Assessment of Invasive Alien Plant Species in Buffer zone and Indo-Nepal Border Area and their Impact on Native Biodiversity in Kanchanpur, Nepal

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ABSTRACT

IAPS are already a huge worldwide environmental issue, endangering biodiversity, altering ecosystems, and disrupting socioeconomic systems. The current study aimed to assess the distribution, diversity, and effect of IAPS in the Indo-Nepal buffer zones of Kanchanpur District, Nepal, with a focus on Bhimdatta and Dodharachadani Municipality. Between September 2023 and July 2024, a comprehensive field survey was undertaken at the research sites. Using quadrat sampling and herbarium identification, 21 plant species were identified. These species belonged to 11 families of which Asteraceae family was dominant in all study sites; holding 8 species. On the basis of IVI, 10 invasive plant species were recorded as dominant in all study sites. Of these, the highest importance value index of dominant invasive alien plant species at site 1 was recorded by *Partheniun hysterophorus* (41.39) and lowest by *Mimosa pudica* (2), whereas among dominant invasive alien plant species of site 2 the highest IVI was of *Lantana camara* (56.46) and lowest by *Argemone maxicana* (3.82). At site 3, the highest importance value index of dominant invasive alien plant species was recorded by *Parthenium hysterophorus* (28.35) and lowest by *Bidens pilosa* (2.85). The study's findings could have ecological and economic implications, such as loss of biodiversity, soil degradation, and health dangers. Furthermore, the study revealed the adaptive reproductive tactics of IAPS, such as allelopathy and seed viability, which increase their invasive nature. The findings highlight the critical need for focused management techniques to minimize the growing threat of IAPS, particularly in buffer zones where conservation efforts are currently underexplored.

1. INTRODUCTION

The word ‘invasive’ comes from the word ‘invasion’ which means to invade and the word ‘alien’ means foreigner or migratory. Invasive alien species refers to those plant and animal that have been moved or imported either intentionally or unintentionally by human, from their native habitat to new environment [1]. The spread of IAS is recognized as one of the significant threats to the biodiversity often leading to the loss of native species and altering ecosystem [2,3]. The issue of IAS is a global concern, affecting both developed and developing countries like Nepal, where the resources of their management are limited [4]. IAPS can drastically change species composition and reduce biodiversity, thereby threatening global biodiversity [5,6].

The invasive alien plant species (IAPS) are characterized by their fast growth and extensive spread, causing significant damage to native species and habitats globally [7]. Invasion of habitats by these species is a global problem impacting ecological, economic and social system [8]. One-sixth of the world’s land surface is highly vulnerable to invasion including developing countries and biodiversity hotspots [9]. The risks of invasions are increasing due to expanding transportation networks, technological advancements, landscape transformations, climate change, and geopolitical events such as warfare and migration [10]. For example, territories occupied by the IAPS in South Africa increased by 50% between 2000 and 2016 [11].

Over several generations, the IAPS are capable of adapting to their introduced habitat [12]. This adaptability is often facilitated by their ability to adjust to new climatic condition [13], which can further exacerbate their negative impacts on the ecosystem [14,15]. For instance, some IAPS, such as *Parthenium,* exhibit allelopathic effects due to the presence of water-soluble phenolic and sesquiterpene lactones like parthenin [16]. This compound inhibits the growth of other plants through soil contamination [17,18], allowing IAPS to dominate in their introduced habitat [19].

Banerji conducted the first survey of invasive alien species (IAS) in Nepal in 1958, focused on the invasion of *Eupatorium glandulosum* in Eastern Nepal [20]. Subsequent IUCN research revealed 21 distinct IAS in the country [21], which increased to

25 in Shrestha's 2016 study and 26 according to the Department of Plant Resources in 2020 [20]. This reflects an alarming rise in the rate of invasions by IAS over the last couple of decades.

Previous research is focused on ecological studies within wetlands and protected areas [22]. Limited studies have been done or emphasis laid on buffer zones and the bordering regions. A buffer zone-also known as a multiple use or transitional zone-is a relatively new concept, while the notion has been used for some time [23]. The buffer zone concept, introduced by UNESCO, aims to integrate conservation goals with local development by encouraging sustainable resource use and active community participation [24,25]. In Nepal, buffer zones serve as a strategy to reduce conflicts between protected areas and neighboring communities by supporting wildlife conservation while addressing the immediate needs of local residents [26]. These zones improve ecological conditions as well as increase the ranges of wildlife habitats. Buffer zones are regarded as critical for protecting biologically valuable places while meeting developmental objectives [23]. Long-standing cultural bonds and shared resources have in the past been the base of cross-border relations on the 1,751 km open India-Nepal border. In recent times, problems of human and drug trafficking, illegal trade, and environmental degradation have cropped up to put pressure on coordinated, sustainable management of biodiversity and security concerns as a challenge [27]. According to [28], a border region is an area, and a border is a line that divides the territories of different states. As noted by [29], all such regions display differences in spatial planning and subsidy and tariff policies, in social and tax legislation, economic intercourse, standards and levels of living, purchasing power, and wage rates. Over the years, various IAS have emerged to threat local biodiversity by inhibiting the regrowth of native species. However, no systematic assessment of IAS has been conducted outside the protected areas mainly in buffer zones. The present study focuses on Indo- Nepal border areas and Suklaphanta National Park buffer zone of Kanchanpur district and focuses more precisely on Bhimdatta and Dodharachadani Municipality in order to assess the status regarding IAS. This research represents the current situation of IAPs in these transitional locations and gives an overview of their diversity, implications, and management option.

