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Dynamics of Ecological Value and Biodiversity of Invasive Plant Species and Grass Species in Protected Areas (Study from Shivapuri Nagarjun National Park, Nepal)

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ABSTRACT

Invasive species are upsetting the native grass species in protected areas. However, there is limited study regarding the invasive species so far. Thus, the study was objectively conducted to assess grass species and invasive plant species in Shivapuri Nagarjun National Park, where ecological value and biodiversity index as well as illustration of distribution of invasive plant species and grass species in a map was done. The preliminary field visit was done to identify the areas affected by invasive plant species in Shivapuri Nagarjun National park. Panimuhan, Gurje Bhanjyang, Sundarijal, and Fulbari Gate were chosen as research sites. A map of research sites was developed with the coordinates by using Google earth and Arc GIS 10.5. Total 40 samples having 5m x 5m plots were randomly distributed on the affected sites to collect data. The plant's number, diameter and crown width were recorded. The Importance Value index was calculated for both the grass species and invasive plant species. Similarly, Shannon-Wiener index, Simpson's index of diversity and Species richness were calculated. The result showed that total 23 plant species were recorded in these sites. Out of these, there were 18 grass species and 5 invasive species. In Panimuhan, *Ageratina adenophora* was resulted as highest with 68.10%. *Bidens pilosa* was recorded highest with 48.18% followed by *Ageratina adenophora* with 47.48% at Gurje Bhanjyang. Similarly, *Ageratina adenophora* was recorded highest with 60.12% in Sundarijal site. In Fulbari Gate, IPS Lantana camara was recorded highest with 44.22%. The Importance Value index was recorded highest in Panimuhan, Gurje Bhanjyang and Sundarijal with 184.77, 126.67 and 121.36 respectively. In Fulbari Gate, the highest Importance Value index was recorded by Lantana camara with 107.14. Though Shannon- Wiener index and Simpson's index of diversity was higher of grass species, Species richness was resulted higher of Invasive plant species in all sites. The independent t-test showed that there significant differences between grass species and Invasive

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plant species at 95% confidence level. The spatial distribution of *Ageratina adenophora* was highest in Panimuhan, Gurje Bhanjyang and Sundarijal whereas *Lantana camara* was distributed highest in Fulbari Gate.

Keywords: Invasive plant species, *Ageratina adenophora*, Shivapuri Nagarjun National Park

1. INTRODUCTION

Invasive Plant Species (IPS) are the newly introduced plant species in the environment that is imported either by natural processes or human activities from their original habitat, and it causes harm to the environment, economy, human health, and ecosystems. All exotic plants are not harmful but some alien species creates damage to the natural habitat it is known as Invasive Alien Plant Species which goes through a rapid succession process [1]. It is considered as the second threat to the biodiversity in the world [2]. The global spread of invasive plant and animal species affect the growth and survival of other species [3,4]. The invasive plant species can destroy the native habitat of plants and animals [5, 6].

Several parts of world have facing the effect of invasive plant species in the world. For example, the destruction of habitat, a danger to human safety, and damages seen on agriculture caused by invasive species in Japan [15]. Similarly, around 513 species of alien invasive seed plant species have been recorded in China which are causing the biodiversity loss[16]. *Mimosa pudica, Mikania micanthra, Lantana camara, Chromolaena odorata* are causing diversity loss in Bangladesh, Bhutan and India [17]. Total 66 species of invasive plants were recorded in Darjeeling India [18].

Nepal is facing a great challenge of invasive species. The study done by Shrestha (2017) showed that there are 26 invasive plant species in Nepal. Out of this, *Lantana camara, Mikania micrantha, Chromolaena odorata,* and *Eichhornia crassipes* are serious invasive species in Nepal which are also enlisted in The World's Worst Invasive Species [8]. The effect of invasive species particularly in national park is more serious because it causes the loss of native grass species which are major food for most of the wild herbivore animals. [9]. Most of the study showed that most of the parts of grassy areas in national park is affected by invasive species in Nepal [4], [10] [11]. Shivapuri Nagarjun national park is one of the famous national park in Nepal because this is nearest to capital city and represents biodiversity of hilly areas. However, invasive plant species have been affecting the native grass species which are food of variety hilly herbivores. These days, native grass species have been seriously affected because of invasive plant species. However, there is no any study regarding this. Thus, this study was objectively conducted to assess effect of invasive plant species on native grass species.

2. MATERIALS AND METHODS

Study area: The forest of Shivapuri lies within 27°45' to 27°52' N latitude and 85°16' to 85°45' E longitude and the forest of Nagarjun lies within 27°43' to 27°46' N latitude and 85°13' to 85°18' E longitude. The elevation range lies from 960m to 2732m. The total area of SSNP is 159 km^2 where Shivapuri covers 144 km^2 and Nagarjun covers 15 km^2. It covers part of Kathmandu, Nuwakot, Dhading, and Sindhupalchwok districts of Nepal. Panimuhan, Gurje Bhanjyang, Sundarijal and Fulbari Gate sites in the national parks were study area (*Figure 1*) [2] [3].

The average mean temperature ranges from 22.7 °C to a minimum temperature of 0.30°C. The SNNP average annual rainfall is 2727 mm. There are four types of forests namely lower mixed hardwood forest, Chirpine forest, Upper mixed hardwood forest, and Oak forest in the national park. This national park is habitat for 1114 species of flowering plants, 102 species of medicinal plants, 49 species of edible plants, and 16 endangered plants. *Schima wallichii, Castanopsis indica, Alnus nepalensis, Pinus roxburghii, Quercus semicarpiflora, Rhododendron arbouem* are dominantly found in the national park[11]. In total 124 species of butterflies, 30 species of mammals, and 320 species of birds are found in the national park [11].

