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RESEARCH ARTICLE

Assessing Status and Impacts of Invasive Plants In Banke District, Nepal

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Abstract

Forest, agricultural lands and wetlands in the low lands Terai belt of Nepal are vulnerable to infestation by invasive alien plant species (IAPS). The study area is characterized by a typical tropical climate and is located in the lowland of the country, making it suitable for biological invasion. The forest in this area is found dominated by *Shorea robusta*. The survey research aimed to assess the invasiveness of IAPS along the roadsides adjacent to agricultural land in Banke district. Five sites Dhakeri, Khajura, Chisapani, Narainapur and Nepalgunj areas were selected as sampling sites. The sampling plots of 10m×10m were randomly established at each sites to measure the invasiveness of IAPS. The study revealed total 84 plant species, of which 20 species were identified as non-invasive naturalized and 16 species as invasive plants. Among 16 IAPS, *Ageratum houstonianum* was noticed as the most invaded, followed by *Ipomoea carnea*, *Parthenium hysterophorus*. Among five sampling areas, Nepalgunj area was observed as the most problematic area followed by Dhakeri and Chisapani areas. The impacts of IAPS were noticed in richness of native herb species due to suppressing of their growth and regeneration.

Keywords: *ageratum houstonianum*, coverage, infestation, native herbs, species richness.

Introduction

A biological species occurring outside its bioregion and established itself independent in a new location is called alien or exotic species. Any parts of such species like gametes, seeds, fragments,

or propagules that can survive beyond their native range and rapidly propagate in the new habitat and threaten biological diversity and ecosystems by causing enormous ecological, economic or health problems (Tiwari *et al.* 2005) is considered

an invasive alien species (IAS). When these species are plants, they are referred to as invasive alien plant species (IAPS). Nepal is ranked as the third most threatened country among 124 countries in the world due to IAPS (Paini *et al.* 2016). These plants are among the major cause of species and habitats loss and realized to be necessary for the protection and wise use of biological resources and habitats (IUCN 2025). According to Charles Elton, biological invasions are described as ‘ecological explosions’ (Elton 1958). However, not all the introduced species become invasive according to the “tens rule” (originally the ten-ten rule) proposed by Williamson and Brown (1986). This rule suggests that only approximately 10% of introduced species are established in new range, about 10% of established are naturalized and about 10% of naturalized are spread to become invasiveness (Williamson & Fitter 1996, Richardson and Pysek 2006). Hence, only about 0.1% of introduced species become invasive in new habitat.

In Nepal, a total 29 plant species are identified as invasive plants. Formerly, Tiwari *et al.* (2005) identified 21 invasive plants species, including *Ageratina adenophora*, *Chromolaena odorata*, *Pontederia crassipes*, *Ipomoea carnea* subsp. *fistulosa*, *Mikania micrantha*, *Lantana camara*, *Parthenium hysterophorus*, *Alternanthera philoxeroides*, *Ageratum conyzoides*, *Amaranthus spinosus*, *Bidens pilosa*, *Myriophyllum aquaticum*, *Argemone Mexicana*, *Senna tora*, *Hyptis suaveolens*, *Leersia hexandra*, *Xanthium strumarium*, *Mimosa pudica*, *Pistia stratiotes*, *Senna occidentalis*, *Oxalis latifolia*. Later, eight additional plants were identified as invasive and added to the list, which include *Ageratum houstonianum*, *Erigeron karvinskianus*, *Galinsoga quadriradiata*, *Spermacoce alata* (Shrestha 2016), *Spergula arvensis* (Shrestha *et al.* 2017), *Mimosa diplotricha*, *Sphagneticola trilobata*, *Tithonia diversifolia* (Shrestha & Shrestha 2021). These species pose

significant threat to native biodiversity, leading to the loss of ecosystem services and socio-economic losses. Therefore, the study and management of IAPS have become a national priority in Nepal.

The extensive transboundary movement of seeds and trade and human activities contribute to both global and local dissemination of the IAPS (Bonnamour *et al.* 2021). However, the fallow-land, agricultural land as well as wetlands are the most vulnerable region of IAPS. These regions are highly affected by world’s worst invasive plants like *Lantana camara*, *Ageratum houstonianum*, *Ageratina adenophora*, *Pontederia crassipe* and *Pistia stratiotes* (Lowe *et al.* 2000). Such invasive plants are found to be colonized rapidly and reduce nutrient enrichment in the soil and reduce productivity (Dassonville *et al.* 2008). Consequently, invasive species lead to crop losses and can adversely affect to food security and safety at both national and global levels.