2. MATERIALS AND METHODS

2.1. Study area

The study was conducted in Kanchanpur District, Nepal, particularly in buffer zone of Shuklaphant National Park (SNP) in Bhimdatta Municipality and Indo-Nepal border areas of Bhimdatta Municipality and Dodhara Chandani Municipality. Kanchanpur district of Far western Nepal, Sudurpaschim Province, has the total area of 1,610 sq.km. Topographically the district was divided into three regions; Churia hills, Bhabar range and Terai plains. The climate of Kanchanpur district is dry tropical type with rainy summer and dry winter climate.

The area is situated in tropical zone having an average 1775mm annual rainfall with maximum temperature 42^{o}C during summer and minimum temperature 6^{o}C during winter. The relative humidity is in the range of 84-87%. The average annual rainfall estimated approximately 1575mm [30].The study area is biologically rich and ecologically fragile; hence, it comes within the critical zone for assessing the spread and impact of invasive plant species.

The geographic and ecological context of the Bhimdatta Municipality area spans 171 square kilometers with diverse landscapes, ranging from 60 meters to 1,528 meters above sea level. It borders the globally important biodiversity hotspot of Shuklaphanta National Park, with its urban settlements, agricultural fields, and forest buffer zones. A highway, the Bhramadev Highway, bisects this Municipality, thus providing a pathway that may help in the dispersal of invasive species. Similarly, the Dodhara Chandani Municipality Municipality covers the area of 56.84 sq. km and has been situated in the western frontiers of Nepal bordering the Mahakali River and the Indian State of Uttarakhand. A riverine landscape, regions of forests, and pieces of agriculture have elevations ranging from 60-300 meters, which are seriously vulnerable to the invasion and proliferation of alien plant species through human activities and cross-border relationship.

2.1.1. Study Locations: For capturing the distribution and dynamics of the IAPs the key sites were selected as;

Border Area of Dodhara Chandani Municipality (Site 1): This site focuses on areas in the vicinity of the Mahakali River and the edge of the forest. These are areas where disturbance due to human activities like agriculture and grazing favors the proliferation of invasive plants.

Shuklaphanta Buffer Zone and Border Area (Gaddachauki to Bhramadev) (Site 2): This site provides a focus on the park's peripheral areas and also the westernmost border of Nepal, starting from the busy Gaddachauki checkpoint right down to the ecologically significant Bhramadev region. Anthropogenic activities like trade, road construction, and the expansion of agriculture are leading causes for the introduction and propagation of invasive species in the region.

Bhramdev Highway (Bhasi to Jhilmila Lake) (Site 3): This stretch of highway connects Bhasi to the Jhilmila Lake area and serves as a critical dispersal corridor for invasive species. Roadside vegetation and nearby agricultural lands were surveyed to assess the prevalence of invasive species along this key transportation route.

These sites have been selected to represent both natural and anthropogenic landscapes, in which invasive species thrive in areas with disturbances like road construction, cross-border trade, and agricultural activities. Their proximity to Shuklaphanta National Park presents another layer of complexity due to the invasion of native ecosystems by invasive species, thus posing a threat to biodiversity. The study area indicates its strategic value in understanding the distribution, pathways, and ecological impacts of invasive species in Kanchanpur District (**Figure 1**).

