

Status and impacts of invasive alien plant species in Parsa National Park, central Nepal

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Extent of plant invasions has been expected to be low in protected areas such as national parks due to low anthropogenic activities and high wilderness. However, recent researches across the world have revealed that plant invasions can be severe in the national parks with negative impacts on the protected species and ecosystems. Unfortunately, the status of plant invasions in the national parks of Nepal is mostly unknown. In this study, we sampled at seven locations inside the Parsa National Park (PNP) to document diversity and abundance of invasive alien plant species (IAPS) and their impacts on tree regeneration. Altogether, 130 quadrats of 10 m × 10 m were sampled. We recorded 14 IAPS in the PNP. Three of the IAPS (*Chromolaena odorata*, *Lantana camara* and *Mikania micrantha*) were among the 100 of the world's worst invasive alien species. *C. odorata* was found to be the most frequent IAPS with the highest cover. The frequency and cover of the IAPS were higher at the sites close to the settlements than at the sites away from the settlements. The species richness of the IAPS was also higher at the sites closer to the settlements than away. The sapling density of the tree species was found to have declined with the increasing cover of the IAPS suggesting that the IAPS had negatively affected tree regeneration. Our data revealed that the PNP has already witnessed massive plant invasions with widespread occurrence of three of the world's worst invasive species. Therefore, it is high time to integrate management of invasive alien species in the management plan of the park.

Keywords: Biological invasions, *Chromolaena odorata*, protected areas, species richness, tree regeneration

Any plant species that are native to one region but have been introduced into an area outside their natural distribution range where they colonize and threaten biological diversity, ecosystems and human well-beings are considered as the invasive alien plant species (IAPS), and the processes are known as biological invasions (CBD, 2002). The IAPS can display strong allelopathic properties (Rai and Tripathi, 1982), rapid vegetative growth, prolific seed production capacity (Norbu, 2004), long-lived seeds, early maturation to sexually reproductive stage, phenotypic plasticity and ability to survive in a wide range of environmental conditions (Tiwari *et al.*, 2005). The IAPS can display several negative impacts in wide range of field

such as biodiversity, ecosystems, human health and livelihood, agriculture and aquaculture, and can cause economic losses (Rai and Singh, 2020). Invasion by IAPS is often associated with out-competing native species and homogenizing ecosystems, changing hydrological characteristics, degrading gene pools through hybridization with native species resulting biodiversity loss (Miththapala, 2007; Richburg, 2008; Hui *et al.*, 2011). These damages are aggravated by climate change (Kriticos *et al.*, 2003), pollution, habitat loss and human-induced disturbances (Norbu, 2004; Kohli *et al.*, 2009). The IAPS can break the plant-consumer interactions, drive population declines and species extinction (Donlan *et al.*, 2003; Reaser *et al.*, 2007; Dangermond *et al.*, 2010).

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The problem of plant invasions is also escalating in Nepal (Shrestha, 2019). Altogether, 179 species of naturalized plants have been reported from Nepal (Shrestha *et al.*, 2017), and 26 of them are considered invasive (Shrestha, 2019). Some IAPS, such as *Ageratina adenophora* (Chettri, 1986), *Chromolaena odorata* (Norbu, 2004), *Mikania micrantha* (Sapkota, 2012; Rai and Scarborough, 2012), *Lantana camara* and *Hyptis suaveolens* are serious IAPS disrupting forests and shrub lands in Nepal (Tiwari *et al.*, 2005). Similarly, *Parthenium hysterophorus* has been expanding its distribution from urban areas and grasslands to forest ecosystems including the habitats of endangered mammals (Shrestha *et al.*, 2015, 2019).

