



**Invasive Alien Plant Species and Their Effects on the Habitat
Utilization of Wild Ungulates in Parsa National Park, Nepal**

Basudha Rawal

T.U. Registration No. 5-2-37-1031-2016

T.U. Examination Roll No. 909

Batch: 2077

**Central Department of Zoology
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu
Nepal**

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**In partial fulfillment of the requirements for the award of the degree
of Master of Science in Zoology with a special paper Ecology and
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Signature: Basudha Rawal
Date: ... 2024 March 28
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Basudha Rawal

TU Registration No. 5-2-37-1031-2016

M.Sc. Zoology (Ecology and Environment)

T.U. Examination Roll No. 909/077

Supervisor

Hari Prasad Sharma, PhD

Associate Professor

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu

**Dissertation submitted in partial fulfilment of the requirements for the
degree of Master of Science in Zoology with special paper Ecology and
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E-mail: basudha2055@gmail.com

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University


Kirtipur, Kathmandu, Nepal

Website: <https://www.cdz.tu.edu.np/>

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Declaration

I hereby declare that the work presented in this dissertation “Invasive plant species and their effects on the habitat utilization of wild ungulates in Parsa National Park, Nepal” has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

.....

Ms. Basudha Rawal

T.U. Examination No. 909/077
Email: basudha2055@gamil.com

Date: 28 March 2024



त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY



०१-४३३१८९६

01-4331896

Email: info@cdz.tu.edu.np

URL: www.cdztu.edu.np

प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY

कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.

पत्र संख्या :-

च.नं. Ref.No.:-

Recommendation

This is to recommend that the dissertation entitled "Invasive alien plant species and their effect on the habitat utilization of wild ungulates in Parsa National Park, Nepal" has been carried out by Basudha Rawal for the partial fulfilment of Master's Degree of Science in Zoology with special paper Ecology and Environment. This is her original work and has been carried out under my supervision. To the best of my knowledge, this dissertation work has not been submitted for any other degree in any institutions.

.....
Supervisor

Hari Prasad Sharma, PhD

Associate Professor

Central Department of Zoology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

Date: 28 March 2024



त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY

01-4331896
01-4331896

Email: info@cdz.tu.edu.np
URL: www.cdztu.edu.np

प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY

कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.

पत्र संख्या :-
च.नं. Ref.No.:-



Letter of approval

On the recommendation of supervisor "Associate Professor Dr. Hari Prasad Sharma" this dissertation submitted by Basudha Rawal entitled "Invasive alien plant species and their effect on the habitat utilization wild ungulates in Parsa National Park, Nepal" is approved for the examination in partial fulfilment of the requirements for Master's Degree of Science in Zoology with special paper Ecology and Environment.

Head of Department
Kumar Sapkota, PhD
Professor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

Date: 28 March 2024



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प्राणी शास्त्र केन्द्रीय विभाग

CENTRAL DEPARTMENT OF ZOOLOGY

कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.



०१-४३३१८९६

01-4331896

Email: info@cdz.tu.edu.np

URL: www.cdztu.edu.np

पत्र संख्या :-

च.नं. Ref.No.:-

Certificate of acceptance

This dissertation work submitted by Basudha Rawal entitled "Invasive alien plant species and their effect on the habitat utilization of wild ungulates in Parsa National Park, Nepal" has been accepted as a partial fulfilment for the requirements of Master's Degree of Science in Zoology with special paper Ecology and Environment.

Evaluation committee

.....
Supervisor
Hari Prasad Sharma, PhD
Associate Professor
Central Department of Zoology
Tribhuvan University

.....
External Examiner
Chiranjibi Prasad Pokharel, PhD
Director
National Trust for Nature Conservation

.....
Head of Department
Kumar Sapkota, PhD
Professor
Central Department of Zoology
Tribhuvan University

.....
Internal Examiner
Bishnu Prasad Bhattarai, PhD
Assistant Professor
Central Department of Zoology
Tribhuvan University

Date of examination: 18 April 2024

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Abstract

Invasive alien plant species (IAPS) often have a negative effect on native biodiversity including wildlife, but such effects are specific to habitat and species. This study recorded the occurrence of IAPS in Parsa National Park (PNP) of Nepal and assessed their impacts on the habitat utilization of wild ungulates. Data was collected from December 2022 to October 2023. A total of 106 plots of 50*50 m² at the interval of 1 km were established in PNP. The occurrence of invasive species was recorded through visual observation and wild ungulates were recorded using camera traps and sign survey. A total of eight IAPS were recorded in the survey plots. Among them, siam weed (*Chromolaena odorata*) had the highest coverage i.e. 44%, followed by billy goat (*Ageratum conyzoides*) 21% and the lowest coverage of goat weed (*Ageratum houstonianum*) (1.06%) and sicklepod senna (*Senna tora*) 1.06%. The IAPS coverage was influenced by tree canopy cover, and proximal to road and settlement. A total of 20 IAPS (8 from survey plots and 12 from opportunistic survey) were sighted along the route from PNP. Among the six wild ungulates, the highest detection was of wild boar in 60 plots, followed by chital, barking deer, sambar, and nilgai, and the lowest detection was of gaur in 23 plots. The occurrence of barking deer, and sambar was influenced by IAPS coverage. This study suggests the management of IAPS in PNP for the survival of wild ungulates.