Materials and Methods

Study area

Banke district of Lumbini province was selected as the study area that covers an area of 2,337 km². It is located between 81°29' E to 82°8'E and 27°51' to 28°20'N. This district consists of one Sub-Metropolitan City (Nepalgunj), one Municipality (Kohalpur) and six rural Municipalities; Rapti-Sonari, Narainapur, Duduwa, Janaki, Khajura, Bajjanath (Yadav and Chaudhary 2022), as shown in figure 1. There is an open border with India in southern and an unchecked flow of people between these countries. Thus, there might be heavy import of many invasive alien species.

The district has an altitudinal range from 127 to 1236 m. above the sea level. Most of the district is drained by the Rapti and Babai rivers. Banke district consists of eight types of ecosystems and six types of forests and consists of 296 species of plants (BNP 2014), 52 species of medicinal plants (Manandhar

1998). The dominant plant species of the forest of the district are *Shorea robusta*, *Aegle marmelos*, *Schleichera oleosa*, *Semecarpus anacardium*, *Terminalia bellirica*, *T. chebula*, *Woodfordia fruticosa* and *Zizyphus mauritiana*.

Figure 1
Banke District with local governments

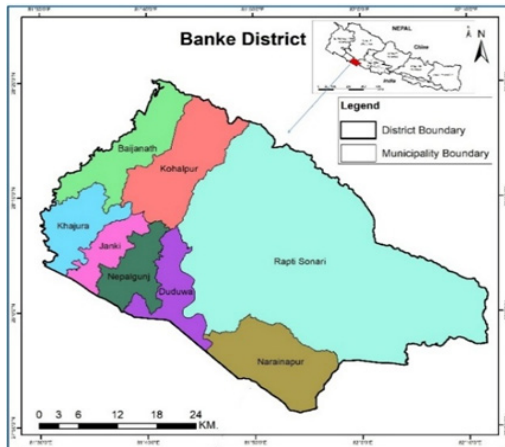
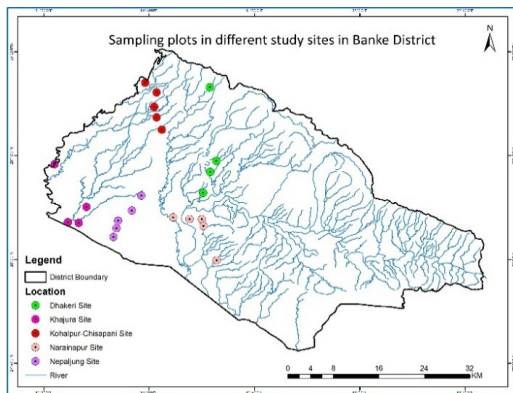


Figure 2
Sampling Plots in Different Sites



The temperature in the district ranges from 5°C to 42°C throughout the year. During spring (March-June), temperature rises and water becomes scarce. The maximum temperature and drought can be felt during May-June. During this period, the temperature rises to 42°C and the climate becomes very dry with hot air blow. During monsoon (June-August), the days become hot and humid while during autumn season (September- November), the days are hot and bring cooling rains. The winter season ranges from December to February. More

than 90 % annual rainfall occurs between May and September. The highest rainfall was recorded in July and August.

Vegetation Sampling

The survey was conducted during February-March, considering five sampling sites of the district for the collection of primary data: Dhakeri, Chisapani, Khajura, Narainapur and Nepalgunj area (Figure 2). Among them, Nepalgunj, Khajura and Narainapur are located along southern border of India and Nepalgunj is highly urbanized. Chisapani and Dhakeri are located adjacent to Banke National Park. Most samplings were drawn along the roadsides of the study area though some community forests and agricultural lands were also not excluded. The roadsides are pioneer place of infestation of IAPS due to human induced activities, from where these species spread towards agricultural and forest lands. To measure the current status and impacts of IAPS, a size of plot 10m × 10m were sampled in all five different sampling sites. The total number of plots was 25 with five plots in each site. An approximate distance of 1-2 km was maintained between plots on each transect. For the collection of qualitative and quantitative data, a data collecting tool was made. To measure the invasiveness of IAPS, parameters such as cover percent of IAPS and canopy were estimated visually in increments of as 2, 4, 6. Flowering plants were recorded from each sample while geographical location of the plots (altitude, latitude and longitude) were measured by using GPS receiver.