The preliminary field visit was undertaken in 2nd February, 2021 to determine the location of invasive plants species affected areas. The data collection was done from 20th February to 5th March 2021. The GPS coordinates was taken to prepare the map. Total of 120 sample plots were distributed on the map and 5mx5m was established to collect the field data. The number of plants was counted. Along with this, diameter and crown width were also measured.

The collected data were analyzed using a. Ecological value of native grass species and invasive plant species and b. biodiversity indexes.

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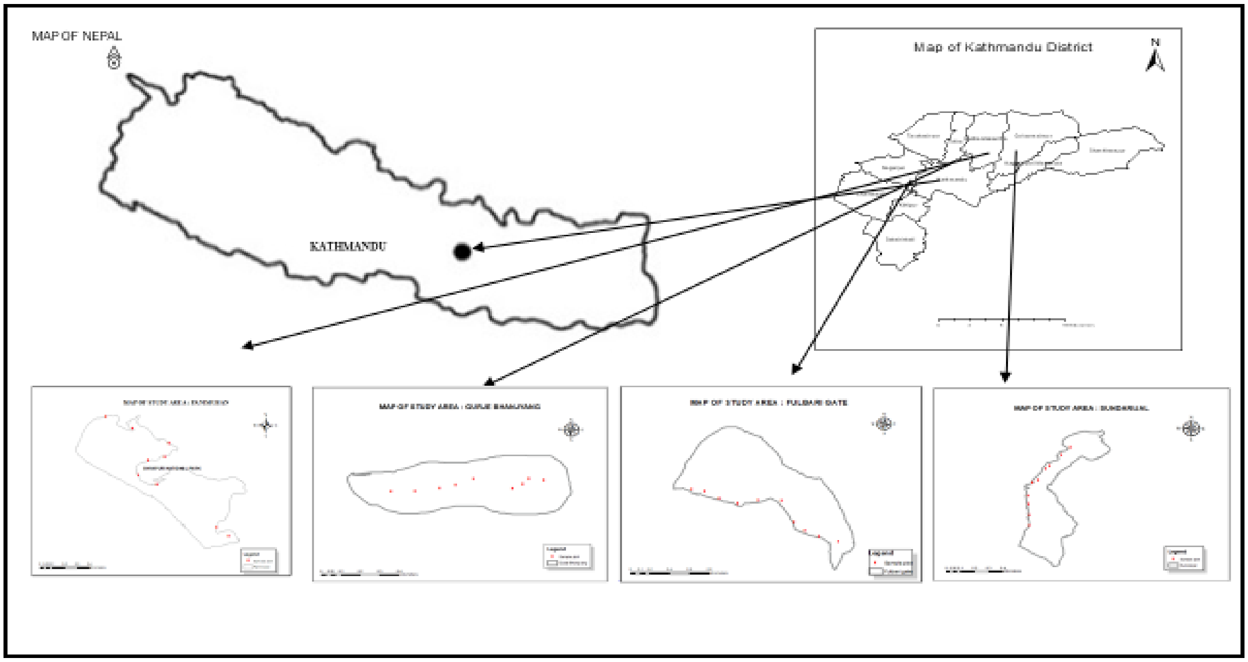

Figure 1: Map of different study areas of Shivapuri Nagarjun National Park

a. Importance Value Index (IVI) (Curtis and McIntosh, 1950, Zobel et al. 1987):

IVI was calculated to determine the dominance of the species in the community. It requires relative measures of density, dominance, and frequency.

IVI= Relative density + Relative frequency + Relative dominance

Where,

Relative density = (Number of specific individuals of the species / Number of individuals of all the species) X 100…….. (i)

Relative frequency = (Number of plots with individual species / Total number of plots studied) x 100……… (ii)

Relative dominance = (Total basal area of a particular species / Total basal area of all species) x100 …… (iii)

b. Biodiversity index of grass species and IAPS

Biodiversity calculation was assessed and compared to understand the effect of invasive species on biodiversity.

I. Shannon-Wiener index (Ma and Liu, 1994)

The value of Shannon Wiener index ranges from 0 to 1. The value of 0 represents the presence of only one species whereas 1 represents all species are equally present.

It was calculated as

$H= \sum^{s}_{i=1} - (P_i \text{ X } \ln P_i)$

Where, H= Shannon Wiener Diversity index

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

S= number of species encountered

II. Simpson's index of diversity (E.H Simpson, 1949)

Simpson's index of diversity is the compliment of Simpson index where the value ranges from 0 to 1, and calculated as 1-D. In Simpson's index of diversity higher the value of the index higher is the diversity of the sample. Simpson's index of diversity is calculated as:

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$$D = \frac{1 - \Sigma n\,(n-1)}{N\,(N-1)}$$

Where, n = the number of individuals displaying one sample
N = the total number of all individuals

III. Species richness

Species richness was also be calculated as follow:
Species richness = S/√N
Where S= Number of species in a community
N= Number of individuals of all species in a community

3. RESULT

3.1 Grass and Invasive Plant Species in different sites of Shivapuri Nagarjun National Park

3.1.1 List of Grass and Invasive Plant Species at different sites in SNNP

The grass species in SNNP differed depending on the location. There were a total of 23 plant species were recorded in these sites. There were 18 grass species and 5 different IPS among them. There were 5, 5, 7 and 10 different type of grass species at Panimuhan, Gurje Bhanjyang, Sundarijal and Fulbari Gate respectively. Similarly, there were 2, 2, 2 and 5 different types of IPS at Panimuhan, Gurje Bhanjyang, Sundarijal and Fulbari Gate respectively (Table 1).