शोध सार

मिचाहा बाह्य विरुवाहरुले वन्यजन्तु सहित जैविक विविधतामा प्राय नकारात्मक प्रभाव पार्छन्, तर त्यस्ता प्रभावहरु वासस्थान र प्रजाति विशिष्ट हुन्छन् । पर्सा राष्ट्रिय निकुञ्जमा पौष २०७९ देखि असोज २०८० (December 2022 to October 2023) सम्म त्यहाँ भएका मिचाहा विरुवाहरु र तिनीहरुले स्तनधारी जनावरहरुको वासस्थान उपयोगमा पारेको असरहरुको तथ्याङ्क संकलन गरि मूल्याङ्कन गरियो । क्यामेरा ट्र्याप र चिन्ह अवलोकनको माध्यमबाट मिचाहा विरुवाहरुको उपस्थिति र तिनीहरुको जम्मा ओगटेको स्थान तथा “wild ungulates” अवलोकन गरिएको थियो । सर्वेक्षणहरुमा कुल अठारा मिचाहा विरुवाको टिपोट गरियो । जसमध्ये आठ मिचाहा विरुवाहरुका उपस्थितिको असर देखियो, सेतो वनमारा ४४% थियो, निलो गन्धे २९% थियो भने अन्य प्रजातीको न्यून उपस्थिति देखियो । मिचाहा प्रजातीहरु घना वन क्षेत्रमा कम थिए भने सडक तथा बस्ती छेउछाउमा धेरै थिए । पानीको मुहान तथा चिसो ठाउमा मिचाहा प्रजातीको घनत्व धेरै थियो यद्यपि यो मात्रै मुख्य कारक होईन । मिचाहा विरुवाहरु मात्र असर नभई उनिहरुको वासस्थानको छनौट र तिनीहरुबिचको एउटै वासस्थानको चयनहरु कारक पाइन्छन् । रतुवा र जरायोलाई मिचाहा बाह्य विरुवाहरुले क्रमश असर पार्ने देखियो । यस अध्ययनले मिचाहा बाह्य विरुवाहरुको फैलावटलाई निरन्तर अध्ययन र नियन्त्रण गर्न सिफारिस गर्दछ ।

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List of abbreviations

Abbreviated form

Details of abbreviations

IAPS	Invasive Alien Plant Species
DNPWC	Department of National Parks and Wildlife Conservation
PNP	Parsa National Park
GPS	Global Positioning System
GIS	Geographical Information System
GLM	Generalized Linear Model

1. Introduction

1.1 Background

Biological invasion is one of the major significant factors contributing to biodiversity loss (Gaertner et al., 2009). Invasions are a primary driver of the decline and depletion of native biodiversity (Kohli et al., 2006). Invasive alien animal and plant species have the potential to spread rapidly over larger areas due to their high reproductive and dispersal rates (Low et al., 2000; Pysek et al., 2004). The spread of alien species results from habitat fragmentation, agricultural expansion, and urbanization (Vitousek, 1996). Human activities transport these species, intentionally or accidentally, outside of their natural habitat into new areas where they may establish themselves and propagate (IPBES, 2023). Alien plant species (APS) are intentionally brought for economic, ornamental, and industrial reasons, including habitat restoration and biological control (Tiwari et al., 2005). For example, the intentional introduction of water hyacinth (*Pontederia crassipes*), originally native to America, was introduced in Europe for water waste treatment and ornamentation (Xie et al., 2000). Siam weed (*Chromolaena odorata*), which originates in Central and South America and the Caribbean, was introduced into Asia in the 19th century due to the movement of military equipment during World War II (McFadyen, 2000). The animal's unintentional spread was recorded through transportation, religious aspects, and international trade has been observed for various species, such as the invasive giant African land snail (*Achatina fulica*) (Adhikari et al., 2020). Due to increasing transportation networks, technological developments, changing landscapes, and climate change dispersion of IAPS is increasing (Ricciardi et al., 2017). The unchecked proliferation of certain plant species, competing native flora and disrupting entire ecosystems, poses a grave threat to biodiversity, ecosystem stability, and overall environmental health (Vitousek et al., 1997; Mooney & Hobbs, 2000).

The IAPS can bring about both positive and negative effects (Shrestha, 2021). Interestingly, certain IAPS have exhibited positive effects on particular mammal species (Dutra et al., 2011). For instance, monospecific stands of IAPS such as Japanese barberry (*Berberis thunbergii*) create dense covers that offer and promote safe foraging opportunities for small mammals (Dutra et al., 2011; Utz et al., 2020). However, the effect of IAPS is mostly negative (Vila et al., 2011). When these species aggregate in

environments, such as forests, water bodies, and grasslands, they don't simply coexist; they tend to create an uninhabitable environment for native species (Karki & Paudel, 2014). When IAPS infiltrate terrestrial ecosystems, they diminish space, water, sunlight, and nutrients available to native species, altering species composition and soil chemistry crucial for the germination of indigenous flora (Basnet et al., 2016; Tiwari et al., 2005; Rao & Murugan, 2006; Timsina et al., 2011). Consequently, they negatively impact grasslands and grass biomass, impeding the germination and growth of native species and altering community structure (Ram, 2008; Karki & Poudel, 2013; Singh et al., 2014; Arandhara et al., 2021). This invasion leads to extensive declines in the abundance and diversity of native species (Pyšek et al., 2012). Once IAPS invades habitats, habitat degradation occurs, affecting ecosystem biodiversity and intensifying interspecies competition (Shrestha, 2016), resulting in diminished food resource variation necessary for herbivores (Brooks et al., 2004). Consequently, the mammal species that primarily rely on grass foraging tend to avoid these areas (Chaudhary et al., 2020), primarily due to decreased productivity induced by IAPS, resulting in food shortages (Shrestha et al., 2018).

The adverse effects of IAPS extend beyond impacting the distribution and survival of native species (Gaertner et al., 2009), influencing the habitat utilization patterns of mammalian species (Dutra et al., 2011), prompting alterations in their primary habitats (Lahkar et al., 2011; Murphy et al., 2013), and leading to the destruction of critical habitats for threatened species (Lahkar et al., 2011). Consequently, mammal species adjust their habitat usage (Dutra et al., 2011), while areas experiencing a high influx of IAPS witness a decline in the population of large herbivores (Lahkar et al., 2011), thereby exacerbating pressure on prey and prey base species regarding food availability and habitat alteration due to disrupted ecosystem services (Bhattarai, 2013). The extinction of megafauna has profoundly disrupted ecosystems by altering the natural flow of nutrients (Doughty et al., 2016).