Plant Identification

Out of the 29 invasive plants recorded in Nepal, 16 species were identified as invasive plants in the study site leading threats to native biodiversity and ecosystem. These invasive plants were identified in the field by using their morphological characters like flower characters, seeds, stem, leaves and fruits. They were further

confirmed with the help of online database (www.issg.org/database/welcome/content.asp) and published literatures like Tiwari *et al.* (2005), Shrestha (2016), Shrestha *et al.* (2017) and Shrestha and Shrestha (2021). Native and other flowering plant species were also identified by using some published literatures: Flowers of the Himalaya (Polunin & Stainton 1984, 1988), Annotated Checklist of the Flowering Plants of Nepal (Press *et al.* 2000) and A Handbook of the Flowering Plants of Nepal Vol.1 (Rajbhandari & Rai 2017).

Data Analysis

Two statistical tools SPSS (Statistical Package for Social Sciences) version 16.0 and Ms-Excel (Office 16) were used to analyze the quantitative data to measure the invasiveness of IAPS in the study area. The parameters species richness and cover value of IAPS were used to measure the infestation level of IAPS across the five sampling sites. Here, the number of the species represented the richness on each plot and mean number represented the richness at each sampling site. Furthermore, the percent coverage and richness of IAPS were compared using independent sample t-test. Similarly, the site-wise mean comparison of species richness of flowering plants and invasive and non-invasive naturalized plants were also compared together using ANOVA test to determine statistical significance.

Parameters like percent canopy cover and richness of naturalized plants were taken as factor governing infestation of IAPS. The relationship between these factors and IAPS was evaluated by using linear regression model. Similarly, the impacts of invasiveness with richness of native plants specially herbs were measured using linear regression model. The normality of data and homogeneity of variance were tested using SPSS version 16.0. A P value of <0.05 was considered statistically significant. If $P < 0.05$, the data were considered to meet the assumptions of normality and homogeneity. All the figures

were made by using Ms-Excel (Office 16) while all statistical analysis were completed using SPSS version 16.

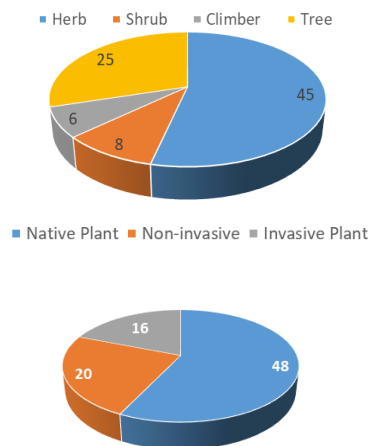
Results

Enumeration of Plant Species

By the field survey, altogether 84 species of flowering and non-flowering plants were recorded from different sampling sites (Figure 3 A&B). Among these, 36 species were of naturalized plants and 48 species were native plants. This result represents ca. 57% native plants and ca. 43% naturalized plants of the total record of the study. Out of all naturalized plants, 16 species were noticed as invasive plant (Figure 3 A&B) on the study area. Approximately 20% species were represented by IAPS of the total record of plant species. Among the 16 IAPS, only one belongs to monocotyledonous plant while 15 species were enumerated as dicotyledonous. Furthermore, 15 species of invasive plant were herbs while only one was shrub.

Figure 3

A&B: Number of Species Recorded in Study Area

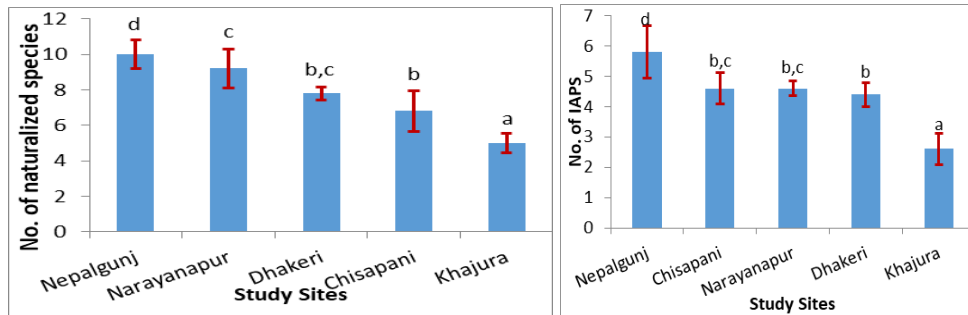


Species Richness

Out of five sampling sites, Narainapur was covered with the highest richness of all the plants while Khajura showed the lowest richness (Table 1). The richness of all plants on different sites were found significantly different ($P < 0.05$).