Table 1: List of grass and IPS at different sites in SNNP

S.N	Name of species	Local/Common Name	Panimuhan	Gurje Bhanjyang	Sundarijal	Fulbari Gate
			GRASS SPECIES			
1	*Artemisia vulgaris*	Titepati	✓	✓	*	✓
2	*Athyrium filix- femina*	Lady fern	*	✓	✓	✓
3	*Buddleja asiatica*	Bhimsenpati	✓	*	*	*
4	*Cenchrus ciliaris*	Fox tail buffalo grass	*	✓	*	*
5	*Colocasia antiquorum*	Karkalo	*	*	✓	*
6	*Cynodon dactylon*	Dubo	*	✓	✓	✓
7	*Cyperus iria*	Rice flat sedge	✓	*	*	*
8	*Digitaria sanguinalis*	Hairy crab grass	*	*	*	✓
9	*Equisetum arvense*	Field horse tail	*	*	✓	*
10	*Eragrostis tenella*	Banso	*	✓	*	*
11	*Eulaliopsis binate*	Babiyo	*	✓	*	✓
12	*Galinsoga parviflora*	Gallant soldier	*	*	✓	*
13	*Homalium ceylanium*		*	*	*	✓
14	*Imperata cylindrical*	Siru	*	✓	✓	✓
15	*Plantago lanceolata*	Ribwort plantain	*	*	*	✓
16	*Sachharum spontaneum*	Kash	✓	*	*	✓

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17	*Trifolium repens*	White clover	*	*	*	✓
18	*Utrica dioica*	Sisnu	✓	*	✓	*
		INVASIVE PLANT SPECIES				
1.	*Ageratina adenophora/ Eupatorium adenophorum*	Crofton weed , Kalo banmara	✓	✓	✓	✓
2.	*Bidens pilosa*	Beggar's stick , Kuro	✓	✓	✓	✓
3.	*Lantana camara*	Ban phanda	*	*	*	✓
4.	*Ageratum conyzoides*	Billy goat weed ,Raunne	*	*	*	✓
5.	*Amaranthus spinousus*	Spiny pigweed, Kande lude	*	*	*	✓

✓ *= present* *= absent*

3.1.2 Percentage of total number of grass and IP species in different sites of SNNP

Various grass species and IPS were present in sample sites, with varying percentage.

Percentage of grass species and IPS at Panimuhan (Site 1)

Depending upon the species, the percentage of grass and IPS was different. In case of grass species *Artemisia vulgaris* was the highest percentage of presence with 7.57%. The least percentage was recorded by *Buddleja asiatica* with 0.33%. In case of IPS *Ageratina adenophora* had the highest percentage of presence with 68.18 % and *Bidens pilosa* was recorded with 15. 80% (Figure 2)

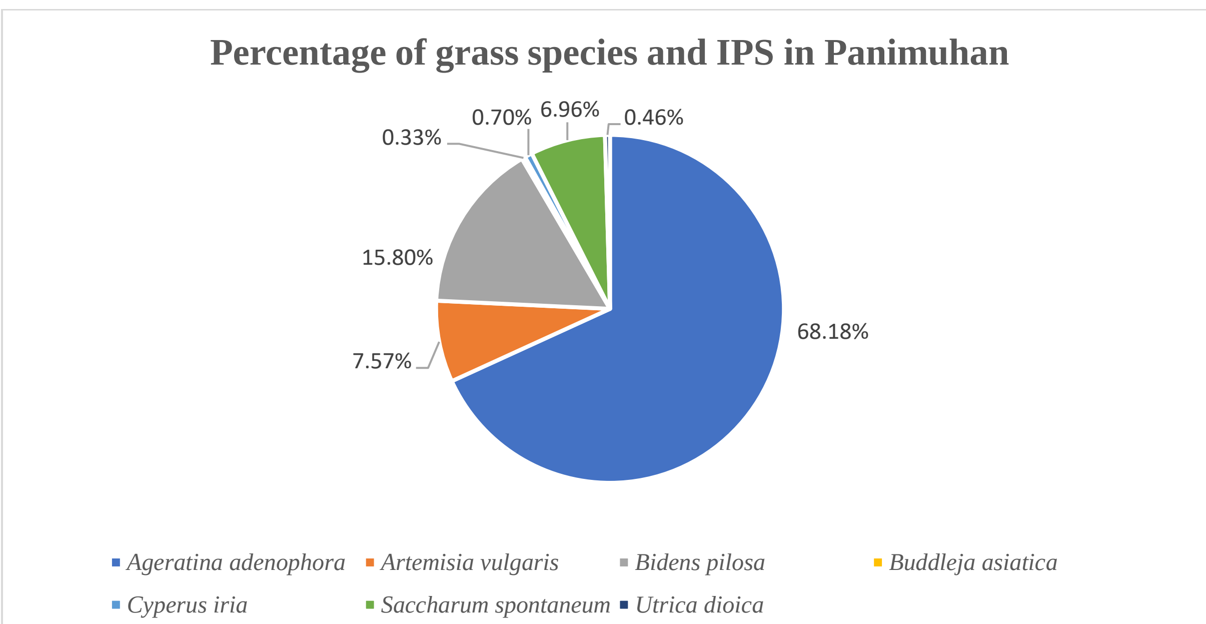

Figure 2: Percentage of grass species and IPS in Panimuhan

Percentage of grass species and IPS at Gurje bhanjyang (Site 2)

The percentage of presence was highest of *Eragrostis tenella* with 2.49 % whereas, *Artemisia vulgaris* was the least percentage of presence accounting with 0.04 %. In case of IPS *Bidens pilosa* recorded highest percentage of presence with 48.18% followed by *Ageratina adenophora* with 47.48 % (Figure 3).