The impact of IAPS, such as the alteration of plant community structure and suppression of native plant species growth, has been documented globally (Singh et al., 2014). Developing countries and biodiversity hotspots, covering one-sixth of the world's land surface, are particularly vulnerable to invasion (Early et al., 2016), as seen in Nepal due to limited resources and IAPS management (Shrestha, 2021). Furthermore, these species

proliferate rapidly in Nepal due to climatic variations and physiographic conditions (Shrestha & Shrestha, 2021), with dry tropical to subtropical climates, especially in southern regions, favoring IAPS dispersion (Shrestha, 2021). Infrastructure development, such as road construction, has facilitated the spread of IAPS across the landscape in Nepal (Shrestha & Shrestha, 2021), with roadsides providing conducive microhabitats, including drainage, light availability, stem density, and substrate character (Shrestha et al., 2019). Furthermore, numerous environmental factors, such as vegetation structure, distance to a water body, and tree canopy cover influence the species distribution (Field & Laws, 1970). Ultimately, this leads to biodiversity loss (Karki & Paudel, 2014).

Protected areas (PAs) offer diverse ecosystem services, such as reducing the risk of natural disasters and regulating climate (Castro et al., 2015). The PAs are crucial for conserving biodiversity (Rodrigues et al., 2004), and those PAs located in Tarai, Siwalik region of Nepal are at risk of IAPS due to massive invasion (Bhatta et al., 2020; Chaudhary et al., 2020). The introduction of IAPS becomes more problematic in the PAs due to the activities of tourists, which facilitate the IAPS dispersion (Murphy et al., 2013). For example, boating, fishing, and vehicles aid in the dispersion of IAPS (Pathak et al., 2021). Meanwhile, IAPS thrive and proliferate in those PAs which are near to settlement (Simberloff, 2009). In forest landscapes, a road provides an open space that is suitable for growth (Deeley & Petrovskaya, 2022). This might be the reason IAPS are more commonly found in forest edges and gaps, with a fewer occurrence in the core of the forest (Khaniya & Shrestha, 2020).

Parsa National Park (PNP) serves as a crucial habitat for top predators like tigers (*Panthera tigris*) and leopards (*P. pardus*) (PNP, 2018), whose survival depends on the presence of wild ungulates, and the abundance of ungulates is influenced by the quality of their habitat (Bjørneraas et al., 2012). The habitat quality might be influenced by around 14 IAPS, such as siam weed, lantana (*Lantana camara*), and mile-a minute weed recorded in the PNP (Chaudhary et al., 2020). Therefore, this study aims to focus on the coverage of IAPS and its effects on the wild ungulates' habitat. The findings from this research can inform conservationists, policymakers, and researchers of effective management strategies to mitigate the ecological consequences of IAPS invasion.

1.2 Objectives

1.2.1 General objective

The general objective of this study was to identify the effect of Invasive Alien Plant Species (IAPS) on the habitat utilization of wild ungulates in Parsa National Park, Nepal.

1.2.2 Specific objectives

The specific objectives were as follows:

- To assess the invasive alien plant species coverage in PNP.
- To analyze the effect of invasive alien plant species on the habitat of wild ungulates in PNP.

1.3 Significance of the study

Biological invasion has emerged as a significant threat within protected areas (Bhatta et al., 2020; Chaudhary et al., 2020). In Nepal, protected areas mainly located in the Siwalik and Terai regions area invaded by IAPS (Karki & Paudel, 2014). They are the major factor in biodiversity loss (Shrestha & Shrestha, 2021), with a major impact on habitat loss of mammal species (Bhattarai, 2012). As a result, mammal species do not use these habitats (Aravind et al., 2010; Murphy et al., 2013). IAPS were more problematic to the survival of threatened species (Lahkar et al., 2011; Murphy et al., 2013). Thus, the control and management of these invasive species are prerequisites for biodiversity conservation. Despite the extensive studies on the IAPS and their distribution, relatively few investigations have explored the effect of IAPS (Adhikari et al., 2022). The limited research on the ecological impacts of IAPS in Nepal hinders effective management and policy development, particularly concerning the rise and control of the 14 IAPS in PNP that are negatively altering critical habitat (Chaudhary et al., 2020). It's creating a problem for developing policies to minimize the effect. Therefore, the data on the IAPS coverage and their potential effects on the wild ungulates obtained from this study can be used by policymakers and park managers for developing a site- specific management plan.

2. Literature review

2.1 Invasive Alien Plant Species

The IAPS are one of the biggest hazards to all-natural life at present (Shrestha, 2019). They are native to a particular area and may be intentionally or unintentionally distributed in another area, colonized, and affect in distribution of native species of that area (Gaertner et al., 2009). Intentional introduction of water hyacinth, originally native to America, was introduced into Europe for purposes of water waste treatment and ornamentation (Xie et al., 2000). Spread of non-native species can result in habitat fragmentation due to encroachment into natural habitats, agricultural expansion, and urbanization (Vitousek, 1996). An illustrative case is the Eurasian zebra mussel (*Dreissena polymorpha*), extensively distributed in North America, covering river and lake beds underscores that the appearance of alien species is predominantly influenced by human activities, encompassing both intentional and unintentional dispersion (Vitousek, 1996). Specifically, IAPS are utilized as fuel, food, medication, or fodder in particular areas (Kull et al., 2007). Silver wattles (*Acacia dealbata*), utilized worldwide for ornamental, economic, and environmental purposes (Kull et al., 2007). Delving into how transportation and international trade, propelled by rapid economic development, foster the dispersal, growth, and establishment of invasive species (Xie et al., 2000).