The introduction and colonization of IAPS is one of the serious threats to different protected areas, particularly the lowlands of Nepal. The IAPS like *C. odorata*, *M. micrantha*, *L. camara*, *Ipomoea carnea* and *P. hysterophorus* were the most common and problematic species in the national parks and wildlife reserves of the Terai region in Nepal (Bhujju *et al.*, 2013). *M. micrantha* has proliferated rapidly in forest, grasslands and wetland areas, and has been categorized as the most serious weed of Chitwan National Park (Sapkota, 2012, Murphy *et al.* 2013). The invasion of such IAPS disrupts the ecosystems in the Park, and may disturb the lives of flagship species and various threatened floras and faunas (e.g. Murphey *et al.*, 2013). The management of such IAPS requires park specific data related to the IAPS diversity, their abundance and impacts on native species. In this context, the present study was undertaken with the following objectives: i) to identify the IAPS invading the Parsa National Park, and analyze their abundance; ii) to analyze how the species richness of the IAPS vary spatially within the Park, and iii) to assess the impacts of the IAPS on the regeneration of tree species. The data generated from this study is useful for the management of the IAPS in the Parsa National Park (PNP).

Materials and methods

Study area

The study was conducted in the Parsa National Park (PNP) which is located in the south-central lowland Terai of Nepal (Figure 1).

The Park extends over 627.39 km² area, and is located between 27°13'52" N and 27°32'26" N latitudes, and 84°40'22" E and 84°58'41" E longitudes (DNPWC/PCP, 2003). It partially covers three districts, *viz.* Parsa, Makawanpur and Bara. Most of the Park's landscape consists of Siwalik Hills. The soil is primarily composed of gravel and conglomerates susceptible to erosion. The foothills are very porous; hence, water is scarce in this Park (Bhujju *et al.*, 2007). The Park has eight types of ecosystems and two types of forest vegetation with 298 species of vascular plants, 37 mammals, 503 birds, 8 herpeto and 8 fish species (Bhujju *et al.*, 2007). The forest in the Park is mostly composed of Sal (*Shorea robusta*) mixed with broadleaved vegetation. The Park focuses on the protection of plants like *Dalbergia latifolia* (Satisal) and faunas like *Bos frontalis gaurus* (Gaur), *Elephas maximus* (Elephant), *Panthera tigris* (Tiger), *Rhinoceros unicornis* (Rhino) and *Python molurus* (Python). The main threats to the biodiversity of the Park are the illegal hunting and poaching, illegal collection of non-timber forest products (NTFPs) and rapid spread of IAPS (DNPWC, 2003).

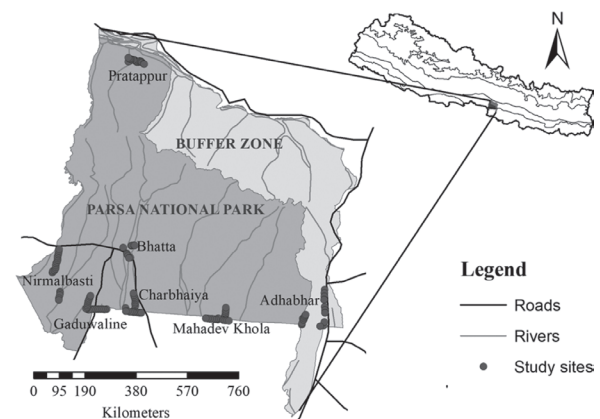


Figure 1: Map showing the sampling sites and locations of sample plots within the PNP (The map was prepared using the ArcGIS version 10)

According to the records of the Hetauda Weather Station, which is located at about 12 km north-east from the study area, the average annual rainfall of the study area is 2,256 mm with more than 90% rainfall during May-September, and highest during July and August (Figure 2). The monthly mean temperature ranges from a minimum of 17°C to a maximum of 30°C.

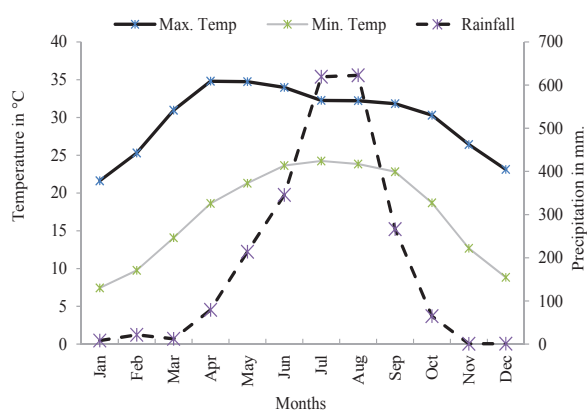


Figure 2: Five-year (2009–2013) average minimum and maximum temperatures and monthly precipitation recorded at Hetauda Weather Station. (Source: Department of Hydrology and Meteorology, Government of Nepal)