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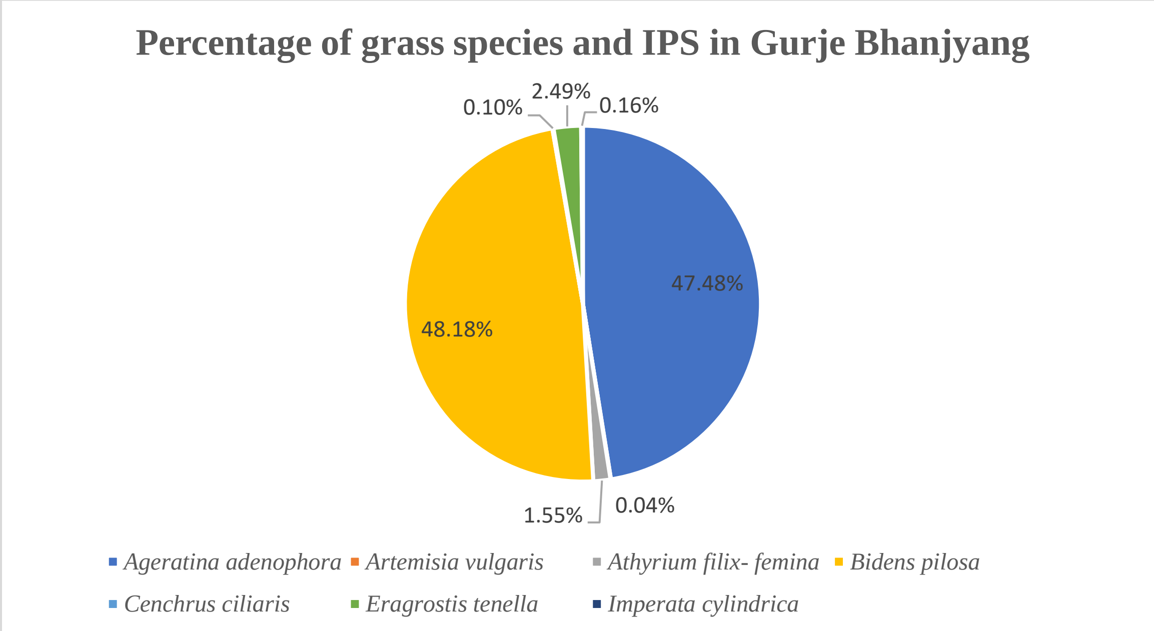

Figure 3: Percentage of grass species and IPS in Gurje bhanjyang

Percentage of grass species and IPS at Sundarijal (Site 3)

Sundarijal was the third site where the study was done. In case of grass species, *Colocasia antiquorum* was with highest percentage of presence with 18.20 % whereas *Imperata cylindrica* was the grass species which was seen in lowest number, which accounted with 0.12 %.

In case of IPS *Ageratina adenophora* was recorded with highest percentage of presence with 60.12 % followed by *Bidens pilosa* with 0.12 % (Figure 4).

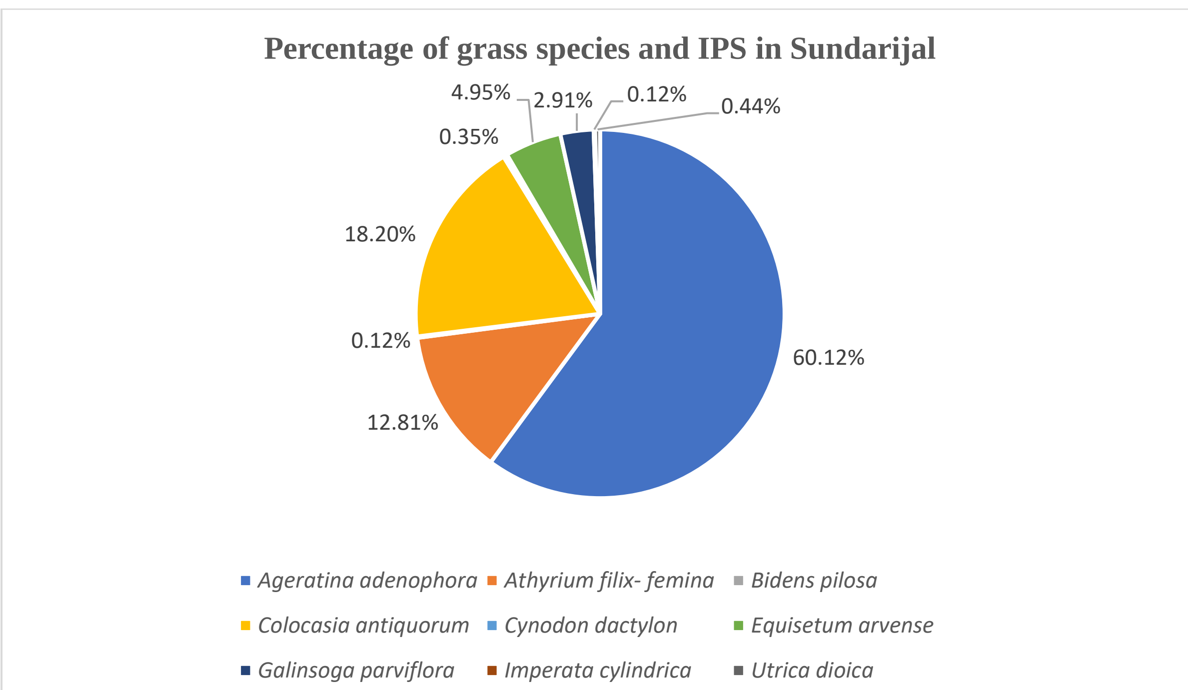

Figure 4: Percentage of grass species and IPS in Sundarijal

Percentage of grass species and IPS at Fulbari Gate (Site 4)

Fulbari Gate is one of the entry point of Nagarjun National Park and in this site as well species were observed and studied. In terms of grass species *Cynodon dactylon* was found more in number which accounted 10.40 % of presence whereas, *Sachharum spontaneum*

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was least percentage of presence with 0.21%. Out of five different types of IPS, *Lantana camara* had the highest percentage of presence with 44.22 % while *Amaranthus spinousus* had least percentage of presence with 1.39 % (Figure 5).