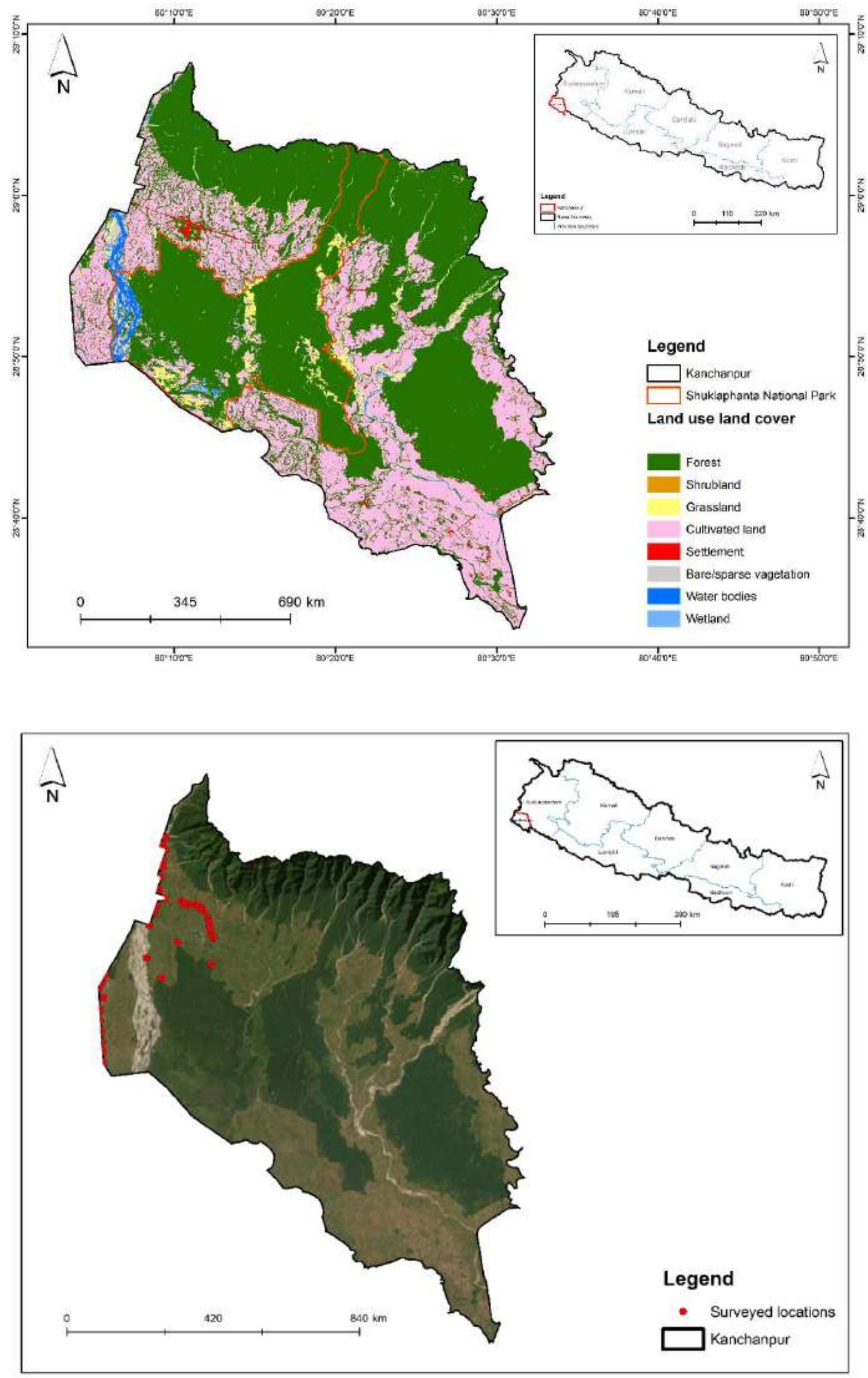

Fig. 1: Maps of study area.

The survey, which runs from September 2023 to July 2024, include systematic monthly visits to study plant species' growth forms, phenology, and status, as well as the collection of samples for morphological investigations. A quadrat sampling approach (5×5 m) was used to calculate density, frequency, coverage, and the Importance Value Index (IVI) using [31] and [32] methodologies. The plant species referred to be invasive by respondents were collected, pressed, dried, mounted and preserved based on standard methods as given by [33]. Before preservation all the collected vouchers were examined and identified with the help literature [34,35,36]. Furthermore, the species were confirmed by comparing with herbarium specimens deposited at KATH (National Herbarium and Plant Laboratories, Godawori, Lalitpur, Nepal), TUCH (Tribhuvan University Herbarium, Department of Botany, Kirtipur, Kathmandu), and Department of Botanty, Siddhanath

Science Campus, Mahendranagar. All voucher specimens were deposited at Department of Botany, Siddhanath Science Campus, Mahendranagar. Scientific name of plants and their families were verified with referring to the plant list (http://www.theplantlist.org/). The reproductive biology of dominant invasive species was evaluated, including seed weight, size, shape, and germination tests, with field activities captured through photography. The collected data was recorded in notebooks and evaluated on a computer to provide thorough study results.