Vegetation sampling

The field data were collected through vegetation sampling using quadrat method. Considering representativeness and accessibility of the potential sampling sites and safety from wildlife, we selected Adhabhar, Mahadev Khola, Charbhaiya, Gadualine, Nirmalbasti, Bhata and Pratappur areas for sampling (see Figure 1 above). These were also the sites where security posts of the Park were located. Among them, three sites (Adhabhar, Bhata and Pratappur) were close to the human settlement, and the remaining four were away from the settlements. At each of the six sites except Bhata, 20 quadrats (10m × 10m) were sampled within a distance of about 200–250m. At the Bhata Site, only 10 quadrats were sampled due to the high risk of wild animal. Therefore, the total number of quadrats sampled was 130. In each quadrat, we recorded the flowering plant species, and visually estimated the cover of both the individual IAPS as well as the combination of all the IAPS. Besides, we measured the diameters of the tree trunks at breast height (137cm, DBH) and counted the number of saplings (height > 137cm and DBH < 10cm) of all the tree species and fire marks (*i.e.* presence/absence of burnt plant parts). In addition, the geographic locations (latitude, longitude and elevation) of all the quadrats were recorded with the help of Global Positioning System (GPS) Receiver. The herbarium specimens of all the flowering plants were collected.

Plant identification

Flowering plant species were identified on the basis of their morphological features with the help of a number of references (e.g. Polunin and Stainton, 1984; Grierson and Long, 1984, 1987, 1991, 1999 and 2001; Malla *et al.*, 1986; Siwakoti and Varma, 1999; Press *et al.*, 2000; Wu *et al.*, 2011; Bhujju *et al.*, 2013). We identified the invasive alien plant species (IAPS) following Tiwari *et al.* (2005).

Data analysis

The flowering plant species were categorized into dicotyledonous and monocotyledonous. They were further categorized into different life forms such as tree, shrub, climber and herb. The frequencies of the IAPS for each site were calculated separately in terms of the percentage of the quadrat. Similarly, the cover values of the individual IAPS for each site was calculated in terms of the mean of the cover values estimated for each quadrat. These site-wise frequencies and cover values of the IAPS are presented in Table 1. The frequencies and cover values of the IAPS for the PNP were calculated using the methods mentioned above by pooling the data of the three sites (Adhabhar, Bhata and Pratappur) which are close to the human settlements and another four sites (Mahadev Khola, Charbhaiya, Gadualine, and Nirmalbasti) which are far from the settlements. That means the combined frequencies and covers of the IAPS were calculated for two groups of the sites, *viz.* i) near the settlements and ii) away from the settlements. The combined cover value (0–100%) of all the IAPS present in each quadrat was converted to Domin Cover Scales to minimize the errors and to normalize the data (Kent and Coker, 1994). The Domin Cover Scales were 1=1–2 individuals with no measurable cover, 2=several individuals but less than 1% cover, 3=1–4% cover, 4=4.1–10% cover, 5=10.1–25% cover, 6=25.1–33% cover, 7=33.1–50% cover, 8=50.1–75% cover, 9=75.1–90% cover, 10=90.1–100% cover. These cover classes were used to compare the IAPS cover by independent sample t-test between the sites close to and away from the settlements; between quadrats with and without fire marks. Using the same method, the species richness of the IAPS (*i.e.* the no. of IAPS/quadrat) was also compared between sites. Analysis of variance (ANOVA) was used to compare the cover class values and the IAPS species richness among seven sites.

In order to access the impact of the IAPS on tree regeneration, the variation of tree sapling density with the combined cover percentage of all the IAPS was analyzed with the help of linear regression. Before accomplishing the statistical analyses, the data were checked for normality (Kolmogorov-Smirnov Test) and homogeneity of variance (Levene's Test). All the statistical analyses were accomplished using the Statistical Package for Social Sciences (SPSS, version 16.0).