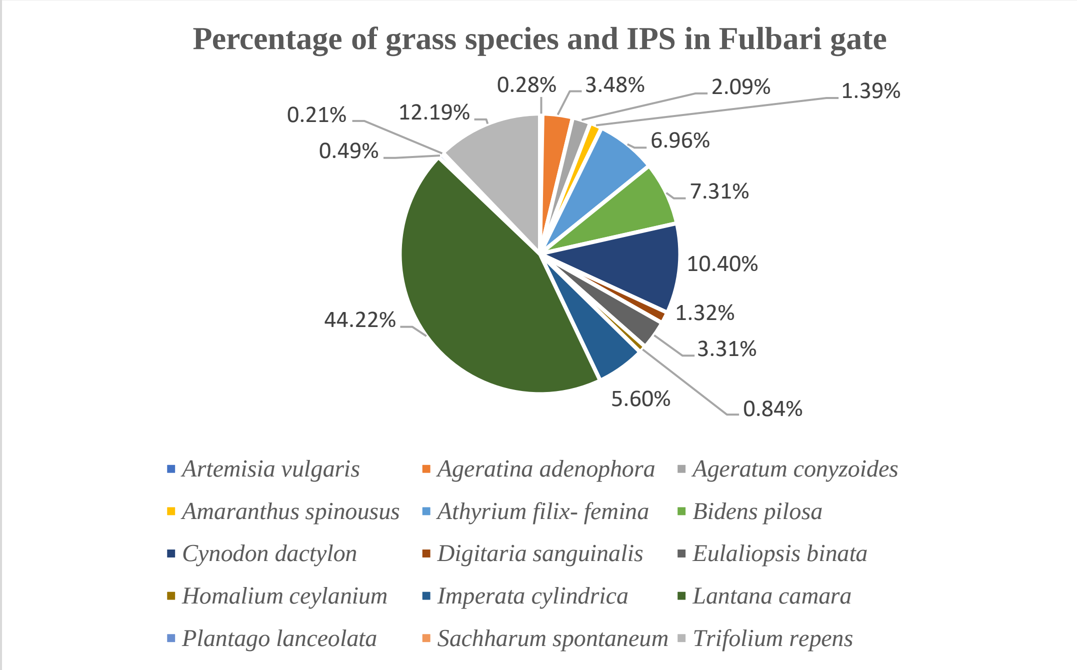

Figure 5: Percentage of grass species and IPS in Fulbari Gate

Importance Value index of grass species and IPS at Panimuhan:

The IVI was varying according to plant species. The IVI of *Ageratina adenophora* accounted with, 184.77 which resulted as the most dominant species whereas *Utrica dioica accounted* lowest IVI, 7.60 which resulted as the least dominant species (figure 6).

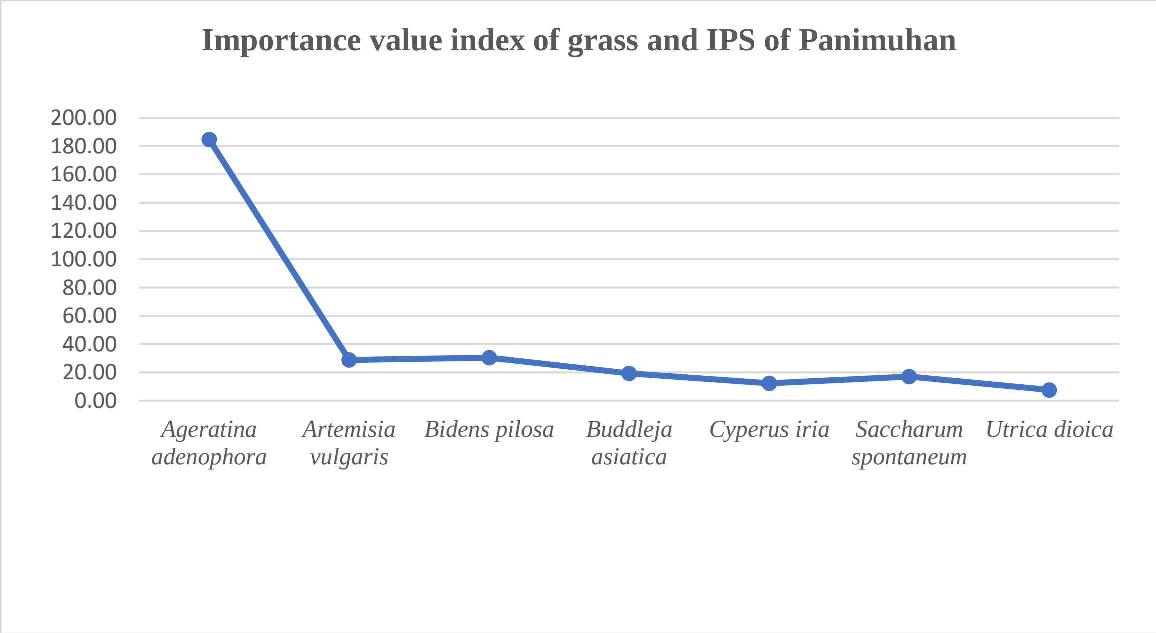

Figure 6: Importance value index of grass and IPS of Panimuhan

In Panimuhan, ecological value of IPS was higher than that of grass species.

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Importance Value index of grass species and IPS at Gurje Bhanjyang:

The result showed that the highest value of IVI was recorded of *Ageratina adenophora* (invasive species) with 126.67 whereas *Cenchrus ciliaris* (grass species) accounted lowest IVI with 9.26 (Figure 7).