3. RESULTS AND DISCUSSION

3.1. Floristic composition and Diversity pattern of plant species

A total of 21 plant species were reported at three study sites, including 16 species at site 1, 18 at site 2, and 20 at site 3. *Ageratum houstonianum, Alt-ernanthera philoxeroides, Bidens pilosa, Calotropis gigantean, Echhornia crassipes, Galinsoga quadriradiata, Hyptis suaveolens, Imperata cylindrica, Ipomoea carnea, Lantana camara, Mimosa pudica, Parthenium hysterophorus, Senna alata, Senna occidentalis, Senna tora,* and *Xanthium strumarium* are among the plant species found at site 1 (**Table 1**). At site 2, there are also *Ageratum houstonianum, Ageratina adenophora, Amaranthus spinosus, Argemone maxicana, Bidens pilosa, Calotropis gigantean, Chromolaena odorata, Galinsoga quadriradiata, Hyptis suaveolens, Ipomoea carnea, Lantana camara, Mimosa pudica, Parthenium hysterophorus, Senna occidentalis, Senna tora, and Xanthium strumarium* **(Table 1).** Similarly, site 3 contains *Alternanthera philoxeroides, Ageratum conyzoid, Ageratum houstonianum, Ageratina adenophora, Amaranthus spinosus, Argemone maxicana, Bidens pilosa, Calotropis gigantean, Chromolaena odorata, Galinsoga quadriradiata, Hyptis suaveolens, Ipomoea carnea, Lantana camara, Mimosa pudica, Parthenium hysterophorus, Senna alata, Senna occidentalis, Senna tora,* and *Xanthium strumarium. Ageratum haustoniaum, Bidens pilosa, Calotropis gigantean, Gallinsoga quadradiata, Hyptis suaveolens, Ipomoea carnea, Imperata cylindrica, Lantana camara, Parthenium hysterophorus, Senna occidentalis, Senna alata, Senna tora,* and *Xanthium strumarium* are the prevalent species found in all three locations. The distribution of invasive species in reference to Nepal was studied by [21,37,38].

These species are classified into 11 families (**Figure 2**): Asteraceae (8), Amaranthaceae (2), Apocynaceae (1), Convolvulaceae (1), Fabaceae (2), Lamiaceae (1), Mimosaceae (1), Papaveraceae (1), Pontederiaceae (2), Poaceae (1), and Vebenaceae (1). The major family at our study site was Asteraceae. The present investigation of dominant family correlates with the study of [39]. The dominant family was Asteraceae due to its vast seed output and efficient seed and pollen grain dissemination. The majority of IAPS are now widespread, although a few are limited to a specific geographical area. They're invading a vast amount of country. The most prevalent invasive alien plant in forests and shrublands is *Lantana camara*, while the least common is *Hyptis suaveolens*. *Parthenium hysterophorus* is the most prevalent in grasslands and residential areas; *Senna alata* is the least common. *Parthenium hysterophorus* is the most frequent in agroecosystems, and *Ageratum houstonianum* is the least common. *Eichhornia crassipes* is the most frequent in wetlands, whereas *Alternanthera philoxeroides* was the least common [40].

Table 1: Floristic composition, density and IVI of Plant Species in different study sites

Name of IAPs	Common Name	Local Name	Family	Site1 (D1)	Site2 (D2)	Site3 (D3)	IVI
Ageratum conyzoid L.	Billygoat weed	Gandhe	Asteraceae	-	-	3	11.84
Ageratum houstonianum Mill.	Blue billigoat weed	Nilo Gandhe	Asteraceae	12.64	17.86	8.88	31.84
Ageretena adenophora L.	Crofton weed	Kalo Banmara	Asteraceae	-	1.14	5.25	12.26
Alternanthera philoxeroides (Mart.) Griseb.	Alligator weed	Jalajambhu	Amaranthaceae	1.55	-	6.63	15.68
Amaranthus spinosus L.	Spiny pigweed	Kande lude	Pontederiaceae	-	2.86	0.63	8.3
Argemone maxicana L.	Mexican poppy	Thakal	Papaveraceae		0.43	0.38	3.62
Bidens pilosa L.	Black jack	Kalokuro	Asteraceae	1.18	0.43	0.25	4.64
Calotropis gigantean	Milk weed	Aank	Apocynaceae	0.55	1.43	2.13	7.52
Chromolaena odorata (Spreng.) King andRobinson	Siam weed	Setobanmara	Asteraceae	-	3.14	8.25	17.4
Eichhornia crassipes (Mart.) Solms.	Water hyacinth	JalaKumbhi	Pontederiaceae	0.64	-	-	5.19

