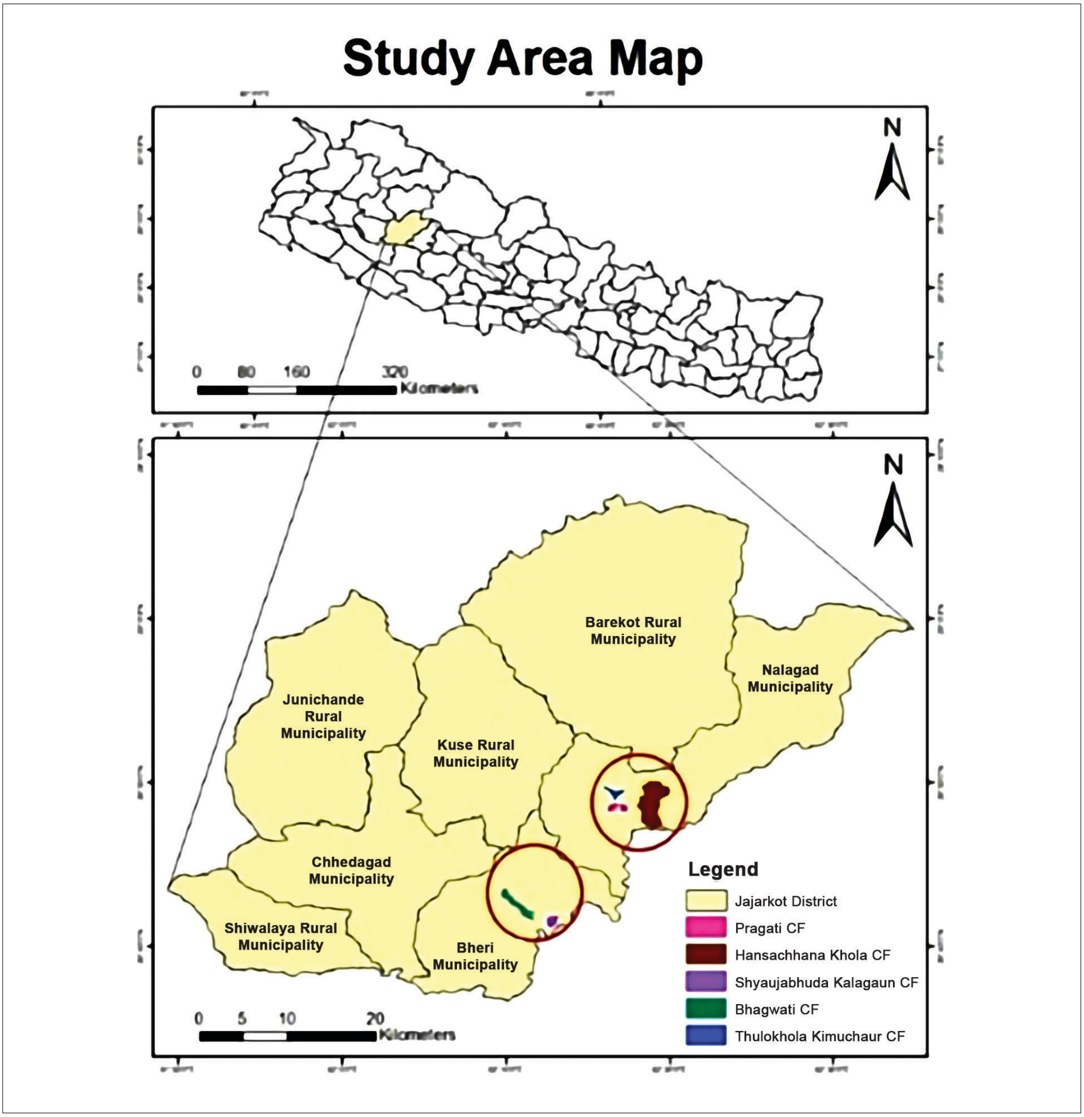


Figure 1: Map of the study area

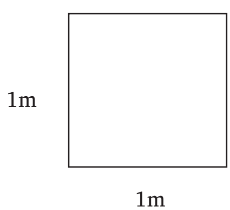
Data collection

Field reconnaissance surveys were conducted following preliminary visits to selected CFs across varying altitudinal ranges identified in consultation with local forestry authorities and community forest user groups (CFUGs).