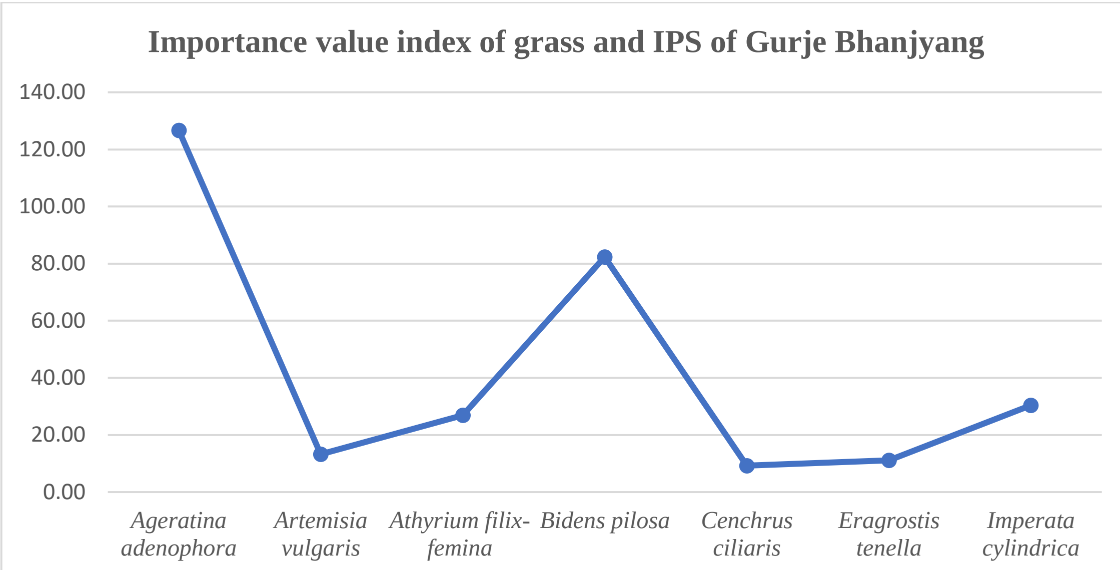

Figure 7: Importance value index of grass and IPS of Gurje Bhanjyang

Percentage of Importance Value index of grass species and IPS at Sundarijal:

The highest was accounted of *Ageratina adenophora* with 121.36 but it was the lowest value of IVI of *Cynodon dactylon* (most preferred grass species of deer) with 8.40 (Figure 8).

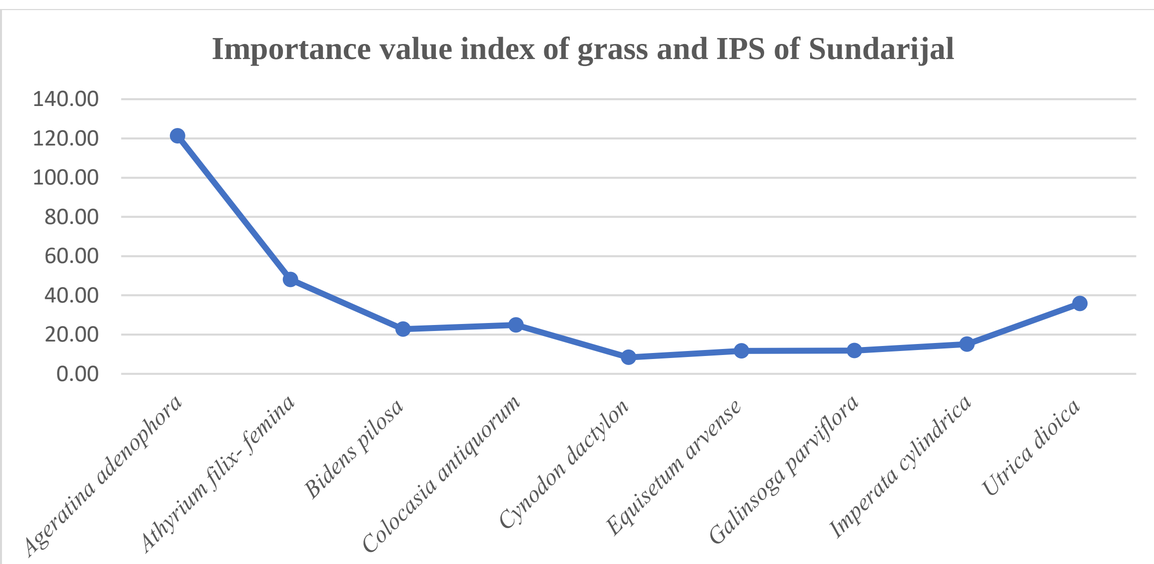

Figure 8: Importance value index of grass and IPS of Sundarijal

In Sundarijal, IVI of IPS was more than the grass species.

Percentage of Importance Value index of grass species and IPS at Fulbari Gate:

The highest IVI was found of *Lantana camara* with 107.14 but it was only 6.43 IVI of *Artemisia vulgaris* (Figure 9).