Galinsoga quadriradiata Ruiz & Pav.	Shaggy soldier	Jhusechirlanga	Asteraceae	4.09	0.43	2	9.98
Hyptis suaveolens (L.) Poit.	Bushmint	Tulsijhar	Lamiaceae	9.09	2.43	7.88	19.5
Imperata cylindrica (P. Beauv. and Rubus ellipticus Sm.)	Cogongrass	Siru	Poaceae	1.82	11.86	4.38	18.07
Ipomoea carnea Jacq.	Pink morning glory	Beshram	Convolvulaceae	2.36	4.57	8.88	17.05
Lantana camara L.	Lantana	Kirnekanda	Vebenaceae	6.45	30.14	11.25	34.68
Mimosa pudica L.	Sensitive plant	Lajjawati	Mimosaceae	0.18	0.43	1.38	4.36
Parthenium hysterophorus L.	Parthenium	Patijhar	Asteraceae	11.09	6.57	11.25	29.32
Senna alata	Candle bush	Alu Pate Jhar	Fabaceae	0.27	1.14	0.38	4.77
Senna occidentalis (L.) Link	Coffee senna	Panwar	Fabaceae	1	1.86	1.63	7.78
Senna tora (L.)	Sickle pod senna	Tapre	Amaranthaceae	12.27	14.14	8.38	31.58
Xanthium strumarium L.	Rough cockle bur	Bhedekuro	Asteraceae	7.18	6.71	5.75	19.68

Note: D1= Density at Site 1, D2= Density at site2 & D3= Density at site 3.

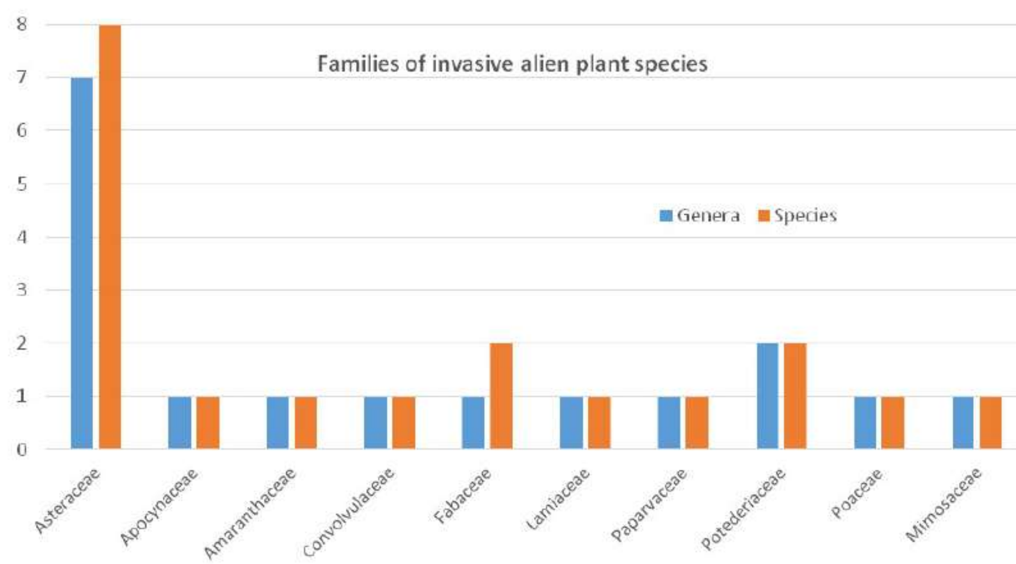

Fig. 2: Families of invasive alien plant species

The scatter plot graph of composition of different genera and species of IAPs, refers to the density of invasive alien plant species across three different sites, whereby D1, D2, and D3 corresponds to measurement across Site 1, Site 2, and Site 3, respectively. Most data points across the three sites lie at the lowest part of the y-axis. Hence, most of the species have low densities irrespective of the sites. However, a few species were high-density outliers, such as *Lantana camara,* which had a D2 value of 30.14 in Site 2, and *Imperata cylindrica*, which had a D2 value of 11.86 also in Site 2, indicating higher invasiveness in the site. The overall downward trend of the scatter plot suggests that the densities are somewhat lower in Site 3, which may reflect environmental or ecological differences among the sites. This distribution underlines the fact that, while the majority of species remain at low density across all sites, a few high-density species have to be taken care of through focused management in Site 2, where the density level is more pronounced **(Figure 3)**.

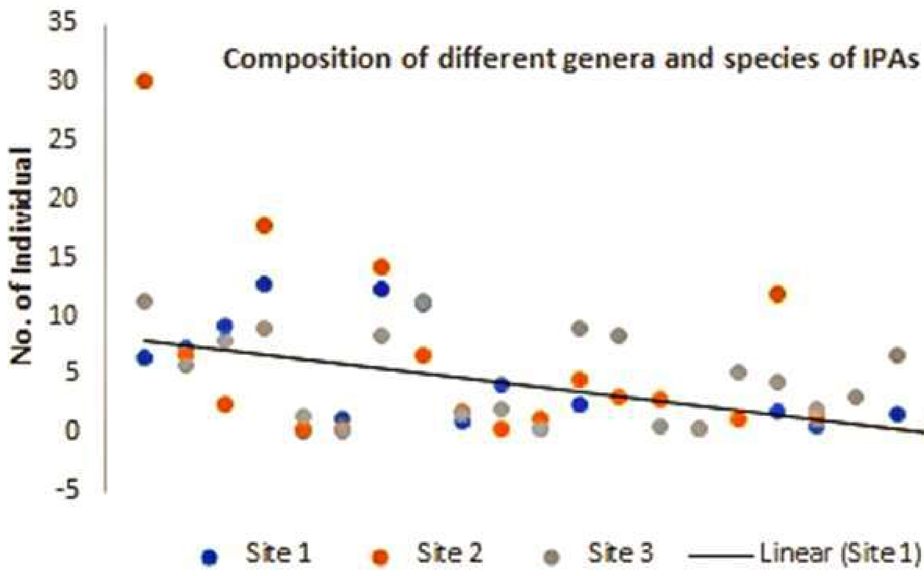

Fig. 3: Composition of different genera and species of IAPs in the study sites.