Results

Flowering plant species

Altogether, we recorded 231 flowering plant species belonging to 63 families from the sampling sites of the PNP (Figure 3). Majority of them were found to be dicotyledonous. In terms of life forms, the highest number of species belonged to herb. Among all the flowering plants, 14 species were IAPS.

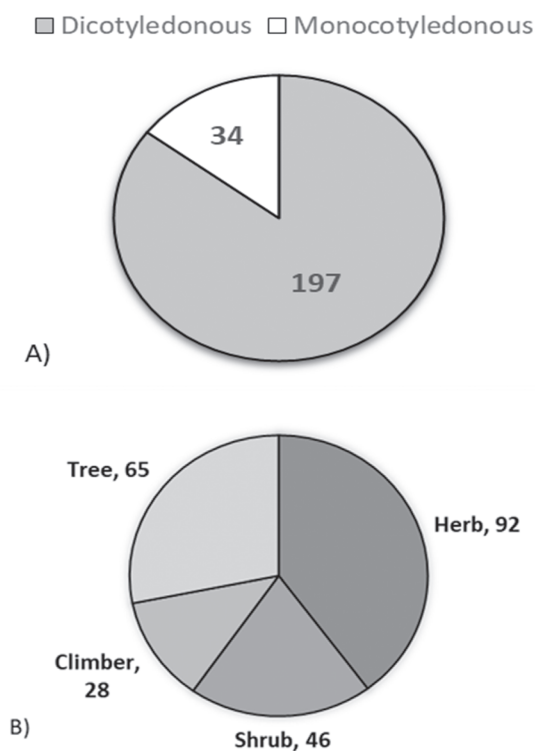


Figure 3 (A - B): Diversity of the flowering plants collected within the sampling sites.

Frequency, cover and richness of the IAPS

We recorded 14 IAPS representing 5 families in the PNP (Figure 4 and Table 1). The most species rich family was found to be Asteraceae with 7 species followed by Fabaceae with 3 species, Amaranthaceae with 2 species, Lamiaceae and

Verbenaceae, each with 1 species. Among them, *C. odorata* had the highest frequency and cover (Figure 4a and Figure 4b). The frequency and cover of each IAPS within the sites near the settlements were found to be always higher as compared to the ones within the sites away from the settlements (Figure 4). Across the sampling sites, *C. odorata* was the most frequent IAPS with the highest cover in all the sampling sites except in the Bhata Site where *Senna tora* was the most frequent but *M. micrantha* had the highest cover (Table 1).

When the coverages of all the IAPS was combined, it was found to be higher near the settlements than away from the settlements (Table 2a) and lower in the plots with fire marks than the ones without fire mark (Table 2b). Similarly, the cover of all the IAPS combined was higher at Bhata and Pratappur Sites than at the other sampling sites (Table 2c).