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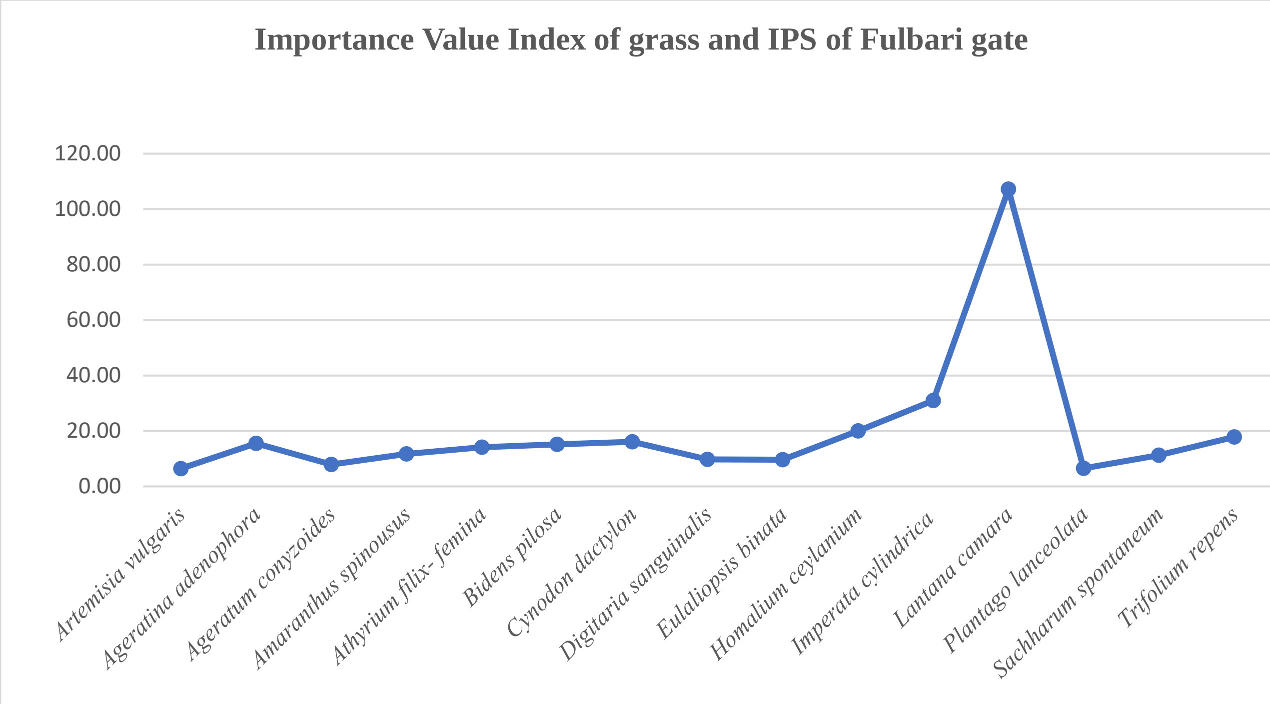

Figure 9: Importance Value Index of grass and IPS of Fulbari gate

Percentage of Ecological value of grass species and IPS:

The ecological value of grass species and IPS was totaled separately for each sites and the percentage of both grass and IPS was calculated (Table 2).

Table 2: Percentage of Ecological value of grass species and IPS

S.N	Location	Total IVI of grass species	Percentage of IVI of grass species	Total IVI of IPS	Percentage of IVI of IPS
1.	Panimuhan	84.90	28.3	215.10	71.7
2.	Gurje Bhanjyang	91.02	30.34	208.98	69.66
3.	Sundarijal	155.91	51.97	144.09	48.03
4.	Fulbari Gate	142.63	47.543	157.37	52.457

Sundarijal had the highest percentage of ecological value with grass species, while Panimuhan had the lowest, and the IPS had the opposite result.

Table 3: Biodiversity indices at different sites

Biodiversity index	**Panimuhan site**		**Bhanjyang site**		**Sundarijal site**		**Fulbari Gate site**	
	Value of grass spp	Value of IPS	Value of grass spp	Value of IPS	Value of grass spp	Value of IPS	Value of grass spp	Value of IPS
Shannon – Wiener index	1.03	0.48			1.28	0.01	1.77	0.84
Simpson's index of diversity	0.58	0.30			0.66	0.003	0.79	0.40
Species richness	26.36	60.12			36.96	45.49	24.41	28.98

The diversity of the grass species was resulted as highest in comparison with IPS through calculation even though the number of individuals of IPS was more than grass species.

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Biodiversity indices of grass and Invasive plant species:

The biodiversity indices of grass and IPS was calculated with the collected data of different sites of the NP. Shannon – Wiener index, Simpson's index of diversity and species richness was were included for the determination of biodiversity of the grass species and IPS (Table 3).

Biodiversity indices at Panimuhan site:

The value of Shannon-Wiener index was highest for grass species with 1.03 than in comparison to IPS with 0.48. Similarly, value of Simpson's index of diversity was higher of grass species with 0.58 than in comparison to IPS with 0.30. But the species richness was highest for the IPS with 60.12 than the grass species with 26.36.

Biodiversity indices at Gurje Bhanjyang:

The Shannon –Wiener index was obtained higher for grass species with 0.93 than IPS with 0.69 for the Gurje Bhanjyang site. In case of Simpson's index of diversity the value was obtained higher for grass species with 0.54 as well than IPS. But the species richness was obtained higher for IPS with 87.71 in comparison to grass species. In case of Gurje Bhanjyang site also, the diversity of grass species was obtained high than in comparison to IPS through calculation even though the number of individual of IPS was high.

Biodiversity indices at Sundarijal:

The value of Shannon -Wiener index was obtained highest for grass species with 1.28 than IPS with 0.01. Similarly, the value of Simpson's index of diversity was higher for grass species with 0.66 than IPS with 0.003. Species richness was high for IPS with 45.49 in comparison to grass species.

Biodiversity indices at Fulbari Gate:

For the site, Fulbari gate also Shannon –Wiener index was obtained higher for grass species with 1.77 than IPS with 0.84.Similarly, in case of Simpson's index of diversity also the value was high for grass species with 0.79 than IPS with 0.40. But, Species richness was obtained higher for IPS with 28.98 than grass species in the site. Hence, diversity was found to be high for grass species in Fulbari Gate site even though the number of individual of IPS was higher than other grass species.

Statistical comparison of species diversity of grass species and IPS:

Statistically, independent t-test was applied to compare the biodiversity indices of grass species and IPS. Specifically, the independent t-test showed that there was significant difference in Shannon-Wiener index between grass species and IPS at 5% level of significance since p-value was less than 0.05, while p value was 0.00. Similarly, the Shannon index of diversity was tested with an independent t-test and it showed that there was significant difference in Shannon index of diversity between grass species and IPS at 5% level of significance since p- value was less than 0.05, while the p value was 0.00. Likewise, Species richness of grass species and IPS was also tested with an independent t-test and it showed that there was significant difference in species richness between grass species and IPS at 5% level of significance since p-value was less than 0.05, while p value was 0.00 (Table 4).