The IAPS differs in characteristics from native species as they have high growth rate, high multiplication rate tolerance to climate change, voracious feeders, aggressive behavior, and prey and predation capacity (William, 1996). Typically, IAPS tend to produce a large number of viable seeds (Brooks et al. 2004), and exhibit early sexual maturity (Pyšek et al., 2003). This strategy reduces competition from native species and enhances the survival chances of IAPS (Mack et al., 2000; Knight et al., 2009). The main reason behind the introduction and success of invasive species is due to the global atmosphere change (Vitousek et al., 1996). Additionally, a variety of tourism-related activities aided in the IAPS's dispersion (Pathak et al., 2021). Specifically, the augmentation of human activities in protected regions such as Chitwan National Park due to the promotion of tourism has resulted in a rapid spread of IAPS into these areas (Pathak et al., 2021). Furthermore, to promote tourism, many non-native species are purposefully introduced outside of their normal range (Arismendi & Nahuelhual, 2007).

For instance, sporting fish species like coho salmon (*Oncorhynchus kisutch*) and rainbow trout (*Oncorhynchus mykiss*) are introduced into non-native habitats for recreational fishing activities (Arismendi & Nahuelhual, 2007).

IAPS can bring about both positive and negative effects (Shrestha, 2021), for example, mile-a minute weed is employed in Malaysia as a remedy for itch-related issues (Basnet et al., 2016), but it hinders the germination and growth of native species (Karki & Poudel, 2013). The IAPS exerts adverse impacts on flora, fauna, and their habitats (Karki & Poudel, 2013), and their threat to global biodiversity and livelihood (Early et al., 2016), underscores. introduction of invasive species can lead to a reduction in ecotourism flourish (Shrestha, 2021). The IAPS often exhibits a high growth rate, rapid multiplication, and a tolerance for changing climates (Glowka et al., 1994). When these species aggregate in environments like forests, water bodies, wetlands, and grasslands, they don't just coexist; they tend to create an uninhabitable environment for native species, leading to biodiversity loss (Karki & Paudel, 2014). This has far-reaching consequences, including the threat to global biodiversity and livelihoods (Early et al., 2016), reduced farm productivity, and the risk of food and livestock poisoning (Shrestha et al., 2018).

The detrimental effects of IAPS extend to the distribution and survival of native species (Gartner et al., 2009), altering the habitat utilization patterns of mammalian species (Dutra et al., 2011), as they modify their primary habitats (Lahkar et al., 2011). The higher density of IAPS was found more in dense canopy and less dispersion in forest age and open gap (Khaniya & Shrestha, 2020). While low canopy cover decreases light (Baret et al., 2008). The distribution of IAPS were frequently recorded in disturbed areas (Shrestha, 2017), such as nearer to road areas (Shrestha et al., 2019) because road is the major driver for the dispersal of IAS (Adhikari et al., 2020). For example, some invasive species, such as the siam weed, mile-a minute weed were rapidly spreading and dispersed in and around the road areas of Manas National Park, India than the core areas of the park (Nath et al., 2019). The vehicles and transporting materials are supposed to introduce IAPS in new areas (Adhikari et al., 2020). The appearance of alien species mostly depends on human activities and natural processes (Vitousek, 1996).

2.2 Effects of IAPS on the habitat of wild ungulates

Spread of non-native species can result from habitat fragmentation due to encroachment into natural habitats, agricultural expansion, and urbanization (Vitousek, 1996). In context to negative effects, it has threatened the biodiversity and livelihood of species (Early et al., 2016), decreasing the flow of ecotourism (Shrestha, 2021). The IAPS affect the food web in an ecosystem by removing the natural food sources, they can also change the diversity and abundance of species that are important for a particular habitat (Shrestha, 2019). The IAPS have a detrimental effect on human health (Rai & Singh, 2020), animal grazing (Lahkar et al., 2011), agricultural productivity, and forest regeneration (Shrestha et al., 2018). They draw pollinators and dispersers away from local species, biological invasions can affect pollinator communities (Aravind et al., 2010). For instance, frugivorous birds and mammals are drawn to the berries of lantana, which helps spread the plant's seeds and reduces the likelihood that native species will reproduce (Aravind et al., 2010). The excessive spread of IAPS has contributed to the major loss of biodiversity (Karki & Poudel, 2013). Mile-a minute weed is the most problematic invasive species in terrestrial ecosystems (Basnet et al., 2016). For example, it has invaded the preferred habitats of greater one-horned rhinos in Chitwan National Park (Ashok, 2008). Oxalis is causing problems for swamp deer habitats by spreading over open grasslands in Shuklaphanta National Park (Bhandari, 2019). Since, IAPS species reduce the grass biomass of native species (Arandhara et al., 2021). Which has caused in reduction food availability inside the park. Also, mammal species like barking deer, chital, and wild boar are facing issues due to the impact of mile-a minute weed, siam weed, lantana, and parthenium on their abundance (Adhikari et al., 2021).

Habitat modification due to invasion of siam weed (Dumalisile & Somers, 2011), forced larger mammals to avoid this area in Africa (Koirala et al., 2020). The IAPS *Prosopis juliflora* poses a threat to many mammal species in tiger reserves in India decreasing foraging opportunities (Maheshnai et al., 2022). IAPS has also contributed to the negative effect on wild ungulates' distribution at Barandabhar Corridor Forest (Arandhara et al., 2021; Adhikari et al., 2022), and the distribution and habitat utilization of black buck (Chaudhary et al., 2020).