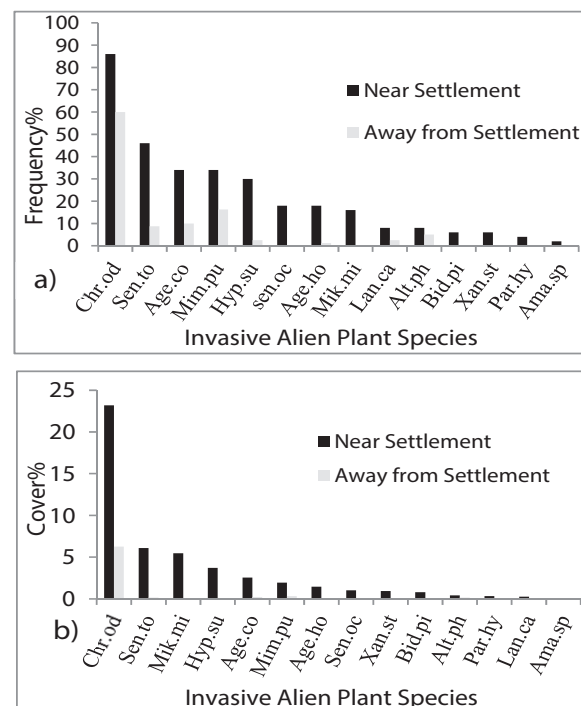


Figure 4 (a): Frequency of the IAPS near and away from the settlements, and Figure 4 (b): Cover of the IAPS near and away from the settlements. (Note: *Chr.od*=*Chromolaena odorata*, *Sen.to*=*Senna tora*, *Mim.pu*=*Mimosa pudica*, *Age.co*=*Ageratum conyzoides*, *Hyp.su*=*Hyptis suaveolens*, *Sen.oc*=*Senna occidentalis*, *Age.ho*=*Ageratum houstonianum*, *Mik.mi*=*Mikania micrantha*, *Alt.ph*=*Alternanthera philoxeroides*, *Lan.ca*=*Lantana camara*, *Bid.pi*=*Bidens pilosa*, *Xan.st*=*Xanthium strumarium*, *Par.hy*=*Parthenium hysterophorus* and *Ama.sp*=*Amaranthus spinosus*).

Table 1: Summary of the site-wise frequencies (%) and coverages (%) of the IAPS in the PNP

S.N.	Invasive Alien Plant Species	Sampling Sites													
		Adhabhar		Mahadev Khola		Charbhaiya		Gaduwaline		Nirmalvasthi		Bhata		Pratappur	
		Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.
1.	<i>Chromolaena odorata</i> (Spreng.) R.M. King & H. Rob	95	21.2	50	2.95	75	7.3	60	5.1	55	9.7	60	16.4	90	28.55
2.	<i>Mimosa pudica</i> L.	45	1.25	30	0.5	10	0.15	15	0.2	10	0.45	40	2.8	20	2.2
3.	<i>Hyptis suaveolens</i> (L.) Poit.	40	1.05	-	-	-	-	5	0.1	5	0.15	10	4	30	6.25
4.	<i>Senna tora</i> (L.) Roxb.	25	0.25	15	0.25	10	0.2	-	-	10	0.2	90	18.5	45	5.7
5.	<i>Lantana camara</i> L.	20	0.65	5	0.05	-	-	-	-	5	0.05	-	-	-	-
6.	<i>Alternanthera philoxeroides</i> (Mart.) Griseb.	10	0.55	5	0.25	-	-	5	0.25	10	0.15	10	0.5	5	0.25
7.	<i>Ageratum houstonianum</i> Mill.	10	0.25	-	-	5	0.1	-	-	-	-	30	3.4	20	1.7
8.	<i>Ageratum conyzoides</i> L.	5	0.05	-	-	15	0.25	15	0.55	10	0.1	60	3.4	50	4.65
9.	<i>Senna occidentals</i> (L.) Link.	5	0.25	-	-	-	-	-	-	-	-	20	0.6	30	2
10.	<i>Mikania micrantha</i> Kunth	-	-	-	-	-	-	-	-	-	-	60	24.8	10	1.25
11.	<i>Parthenium hysterophorus</i> L.	-	-	-	-	-	-	-	-	-	-	-	-	10	0.85
12.	<i>Amaranthus spinosus</i> L.	-	-	-	-	-	-	-	-	-	-	-	-	5	0.25
13.	<i>Bidens pilosa</i> L.	-	-	-	-	-	-	-	-	-	-	10	0.5	10	1.75
14.	<i>Xanthium strumarium</i> L.	-	-	-	-	-	-	-	-	-	-	-	-	15	2.35

Table 2: Mean coverages and species richness of the IAPS**a) Near and away from the settlements**