Table 4: Comparison of species diversity of grass species and IPS

Site	Comparison of biodiversity by p value (t test)					
	Shannon – Wiener index		Simpson's index of diversity		Species richness	
Panimuhan	P value	0.00	P value	0.00	P value	0.00
	Decision	Significant	Decision	Significant	Decision	Significant
Gurje Bhanjyang	P value	0.00	P value	0.00	P value	0.00
	Decision	Significant	Decision	Significant	Decision	Significant
Sundarijal	P value	0.00	P value	0.00	P value	0.00
	Decision	Significant	Decision	Significant	Decision	Significant
Fulbari Gate	P value	0.00	P value	0.00	P value	0.00
	Decision	Significant	Decision	Significant	Decision	Significant

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4. DISCUSSION

The study identified the presence of eighteen different types of grass species and five different types of IPS in different study sites of the NP. No earlier research regarding the IPS was done in the NP as these species had not gained much attention as in Terai belt of Nepal. But unfortunately, the presence of *Ageratina adenophora, Bidens pilosa* and *Lantana camara* were found distributed with large numbers of individuals followed by *Ageratum conyzoides* and *Amaranthus spinousus* in NP.

The native place of *Ageratina adenophora* is Mexico which was introduced in 1952. According to Tiwari (2005), *Ageratina adenophora* was introduced through the land linked border with India which made easier for the entry of the plant into Nepal by trade route and was first seen in eastern and central Nepal. The introduction of *Ageratina adenophora* had affected the areas of layers of grass which included *Digitaria sp*., *Eragrostis sp*. and *Imperata cylindrica* and these species were later found extinct in Dhankuta, Langtang and Doti many years ago. These same grass species were found in Gurje Bhanjyang, Sundarijal and Fulbari Gate and there is a high chance of disappearance of these grass species if the invasive plant is not controlled. Most of the IPS were introduced from India in Nepal[1] . *Lantana camara* is one of the world's 100 worst invasive species[47]. According to Tiwari (2000), *Lantana camara* can also replace *Ageratina adenophora* [1].

The presence of the IPS was found in open areas of the NP. Rapid growth is one of the main characteristics of IPS [1], [4] and as a result, the number of individual of IPS was found high in SNNP. The result of my research illustrates the presence of IPS in the national park which is in much need of being highlighted because there are many consequences of rapid growth of IPS for ecosystem present in the national park and preservation of it. According to Rejmanek (2000), for the management of IPS, one of the fundamentals are early detection followed by rapid assessment [48].

Grass species are the major component for maintaining the balance of the ecosystem of the forest and very important for the survival of herbivorous animals in terms of food chain, especially deer in case of SNNP. The presence of grass species which are preferred by herbivorous animal such as *Sachharum spontaneum, Cynodon dactylon* are in high risk and are affected by the IPS. In Shuklaphanta NP also, high risk on grass species due to IPS was studied which could adversely affect deer in the near future [49].

Ecological value of both grass species and IPS was calculated and the result strongly demonstrated that the IPS had highest IVI value than the grass species in the study area. IVI is the calculation of the total of relative frequency, relative dominance and relative density. Even though the number of different grass species was more than IPS, the number of individual of IPS was found to be more in the study sites which leads to more dominance and ecological importance of IPS than grass species in NP. Out of four different sites, in three of the sites *Ageratina adenophora* had highest IVI with 184.77, 126.67 and 121.36 than the other species. In the other site *Lantana camara* had the highest IVI with 107.14.

The biodiversity indices was also calculated for both the grass species and IPS where the Shannon – Wiener index was obtained highest of grass species with 1.03, 0.93, 1.28, and 1.77 in Panimuhan, Gurje Bhanjyang, Sundarijal and Fulbari Gate respectively. Similarly, Simpson index of diversity was obtained highest for grass species than IPS with 0.58, 0.54, 0.66 and 0.79 in Panimuhan, Gurje Bhanjyang, Sundarijal and Fulbari Gate respectively. The result of Shannon- Wiener index and Simpson index of diversity of the study areas illustrated that the biological diversity of the grass species was higher than IPS in the NP.

The result of calculation of Species richness showed that it was highest for IPS with 60.12, 87.71, 45.49 and 28.98 in Panimuhan, Gurje Bhanjyang, Sundarijal and Fulbari Gate respectively which illustrated that the infestation of individuals of IPS was highest than the grass species.

The independent t-test was also done for biodiversity indices which resulted as significant, with p value as 0.00 which proves that alternative hypothesis is true stating that IPS is affecting grass species of SNNP.

5. CONCLUSION AND RECOMMENDATION

IPS were recorded at Panimuhan, Gurje Bhanjyang, Sundarijal and Fulbari gate sites. IPS like *Ageratina adenophora* and *Lantana camara* were widespread. Thus, the IVI of *Ageratina adenophora* and *Lantana camara* was also very high. Despite the fact that, the Shannon- Wiener index and Simpson index of diversity value of grass species was higher, whereas Species richness was higher of IPS at all sites. The spatial distribution of plant species showed that *Ageratina adenophora* was distributed highest in Panimuhan, Gurje Bhanjyang and Sundarijal while *Lantana camara* was distributed highest in Fulbari gate. IPS were dominantly threatening the grass species and, it is anticipated that the consequences would affect other species as well. This research would help to develop future plans for assessing IPS and determining appropriate management strategies. It is recommended that intensive research on effect of IPS on grass species and ecosystem be conducted. The authority needs to conduct the research to determine the IPS hotspot in the national park.

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Ethical approval

The ethical guidelines for plants & plant materials are followed in the study for species collection & identification.

Data and materials availability

All data associated with this study are present in the paper.

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