It's significant to recognize that invasive species can result in both advantageous and detrimental consequences. While they might have advantageous effects, such as mile-a

minute weed being used for itch-related remedies (Lahkar et al., 2011; Bhatta et al., 2020). Mile-a minute weed for instance, aids in seed dispersal and attracts frugivorous birds and mammals (Aravind et al., 2010). Additionally, water hyacinth is used for water treatment in certain regions (Xie et al., 2000), however, it has negative effects on threatened bird species (Basaula et al., 2021), native fish species (Basaula et al., 2023) and damage habitats of vulnerable species (Shrestha, 2021). After habitat degradation, invasive species are major cause of biodiversity loss (Gaertner et al., 2009).

The prevalence of alien species is a global concern (Liu et al., 2005), leading to alterations in riparian watersheds (Lambert et al., 2010). Mile-a minute weed widespread distribution in wetlands has been noticed (Lamichhane et al., 2018), which impacts the distribution of larger animals like rhinoceroses (Poon et al., 2022). Notably, mile a-minute weed has been recognized as a troublesome invader in terrestrial ecosystems (Basnet et al., 2016), including grasslands (Ram, 2008), impacting grass biomass and affecting the distribution of ungulates species (Arandhara et al., 2021). Furthermore, invasive species can negatively affect deer species example barking deer, chital (Adhikari et al., 2022).

Biological invasions are emerging as a significant threat, impacting protected areas (Chaudhary et al., 2020). Developing countries are particularly affected by the consequences of invasive species (Shrestha, 2016). The rapid spread of aggressive invasives poses challenges due to limited data availability (Shrestha, 2019). Nepal's Siwalik and Terai regions have faced issues caused by a range of invasive species (Ajay et al., 2013), with major siam weed causing problems near settlements in PNP (Chaudhary et al., 2020). The IAPS extent and impact on mammal species in PNP is essential. This research aims to analyze invasive species, understand their effects on mammal habitats, and formulate effective management strategies.

3. Materials and methods

3.1 Study area

This study was conducted in Parsa National Park (PNP; 27°15' N – 27°33' N and 84°41' E – 84°58' E), which comprises an area of 637.37 km² and is situated at elevation ranging from 100 m to 950 m (PNP, 2018). The park is located in Parsa, Makwanpur, and Bara districts, within Madesh and Bagmati provinces.

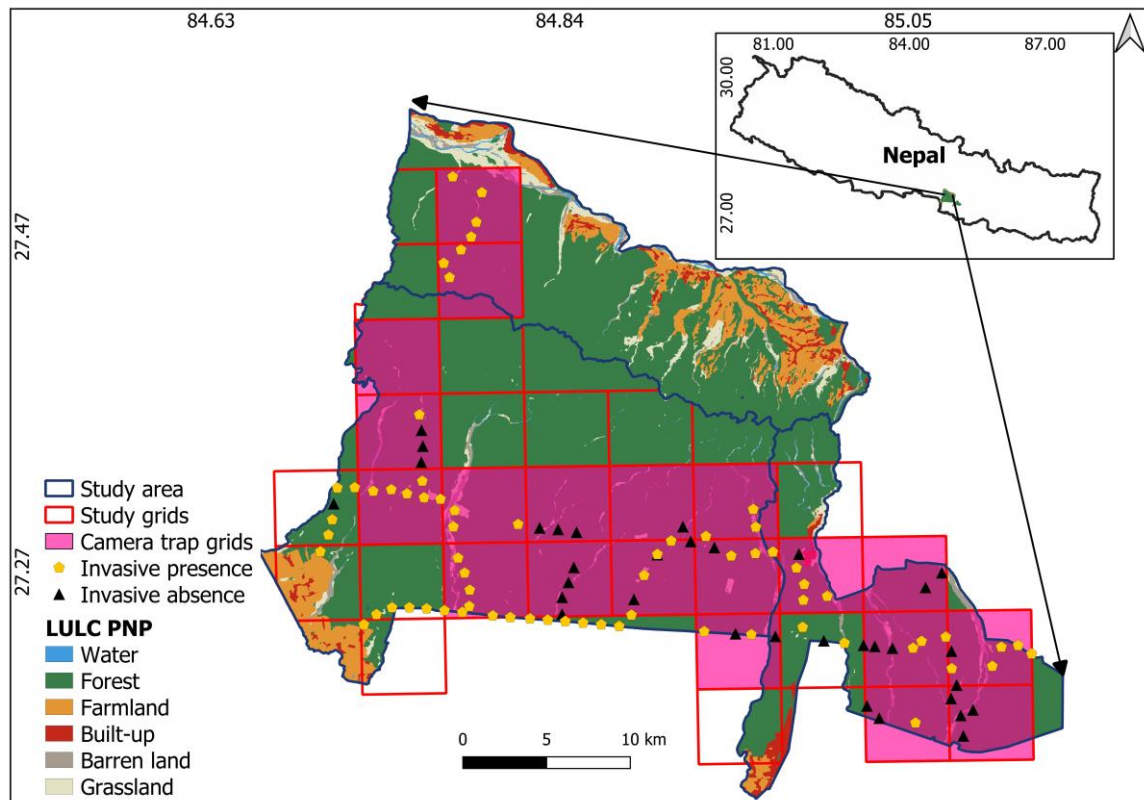


Figure 1. Study area map of Parsa National Park, Nepal

Forest of PNP supports tropical and subtropical species. Approximately, 90% of the park is covered by sal tree (*Shorea robusta*) forest, and remaining vegetation of the park includes sissou (*Dalbergia sissoo*), khair (*Acacia catechu*), simal (*Bombax ceiba*), sindhure (*Mallotus philippensis*), amilo (*Baauhinia malabarica*) riverine forest include silk cotton tree (*Ceiba pentandra*). Whereas dominance of sabai grass is commercially important for species. A total of 37 mammal species have been recorded in PNP (Budha & Chaudhary, 1998). Faunal species including Asian elephant (*Elephas maximus*), sloth bear (*Melursus ursinus*), tiger (*Panthera tigris*), greater one-horned rhino (*Rhinoceros unicornis*), and leopard (*P. pardus*), gaur (*Bos gaurus*), chital (*Axis axis*), barking deer