3.1 Top Dominating Invasive Plant Species

Ten plant species were identified as top dominating (IVI > 15.68) throughout all study sites based on the Importance Value Index (IVI). Of these, *Parthenium hysterophorus* had the highest importance value index (IVI) of the dominant invasive alien plant species at site 1, while *Mimosa pudica* had the lowest (2). In contrast, *Lantana camara* had the highest IVI of the dominant invasive alien plant species at site 2, while *Argemone maxicana* had the lowest (3.82). *Parthenium hysterophorus* had the highest important value index of dominating invasive alien plant species at site 3 (28.35), while *Bidens pilosa* had the lowest (2.85) (**Figure 4**). The present findings were more or less similar with the findings of [41]. Of the reported top dominating IAPs, three of them-*Lantana camara, Chromolaena odorata*, and *Eichhornia crassipes*-are listed among the top 100 invasive alien species worldwide [42].

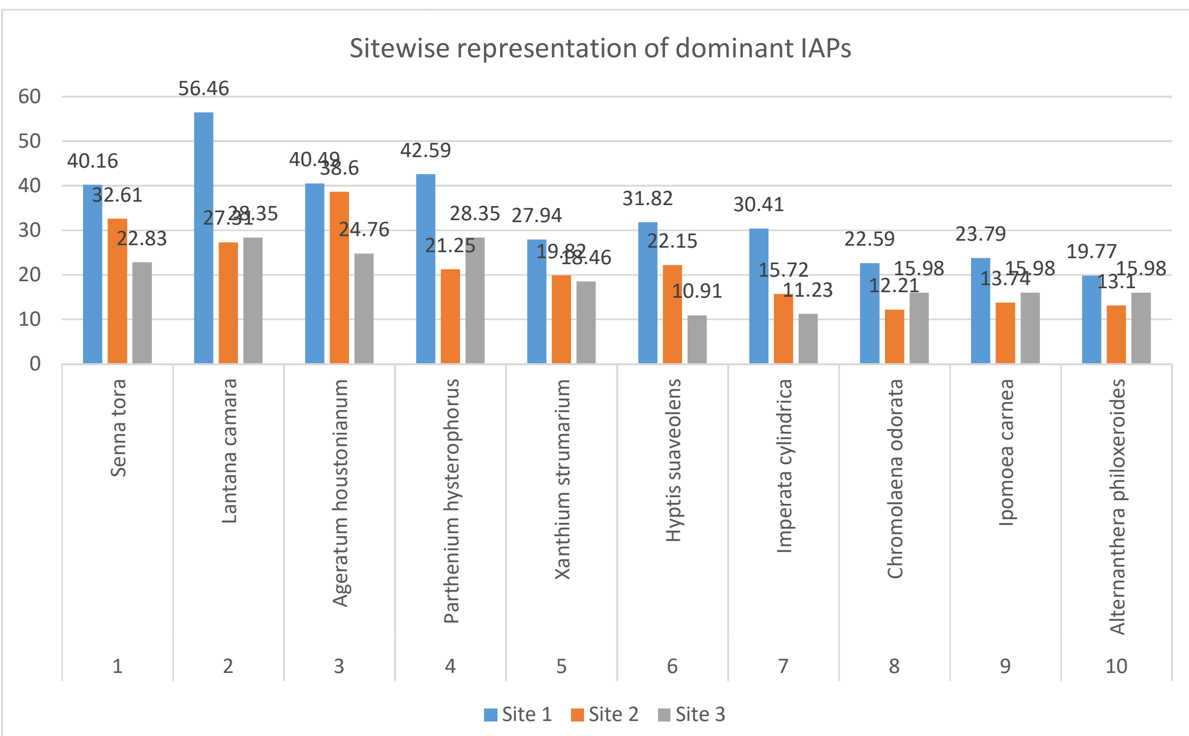

Fig. 4: Site wise representation of dominant IAPs

The plot graph (**Figure 5**) shows the average density of various top dominating invasive alien plant species. The y-axis shows the values of average density that range from close to 50 down to approximately 8, an indication of the extent different species dominates the ecosystem. The x-axis has to refer to the species index from the table, going from highest ranked in density to lowest ranked. Every point in this plot is an average density of some species, and the overall trend is captured by a downward sloping trend line. The slope in this line is steep-it reflects a very strong negative correlation; moving from the first species to the last, average density systematically drops. This is in agreement with the values in the table, which shows that *Lantana camara* has the highest average density, being 47.85, followed by *Ageratum houstonianum* with an average of 39.37, while species like *Chromolaena odorata* and *Alternanthera philoxeroides* are at the lower extreme, with densities of 11.39 and 8.17, respectively. In some ways, this hierarchy of density is reinforced by the plot and table alignment, and it would only be expected that species at the top of such a list may be more common and hence have a stronger effect on the ecosystem. This visual and numerical ranking underlines the dominance of such species as *Lantana camara* and *Ageratum houstonianum*, which can possibly have greater threats to local biodiversity because of their extensive spread. The downward trend in this plot indicates the lesser spread and perhaps lower competitive ability of the species towards the bottom, like *Alternanthera philoxeroides*.

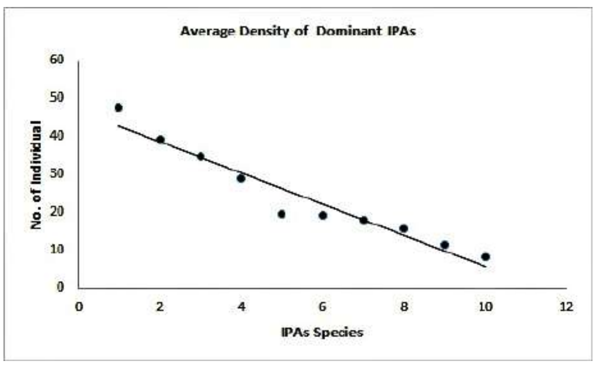

Fig. 5: Average density of dominant IAPs

3.3. Impacts of IAPS

Invasive alien plant species (IAPS) pose a substantial danger to global biodiversity by disrupting ecosystem functioning and services while also contributing to climate change. IAPS is widely recognized as the second biggest driver of biodiversity loss [43,44]. On average, IAPS diminish native plant fitness and growth by 41.7% and 22.1%, respectively, causing severe changes in local-ecosystems [14]. IAPS can also cause "invasion meltdowns," in which one invasive species promotes the invasion of another, exacerbating ecological damage [45]. These species flourish in nutrient-rich settings and changed fire regimes, which increase their dominance and damage local flora and fauna [46,47].