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 CFUGs and key informant interview (KII) (n=40). A sketch map was created, aiding in the purposive selection of CFs impacted by invasive species. Three altitudinal ranges (<1000 m, 1000-2000 m and >2000 m) were selected based on initial surveys, revealing varying distributions of IAPS with altitude. Total 120 plots were established in three altitudinal ranges: 31 plots in <1000 m, 74 plots in 1000–2000 m and 15 plots > 2000 m. Equal plots could not be taken in all altitudinal ranges due to difficult terrain. Each 1X1 quadrat plot (Paclibar and Tadiosa 2019) was assessed along with invasive species, grass and 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 levels 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 Importance Value Index (IVI) (Mueller-Dombois and Ellenberg 1974). The IVI was also calculated for both grass species and IAPS.

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/ number of individuals of species)

S = number of species encountered

Occurrence mapping and hotspot mapping

An IAPS distribution map was prepared by using the presence point of IAPS in the study area. The boundary maps 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, a hotspot map was created in ArcGIS 10.5 following the Kernel density method and reclassification method.

RESULTS

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

A total of thirty-one 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 altitudes (Table 1). There was a total of twenty regenerations of woody species, seven grass species and four IAPS in different altitudinal ranges 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).

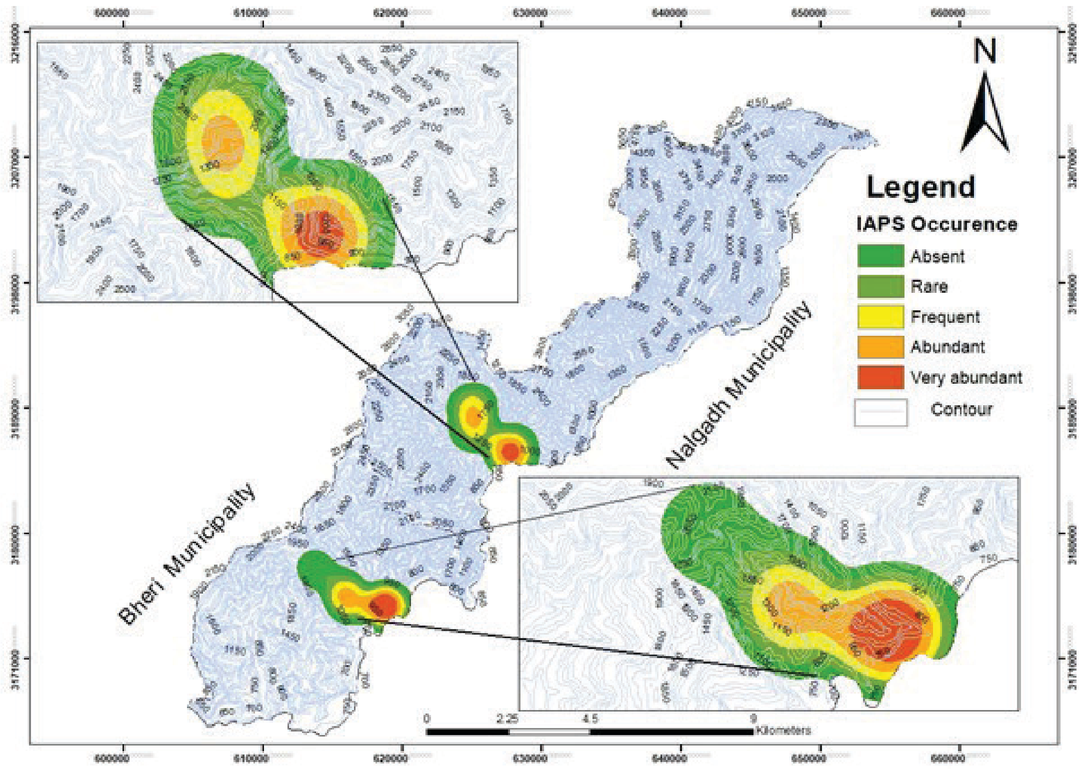


Figure 2: Hotspot mapping of IAPS in different altitudinal ranges

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

S.N.	Name of species	Local/common name	<1000	1000–2000	>2000
Grass species					
1	Pogonatherum Species	Muse Khar	*	*	*
2	Bothriochloapertusa	Pirye Khar/Athikre	*	*	*
3	Seteria pumila	Bale Bale Banso	*	*	*
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 ranges