Samples & tests		Domin Cov. Scale of IAPS ($\bar{x} \pm S.E.$)	IAPS Richness ($\bar{x} \pm S.E.$)
Settlement Status	Near settlements	6.32 \pm 0.29	3.3 \pm 0.16
	Away from settlements	2.72 \pm 0.22	1.29 \pm 0.11
Levene's Test for equality of variances	F-value	0.406	0.491
	Sig.-value	0.525	0.485
t-test	Sig.-value	0.000	0.000

b) With and without fire marks

Fire mark status	No fire mark	4.7 \pm 0.31	2.35 \pm 0.16
	Fire mark	3.2 \pm 0.33	1.61 \pm 0.18
Levene's Test of equality of variances	F-value	2.041	2.260
	Sig.-value	0.156	0.135
t-test	Sig.-value	0.001	0.002

c) Different sampling sites

Sampling Sites	Adhabhar	4.95 \pm 0.45	2.80 \pm 0.27
	Mahadev Kohola	2.00 \pm 0.36	1.10 \pm 0.19
	Charbhaiya	2.85 \pm 0.47	1.25 \pm 0.24
	Gaduwaline	2.70 \pm 0.44	1.25 \pm 0.22
	Nirmalvasti	3.35 \pm 0.49	1.55 \pm 0.23
	Bhata	8.00 \pm 0.42	3.80 \pm 0.25
	Pratappur	6.85 \pm 0.38	3.55 \pm 0.22
Leven's Test of equality of variances	Sig.-value	0.465	0.691
ANOVA	F-value	22.578	22.047
	Sig.-value	<0.001	<0.001

(Note: Domin Cover Scale of IAPS: 1=1–2 individuals with no measurable cover, 2=several individuals but <1% cover, 3=1–4% cover, 4=4.1–10% cover, 5=10.1–25% cover, 6=25.1–33% cover, 7=33.1–50% cover, 8=50.1–75% cover, 9=75.1–90% cover and 10=90.1–100% cover of the IAPS) The species richness of the IAPS was higher near the settlements than away from the settlements (Table 2a) and lower in the areas with fire marks than in the areas without fire marks (Table 2b). Similarly, the species richness was also significantly different ($p < 0.05$) across the sampling sites, with the highest value at the Bhata Site.

Impacts of IAPS on tree regeneration

The sapling density of the tree species was calculated as a measure of tree regeneration in

the study area. The sampling density declined significantly with the increasing cover of the IAPS suggesting that the IAPS had adverse effects on the regeneration of the tree species (Figure 5).

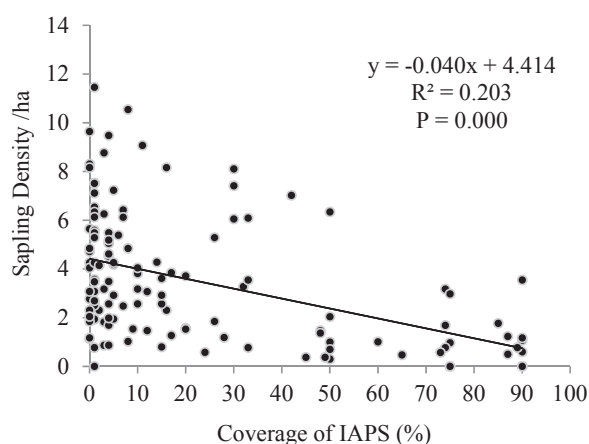


Figure 5: Variation of sapling density with coverage of IAPS. Each point in Figure represents a quadrat (N = 130). The less number of points in the Figure is due to the overlapping of the data among the quadrats. The fitted line is based on the linear regression model.

Discussion

National parks are relatively less disturbed from the anthropogenic activities compared to the surrounding landscape. Therefore, the extent of plant invasions is expected to be low in the national parks. However, our data showed that more than half of the invasive alien plant species (IAPS) found in Nepal has already invaded the PNP. Three of the world's worst IAPS (*C. odorata*, *L. camara* and *M. micrantha*) have invaded several localities inside the Park with potential negative impacts on the protected wildlife and native biodiversity. Due to the logistic and safety reasons, we could not cover the entire area of the Park for sampling the IAPS. There is possibility of finding the additional IAPS through more intensive sampling than the present one (study). However, the results of the present study revealed that the problem of plant invasions in the PNP is already alarming, requiring immediate management interventions.