The repercussions of IAPS go beyond biodiversity loss. They can impair water sources and destabilize soils, causing erosion and increasing water scarcity problems [48,49]. Furthermore, IAPS might restrict water transportation and reduce recreational and tourism opportunities, causing economic losses [50]. While some IAPS may provide aesthetic and recreational benefits, they frequently degrade the ecosystems they invade, resulting in the loss of regulatory services such as biological pest control, pollination, and climate regulation, all of which are essential for agriculture and forestry [49, 51].

The effect of IAPS on human health is multifaceted. Some species, such as *Lantana camara*, are useful for repelling mosquitos [52,53]. Others, like as *Parthenium hysterophorus*, pose serious health dangers by serving as vectors for diseases like malaria and causing allergies, respiratory issues, and skin ailments. Furthermore, *Parthenium* has been shown to transmit phytoplasmas that are damaging to crops [54].

3.3 Reproductive behavior of dominant IAPs

In Nepal very few studies have been conducted on the IAPs, especially their reproductive biology, whereas in developed countries considerable literature is available on the biology of IAPs including characteristics, phenology and life cycle of many species. Only a few works on reproductive biology are available in tropical weeds [55] and temperate weeds [56,57]. The knowledge of reproductive biology is essential for proper management of IAPs.

The current study investigated the reproductive biology of dominant invasive alien plant species across sites. From which 10 species reported as dominant species of which nine terrestrial species were selected for reproductive biological analysis. One species, *Alternanthera philoxeroides,* also known as alligator weed, was not subjected to reproduction measurement in detail, as being aquatic in nature required a different methodology. So, reproductive biology of nine major IAPs identified on the basis of IVI. The seed germination was generally high above 70% in *Lantana camara, Parthenium hysterophorus*, *Senna tora*, *Hyptis suaveolens*, *Senna occidentalis* and low 30% in *Xanthium strumarium* (**Table 3**). The germination data obtained from our study were in their raw form. However, we have tried to make the data clear and valid with the support of the findings of [55,56,57] that correspond with our study. There is a correlation between the seeds and their weight. In the present study the IAPs with lighter seeds produced higher number of seeds which are believed to be a feature of soil seed banks. [58] stated that small seeds have a better chance to enter into the soil easily than the bigger ones. IAPs differ greatly in seed production, seed size, physical conditions of crop fields, competition with the crop and production level factors play important role. In the present study highest seed weight 2.40 gm was recorded in *Xanthium strumarium* species and lowest seed weight 0.03 gm in *Hyptis suaveolens* species.