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

Importance 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 the altitudinal range >1000 m (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

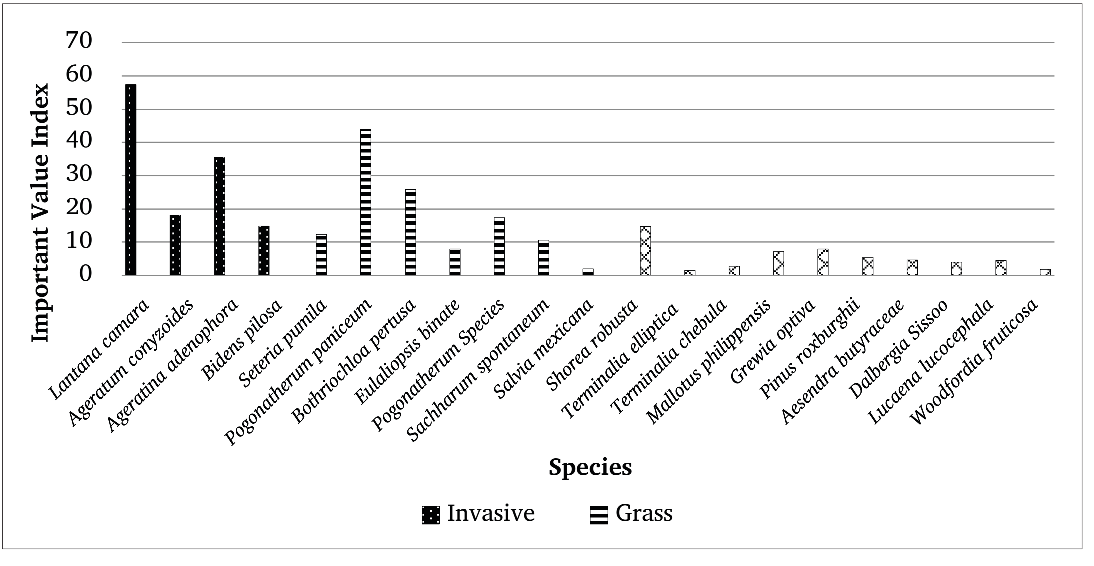


Figure 3: Importance Value Index of IAPS and native species in altitudinal range <1000m

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 >1000–2000 masl (Figure 4). Here, invasive species posed 35.98 per cent of total IVI than other species.

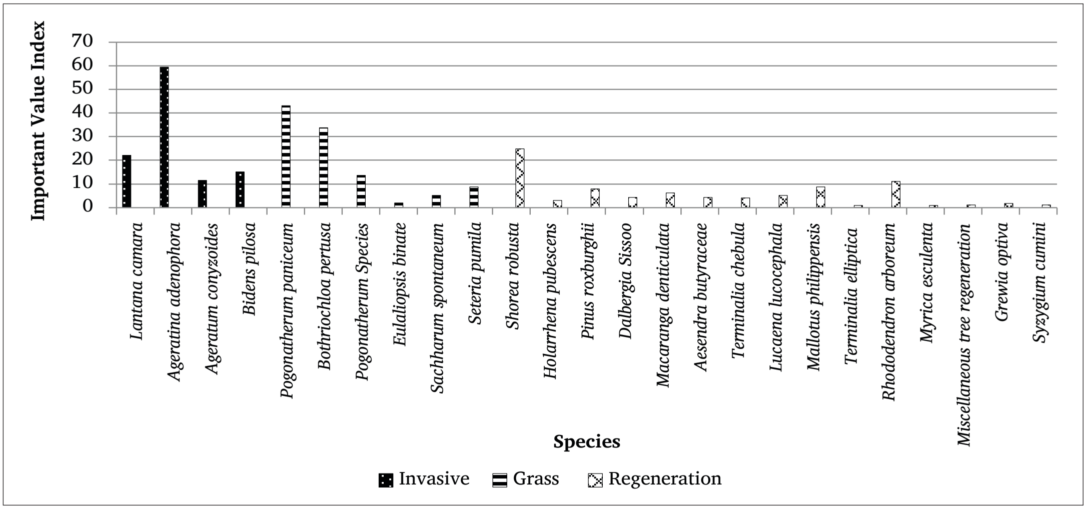


Figure 4: Importance Value Index of IAPS and native species in altitudinal range 1000–2000 m

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 >2000 masl (Figure 5). Here, invasive species posed 24.12 per cent of total IVI than other species.