Figure 4

A&B: Species richness of naturalized and IAPS in different sampling sites



The richness of both naturalized and invasive plants was found the highest in Nepalgunj while lowest in Khajura (Figure 4 A&B). Nepalgunj and Khajura are located

very close to southern border with India. Both the parameters showed a significant site wise variation ($P < 0.05$) (Table 1).

Table 1

Site-wise Species Richness along the Roadsides of Banke District

Sampling sites	Species Richness ($\bar{x} \pm S.E.$)				
	All plant species	IAPS	Naturalized species	Native Species	
Dhakeri	16 \pm 1.09	4.4 \pm 0.4	7.8 \pm 0.37	8.2 \pm 0.86	
Khajura	10.4 \pm 1.57	2.6 \pm 0.51	5 \pm 0.55	5.4 \pm 1.25	
Chisapani	12.2 \pm 0.86	4.6 \pm 0.51	6.8 \pm 1.16	5.4 \pm 0.93	
Narayanapur	18 \pm 0.63	4.6 \pm 0.25	9.2 \pm 1.11	8.8 \pm 1.63	
Nepalgunj	14.4 \pm 1.21	5.8 \pm 0.86	10 \pm 0.8	4.4 \pm 0.68	
ANOVA	F-value	7.22	4.459	5.11	2.994
	Sig.-value	0.001	0.01	0.05	0.04

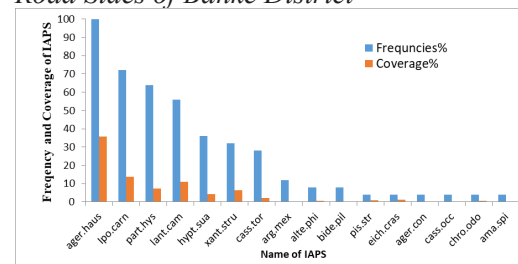
Frequencies and Coverage of IAPS

Among the 16 invasive alien plants (IAPS), *Ageratum houstonianum* was the most frequent and dominant species with highest coverage while *Ageratum conyzoides* showed the lowest frequency and coverage (Figure 5). Therefore, *Ageratum houstonianum* is was found as major IAPS with the highest frequency and coverage followed by other species.

The variances in mean coverage of all IAPS across sampling sites was non-homogenous ($P > 0.05$) (Table 2). Similarly, the mean coverage of IAPS did not differ significantly among sampling sites ($P > 0.05$). however, Nepalgunj was found highly invaded by IAPS which was followed by Dhakeri, Narainapur, Chisapani and Khajura (Table 2).

Figure 5

Frequency and Coverage of IAPS along the Road Sides of Banke District



(Note: *ager.haus* = *Ageratum houstonianum*, *Ipo.cam* = *Ipomoea carnea* subsp. *fistulosa*, *Part.hys* = *Parthenium hysterophorus*, *lant.cam* = *Lantana camara*, *hypt.sua* = *Hyptis suaveolens*, *xant.stru* = *Xanthium strumarium*, *cass.tor* = *Senna tora*, *arg.mex* = *Argemone Mexicana*, *alt.phi* = *Alternanthera philoxeroides*, *bide.pil* =

Bidens pilosa, *pis.str* = *Pistia stratiotes*, *eich.cras* = *Eichhornia crassipes*, *ager.con* = *Ageratum conyzoides*, *cass.occ* = *Senna occidentalis*, *chro.odo* = *Chromolaena odorata*, *ama.spi* = *Amaranthus spinosus*)

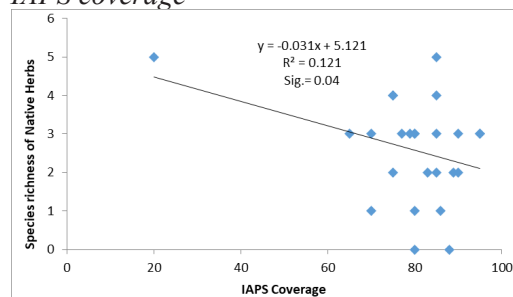
Table 2
Site wise Mean Comparison of Coverage of IAPS.