(*Muntiacus vaginalis*), hog deer (*Axis porcinus*), sambar (*Rusa unicolor*), wild boar (*Sus scrofa*), leopard cat (*Felis bengalensis*), rhesus monkey (*Macaque mulatta*), langur (*Presbytes entellus*), jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*) are major mammal species in the park (PNP, 2018; Sharma et al., 2023; Sharma et al., 2024). The park ecosystem is facing challenges from invasive species, drying up of waterholes, and anthropogenic threats including human wildlife conflict and resource extraction (PNP, 2018). During the dry and late winter seasons, the park's environment becomes extremely dry due to its physiographic location and forest fires, grassland areas are affected by weed invasion (PNP, 2018). Altogether 14 invaded invasive species are recorded in the park, and the major one is siam weed which is most dominant species (Chaudhary et al., 2020).

3.2 Methods

Data on the IAPS coverage and occurrence of wild ungulates were collected between December 2022 and October 2023. The camera trap method was used for the confirmation of wild ungulates' occurrence. In addition, direct observation was conducted for identifying the invasive species coverage, and sign of mammal species for their presence in the study area. The camera trap data was collected between December 2022 and March 2023. A 5*5 km² grid was established throughout PNP and installed cameras at 67 locations (plots: 50 m ×50 m) maintaining a minimum distance of 1 km between adjacent cameras. The cameras were deployed at an average height of 40–60 cm above the ground. The cameras were left in place for 21 days, and monitored in every seven days to identify whether the cameras are properly and monitored in every seven days to identify whether the cameras are properly functioning. Cameras were set to capture three pictures at a time with delay of 30-seconds between detections and species were recorded using these cameras, only focusing wild ungulate mammal species data were used to study.

In addition to camera traps, data on IAPS coverage and wild ungulates' signs were also collected from 3-11 October 2023. A total of 39 plots in addition to a camera trap were used for sign observation. Signs of herbivore species, such as footprints, scratches, burrows and fecal samples were recorded. Where the presence and absence of IAPS, and their number was recorded. A cover of individual IAPS was recorded visually by cover-class scale value (Appendix 3) (Zobel et al., 1987). In addition, the presence of new

invasive species was also recorded opportunistically if they were sighted along the route. In each observation plot, a canopy cover was measured as the average of the four corners and the center. The latitude and longitude of each plot were recorded using the Global Positioning System (GPS; Garmin Etrex 10). Furthermore, using latitude and longitude, distance to the nearest settlement, distance to the nearest road, and distance to the nearest water source were also recorded from the center of each plot with the help of data from OpenStreetMap (OpenStreetMap contributors, 2023). In addition, the signs of ungulate chital, barking deer, sambar, gaur, nilgai, and wild boar were identified using the book “Indian Mammals: A Field Guide” (Menon, 2014), while fecal samples were identified by comparing the sample with species at the Central Zoo, Lalitpur, Nepal.

3.3 Data analysis

A Generalized Linear Model (GLM) with a poisson distribution was used to identify the factors affecting on the invasive plant species coverage. Before that predictive variables were standardized and correlation test was performed among the predictive variables; none of them were highly correlated $|r| > 0.7$ (Figure 2); thus, all variables were used in the analysis. IAPS coverage was considered as response variable, while the distance to the nearest water (m), nearest distance to the road (m), and the nearest distance to settlement (m) were used as predictive variables. In addition, to identify factors affecting the occurrence of ungulates (barking deer, chital, sambar, nilgai, gaur and wild boar), the presence/absence of each ungulate were used as response variable while invasive species coverage along with other variables used earlier were used as predictive variables. All analyses were performed in R Program (R Core Team, 2023).

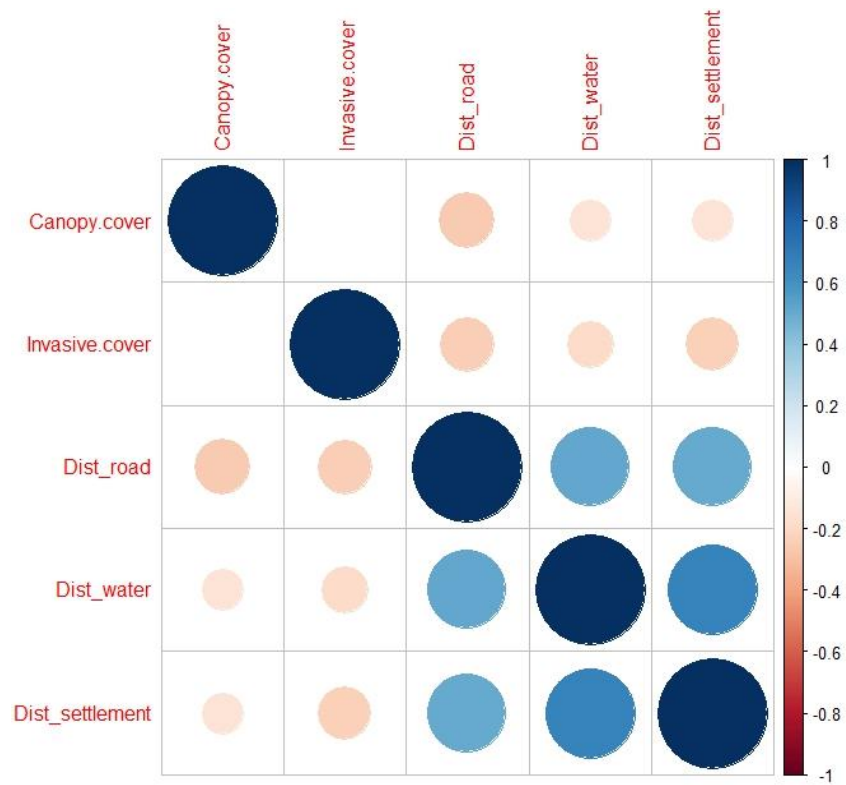


Figure 2. Correlation heat map showing correlation between predictive variables (Dist_water = nearest distance to water bodies, Dist_road = nearest distance to road, Dist_settlement = nearest distance to settlement).