Table 3: Reproductive behaviours of dominant IAPs.

Parameters	*A. houstonianum*	*Chromolaena odorata*	*Lantana camara*	*Parthenium hysterophorus*	*Senna tora*	*Senna occidentalis*	*Xanthium strumarium*	*Galinsoga quadriradiata*	*Hyptis suaveolens*
Flower colour	Blue, white, Pink	Whitish Blue	Mix red, orange, yellow or purple, white	Whitish cream like	Yellow	Yellow	Yellowish Green	Golden Yellow	Purple, blue
Agent of pollination	Insect, Butterflies	Insect	Insect, Butterflies, Bees	Wind, water, insect	Bees	Beetles	Wind	Insect	Bees
Number of seeds/fruit	40,000 seed per plant	80,000 to 90,000 per plant	1 to 20 seeds on each flower	4-5 seed per flower	20 to 40 seeds per pod	30 to 40 seeds	2 seed per fruit	7,500 seed per plant	Up to 3,000 seed per plant
Life span	Annual	Perennial	Annual	Annual	Annual	Annual or perennial	Annual	Annual	annual
Seed colour	Brown to black	Blackish	Blue black	Black	Greenish	Brown with pale band	Green yellow, Brown	Brownish black	Shiny black
Seed shape	Slender	Elongated	Rounded	Wedge shaped	Cylindrical	Flat	Oval	Cylinder or oval	Shield shaped
Seed size (mm)	0.62mm	0.03mm^2	3.233mm^2	0.04mm^2	1.987mm^2	1.573mm^2	5.85mm^2	0.13mm^2	1.02mm
10 seed weight (g)	0.014		0.18		0.15	0.18	2.40	0.033	0.03
Method of dispersal	Wind, animal, human, water	Wind	Wind, animal, bird	Wind, animal, water	Agricultural tool, animal dung, animal, water	Agricultural tools, animal, human, seed,water	Animal, human, water	Animal	Animal, human, water
Time for 1st seed to germinate (days)	3 - 5 days	7 - 9 days	3 - 4 days	6 - 7th days	7 days	8 - 14 days	7 days	9 - 10 days	10 - 12 days
Germination (%)	48 - 50	50 - 80	50 - 80	60 – 90	70 - 90	50 - 80	30 - 40	70 - 90	50 - 80
Reproductive means	Seed	Seed	Seed	Seed	Seed	Seed	Seed	Seed	Seed

4. CONCLUSION

Invasive alien plant species (IAPs) are the species of plant that are non-native, non-indigenous, exotic and foreign and or introduced to an ecosystem other than its natural home by direct or indirect involvement of humans knowingly or unknowingly. Invasive plants usually possess traits that make them effective invaders such as a short life cycle, high growth rate, and large number of seeds with good dispersal ability and good colonizing capacity. A total of 21 species were recorded in three sites of study area of which 16 species were present at site1, 18 species at site 2 and 20 species at site 3 indicate the area was suitable for invasive species. All the investigated species were belonged to 11 families. Of these the maximum importance value index of dominant plant species was recorded by *Lantana camara* (34.68) and minimum by *Alternanthera* *philoxeroides* (15.68). Of the reported species *Lantana camara*, *Chromolaena odorata* and *Eichhornia crassipes* were included in world's 100 worst invasive alien plant species [42]. In the present findings, agriculture, ecosystem services, climate, human health and animal and economy were highly affected by IAPs. IAPs destroy the quality and quantity of natural scenario, soil, crops and thus cause loss in country's economy. As per the [59], management of these alien species, the Strategy has included a number of activities such as nation-wide distribution survey of five most problematic IAPS, development of atlas for the identification and early detection of invasive species, enhancement of the capacity of custom and quarantine offices, use of appropriate biological control agents, and public education and community participation.

5. Recommendations

Invasive alien species are already widespread with wide ranging ecological and socioeconomic impacts which are most likely to increase continuously in future under business-as-usual scenarios. For the proper managements would be applied to conduct initiation of biological control program, education and awareness among all stakeholders including policy makers, community participation, institution and Governance, integration with responses to other components of global environmental changes, particularly the climate change, and land use and land cover change, National Strategy of Invasive Alien Species Management. The integrated approach to IAPS management will includes long-term prevention, border phytosanitary measures, and public awareness for early infestation detection and control. Mechanical removal of the species, pesticide use, and iological means of introducing predators following rigorous risk sessments, as well as restoration of native vegetation by replanting and buffer zone formation, will be used as control approaches. IAPS demands community participation through sustainable livelihoods, and its design, implementation, and monitoring are all done with community input. Strategic management is improved by IAPS biology research, a centralized database, and policy development at all levels, including cross-border cooperation.

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