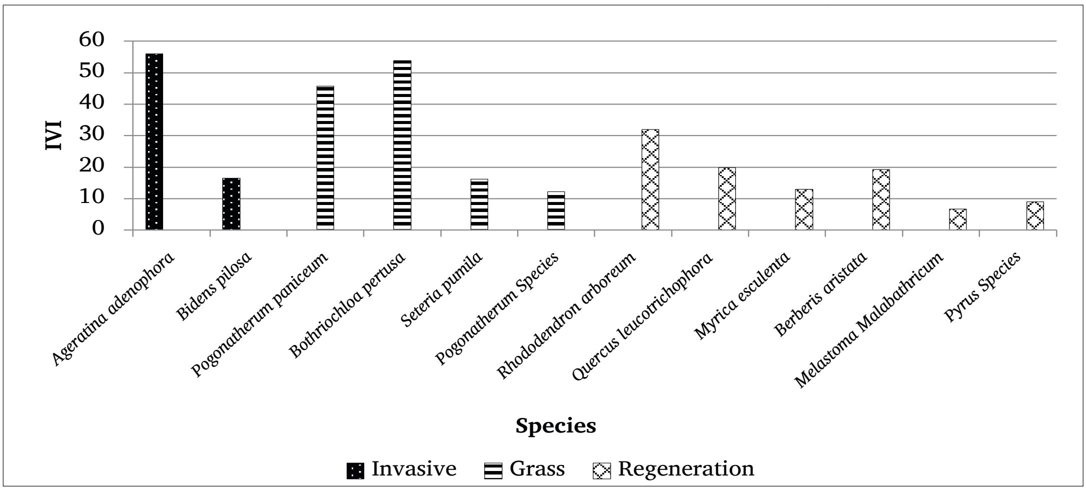


Figure 5: Importance Value Index of IAPS and native species in altitudinal range >2000 m

DISCUSSION

Our study recorded seven grass species, four IAPS and twenty 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 >2000 m. A marked decline in IAPS abundance was observed at higher altitudes (>1000 m), while it was dominant in lowland areas. This altitudinal trend was consistent with the trend found in 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 on the richness and evenness of native species 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 those of Hejda *et al.* (2009), who demonstrated that IAPS suppresses native species through competitive exclusion, with the degree of impact varying by environmental context and invaders' characteristics. 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. Owing to the ongoing climate change, IAPS are encroaching upon higher elevations. Our results from analysing the IVI revealed that IAPS remained dominant and influential on native species across all elevation zones. Paiaro *et al.* (2011) and Gallardo (2014) also report that IAPS with higher IVI values substantially alter the native species distribution. Likewise, 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 existed between canopy density and IAPS proliferation. Despite the ecological impact of IAPS across the altitudinal ranges, our data revealed a gradual expansion of IAPS richness. This trend is a mirror observation by Zhang *et al.* (2015), who reported that species richness peaked at lower elevations and declined 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 altitudes, 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 (<1000 m), 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 IVI and diversity of IAPS at lower and mid altitudes underscore the impact on the native species that need urgent conservation measures to mitigate their impact. Future research should adopt systematic sampling techniques, include diverse land-use types and investigate the socioecological drivers of IAPS spread. Collaborative approaches involving local communities, policymakers and conservation stakeholders are essential to safeguard biodiversity and promote ecosystem resilience.

ACKNOWLEDGMENT

We extend our sincere gratitude to the Karnali province government for granting us an opportunity to conduct this research. We also express our appreciation to our esteemed advisor, Late Dr Ram Asheshwor Mandal, for providing us invaluable guidance and expertise throughout this endeavour.

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