4. Results

4.1 Invasive alien plant species

A total of 20 IAPS were recorded from nine families, like Asteraceae, Fabaceae, Rubiaceae, Lamiaceae, Verbenaceae, Pontederiaceae, Amaranthaceae, Convolvulaceae, and Araceae (Appendix 1) in Parsa National Park, among 30 IAPS recorded in Nepal (Shrestha et al., 2024). Although, only eight IAPS were recorded from surveyed plots in PNP, and other species were recorded from opportunities surveys along the route. IAPS were detected in 71 plots, each showing the presence of at least one IAPS, while 35 plots exhibited the absence of IAPS. Among the eight IAPS, siam weed was found to have highest cover 44% of total plots, and followed by billy goat (21%), mile-a minute weed (19.78%), ban fanda (7.48%), sensitive plant (*Mimosa pudica*) (3.2%), whereas less cover of goat weed bush mint (*Mesosphaerum suaveolens*) (1.6%), (*Ageratum houstonianum*) (1.06%) and sickle pod senna (*Senna tora*) (1.06%), has least cover. The average canopy cover of the study plots was $46.83 \pm 12.315\%$ (range: 0–77%), the average invasive plant cover was 10.14 ± 13.91 (range: 0–77.5%), the average distance to the nearest road was 1138.28 ± 1357.094 m (range: 0.60–7391.51 m), the average distance to nearest water bodies was 3359.65 ± 2466.088 m (range: 39.86–9315.59 m) and the average distance to nearest settlement was 4016.94 ± 2108.04 m (range: 333.93–9127.29 m).

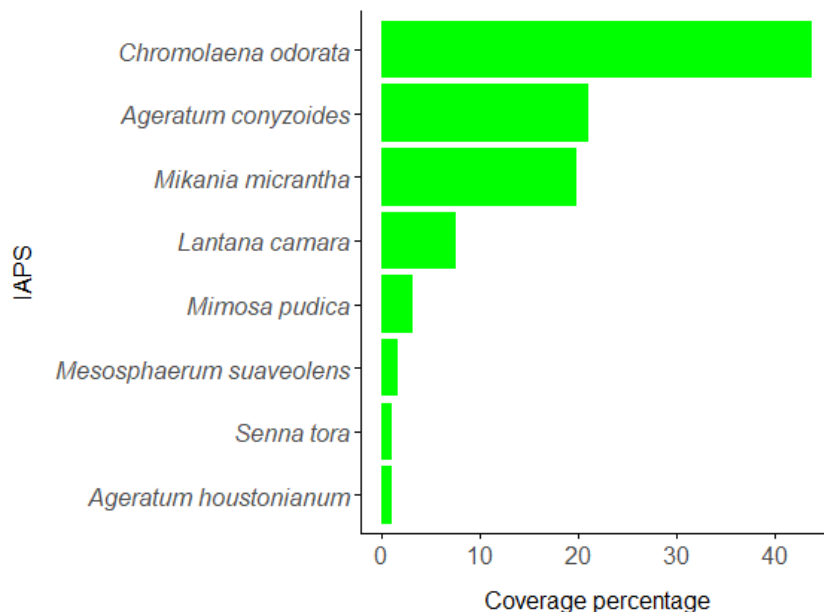


Figure 3. Frequency of invasive alien plant species in Parsa National Park, Nepal in 2023.

4.2 Ungulates presence

A total of 28 wild mammal species (Appendix 2) were recorded from PNP among them only ungulates were used for the analysis. Wild boar was recorded from 60 plots, followed by chital (53), barking deer (46), nilgai (31), sambar (31), and gaur from 23 plots. During the sign survey fecal samples were recorded in 23 plots; and scratches of wild ungulates from 18 plots. During the study period, some ungulates were directly observed in survey plots. Among them the chital was observed in nine plots, wild boar in 10 plots, and gaurs in two plots.