There was spatial variation in the cover and richness of the IAPS. The higher cover and richness of the IAPS in the Bhata, Pratappur and Adhabhar Sites might be due to the effect of human activities. These three Sites were close to the settlements, and the local communities used the adjacent areas for grazing and collection of forest resources. Human movements and associated disturbances increase the propagule pressure of IAPS by dispersing seeds and other reproductive units, and provide opportunity for

the establishment of the IAPS by reducing native vegetation cover (Hobbs and Huenneke, 1992). The frequency of the individual IAPS reported in this study is similar to the findings of Tiwari *et al.* (2005). For example, the most frequent species (*C. odorata*) in the PNP was also reported as the most frequent species in the forest of the Terai region (Tiwari *et al.* 2005). Among the 14 IAPS recorded in the PNP, 3 species (*C. odaorata*, *L. camara* and *M. micrantha*) are in the list of 100 of the world's invasive alien species (Lowe *et al.*, 2004). Similarly, *A. conyzoides*, *C. odorata*, *L. camara*, *M. micrantha* and *P. hysterophorus* present in the PNP were also identified as the noxious invasive plants in the Asia Pacific region (Sankaran *et al.*, 2005).

The high invasion of *C. odorata* in the PNP might be due to the prolific seed production capacity, availability of intermediate light intensity and high efficiency of competition for nutrition (Rejmanek and Richardson, 1996; Norbu, 2004). Sal forest of Terai region with relatively open canopy may provide suitable habitat for the proliferation of *C. odorata* (Joshi, 2001). However at Bhata Site, *M. micrantha* was reported as the most problematic IAPS, and this could be due to the presence of wetlands associated with lakes (Lauki Daha and Devaki Daha) and streams (Bhata Khola and Jalvayu Khola). The moist land with open canopy is considered as the best habitat for the growth, reproduction and rapid colonization of *M. micrantha* (Siwakoti, 2007; Sapkota, 2012).

There was higher abundance of individual IAPS in the areas close to the settlements than in the areas away from the settlements within the PNP. Fugii *et al.* (2008) also reported high level of invasion of each IAPS near the settlements. Anthropogenic activities and animal movement near the settlements may help in arrival and distribution of IAPS propagules (Hobbs and Huenneke, 1992). The level of invasion was found to have declined with decreasing human activities in peri-urban areas (Karki, 2009).

Generally, mild forest fire provide suitable niche for the establishment of IAPS, and promotes their growth (de Rouw, 1991; Witkowski, 2000). However, impacts of fire may depend on intensity and frequency of fire. In the PNP, the cover and species richness of the IAPS was lower in the quadrats with fire marks than in the plots without such marks. Forest floor and grasslands

are frequently burnt in the PNP to induce growth of forage species for wildlife. It was likely that severe fire might have eliminated propagules and seed bank of some IAPS.

In the PNP, the sapling density of the trees was found to have declined with the increase in the IAPS cover. High abundance of IAPS can modify the micro-habitat in such a way that it becomes hostile for seed germination and seedling growth of native species. IAPS release certain secondary metabolites *i.e.* allelochemicals that makes the chemical environment of soil unsuitable for germination of seeds of other species (Inderjit *et al.*, 2008). IAPS are 'passengers' of deforestation and forest degradation at their early stage of colonization, which later change into 'drivers' by disrupting tree regeneration process (Dalal-Clayton *et al.*, 2014).

Conclusion

The presence of 14 IAPS (out of the 26 IAPS reported in Nepal) revealed that the PNP has already witnessed massive plant invasions. The widespread occurrence of three of the world's worst invasive species suggests that the Park Management has been ineffective in preventing introduction of the well-known invasive weed. In absence of specific management plan for the invasive species, it is highly likely that the extent of invasion of the previously established IAPS will increase, which may pose additional threats to the protected wildlife and native biodiversity. Furthermore, there is also a chance of introduction of new invasive species into the Park. Therefore, it is high time to integrate the management of the IAPS in the management plan of the Park. Additional research focusing on spatial distribution mapping of the invasive alien plant species and their impacts on native plant species and ecosystem are essential to better inform the Park management.

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