Study Sites	Cover% ($\bar{x} \pm$ S.E.)
Nepalgunj	86.2 \pm 2.9
Dhakeri	81.2 \pm 2.3
Narainapur	79.4 \pm 2.8
Chisapani	78 \pm 3
Khajura	71 \pm 5
ANOVA	F-value 0.68
	Sig-value 0.61

Impacts of IAPS on Native Herb Species Richness

The impacts of IAPS invasion on native herbs richness was found to be significant ($P < 0.05$) showing a negative relationship ($r = -0.34$). This indicates that increasing IAPS coverage leads to reduction in native herb richness. IAPS showed 12.1% variation in the growth and development of native herb species in the study sites of Banke District (Figure 6).

Figure 6
Variation of no. of native herb species with IAPS coverage



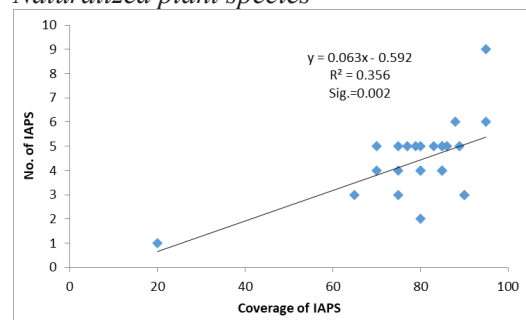
(Note: the total number of plots was 25 and each point explains the sampling plots while line fitted line on the figure represents relationship between to variables made by

linear regression model.)

Impacts of IAPS on its Richness

The richness of IAPS showed a significant positive relationship with naturalized species richness ($P < 0.05$), with a correlation coefficient of $r = 0.59$. The relationship between them is illustrated about 35.6% of variation in IAPS richness across the sampling sites in Banke District (Figure 7).

Figure 7
Variation of no. of IAPS with richness of Naturalized plant species



(Note: the total number of plots was 25 and each point explains the sampling plots while line fitted line on the figure represents relationship between to variables made by linear regression model.)

Discussion

Banke District consists of eight types of ecosystems and six types of forests and consists of 296 plant species (BNP 2014). Bhatta *et al.* (2024), recorded 21 invasive plant species in lowland district Kanchanpur. The documentations of a relatively lower number of species (i.e. 84 plant species and 16 invasive species), might be due to sampling being concentrated mostly on roadsides while excluding Banke National Park and the eastern part of the district. Among the five sampling sites, the richness of native plant species was lowest in Nepalgunj site. This might be due to two main factors; one is high effect of urbanization and another is presence of

the highest invasiveness of IAPS.

Tiwari et al. (2005) reported *Chromolaena odorata* as the most frequent IAPS (30.8%) with highest coverage (12.99%) in forests of Terai in Nepal and Bhatta et al. (2024), reported *Lantana camara* as most dominant in Terai district Kanchanpure. Unlike, this study reported the *Ageratum houstonianum* as the most frequent and most abundant IAPS throughout the ecosystem supporting the work of Baral et al. (2017). This variation might be due to fact that *Ageratum houstonianum* favours the anthropogenic disturbances and agriculture region supporting the invasiveness of each IAPS near settlement. Hence, its invasiveness is more strongly influence by the anthropogenic activities (Chaudhary et al. 2020) rather than phytotoxic chemical allelopathy and high reproductive efficiency of invasive weeds (Fugii et al. 2008).

Furthermore, higher level of IAPS invasion leads to secretion of high amounts of allelopathic and phytotoxic chemicals that mixed with soil. These chemicals show negative impacts to native species and make the soil unsuitable for regeneration of native species and it makes soil favorable for germination and colonization of IAPS. (Inderjit et al. 2008). Therefore, the species richness of native herbs found decreasing with increasing of IAPS infestation while richness of IAPS was found increasing with increase in its coverage.

Conclusion

The study reported 84 plant species including - 36 naturalized species and 16 IAPS in Banke district. Among 16 IAPS, *Ageratum houstonianum* was found as the most problematic species across all sampling sites in the study area. The infestation of IAPS maintain the soil environment to increase the richness of IAPS. Similarly, a significant negative impact of IAPS was observed on richness and regenerations of native herb species. Therefore, this study recommends further comprehensive

research on IAPS distribution and impacts along with the immediate action from local governments and relevant stakeholders for the development and implementation of proper management strategies.

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Availability of Data and Materials

Data are safely stored. They will be made available in special request.

Conflict of Interest

The author declare that there is no conflict of interest in relation to this manuscript.

Ethical Compliance

"Not applicable"

Consent for Publication

"Not applicable"

Plagiarism and AI Use

The manuscript is free from plagiarism and improper use of AI-generated content. Any permitted use of AI tools was limited to language support and has not replaced original scholarly contribution.

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