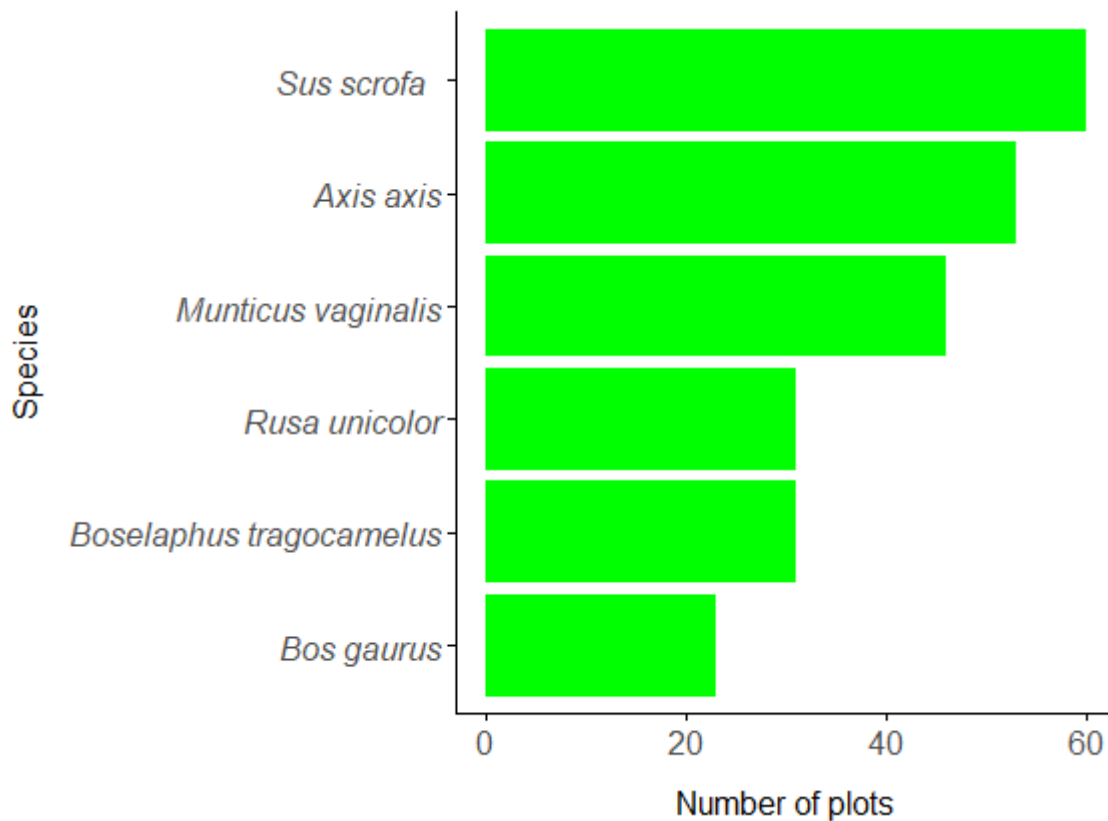


Figure 4. Wild ungulate in the study plot in Nepal Parsa National Park, Nepal in 2023.

Table 1. Model-average parameter estimates and their Lower Confidence Interval (LCI) and Upper Confidence Interval (UCI) 95% confidence limit (CL) describing the factor affecting the cover of invasive plant species in Parsa National Park, Nepal during 2023. Model parameters include tree canopy cover (%), distance to road (m), distance to water (m), and distance to settlement (m). Estimates were averaged from all models. Significant effects are in bold.

Variables	Estimate	SE	LCI	UCI	z	P
Intercept	3.302	0.137	3.027	3.567	24.010	<0.001
Canopy cover	-0.007	0.002	-0.012	-0.002	-2.940	0.002
Distance to road	-0.001	0.001	-0.004	-0.002	-7.617	<0.001
Distance to water	-0.001	0.002	-0.005	0.002	-0.750	0.453
Distance to settlement	-0.001	0.002	-0.001	-0.001	-4.924	<0.001

The invasive species coverage was influenced by tree canopy cover, nearest distance to the road, and settlement. The invasive species coverage was higher at low tree canopy percentage, nearest distance to road and settlement (Table 1). The invasive species coverage increased nearer to water bodies but was not an influencing factor (Table 1).

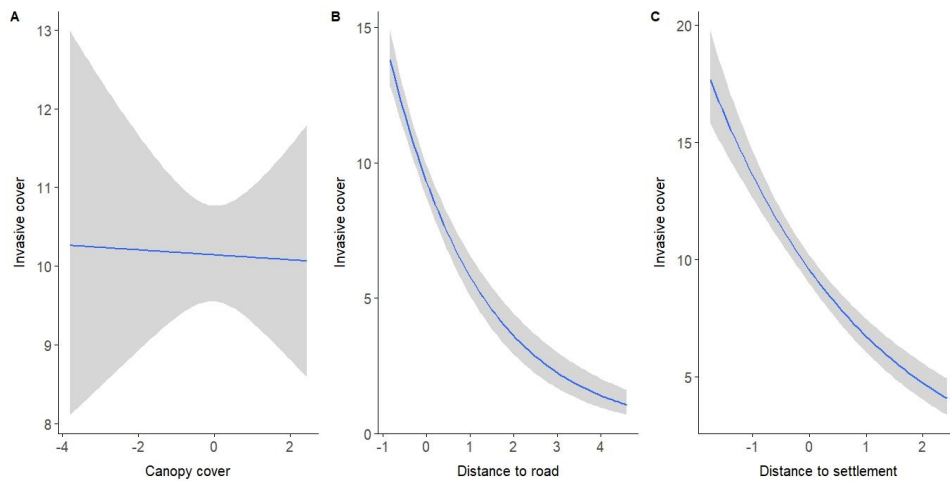


Figure 5. Effect of canopy cover, distance to road, and distance to settlement on invasive alien plant species coverage in Parsa National Park, Nepal in 2023.

Table 2. Model-average parameter estimates and their Lower Confidence Interval (LCI) and Upper Confidence Interval (UCI) 95% confidence limit (CL) describing the factor affecting the occurrence of barking deer in Parsa National Park, Nepal during 2023. Model parameters include invasive cover (%), tree canopy cover (%), distance to road (m), distance to water (m), and distance to settlement (m). Estimates were averaged from all models. Significant effects are in bold.

Variables	Estimate	SE	LCI	UCI	z	P
Intercept	1.331	1.196	-1.006	3.782	1.113	0.266
Invasive cover	-0.065	0.025	-0.118	-0.020	-2.610	0.009
Canopy cover	-0.029	0.020	-0.070	0.009	-1.458	0.145
Chital	1.052	0.493	0.105	2.052	2.132	0.033
Sambar	2.039	0.660	0.811	3.429	3.088	0.002
Nilgai	0.048	0.533	-1.005	1.104	0.089	0.928
Gaur	0.182	0.632	-1.080	1.432	0.289	0.773
Wild boar	-0.242	0.483	-1.208	0.697	-0.501	0.616
Distance to road	-0.641	0.314	-1.309	-0.061	-2.041	0.04
Distance to water	-0.151	0.339	-0.828	0.513	-0.446	0.655
Distance to settlement	0.048	0.329	-0.596	0.705	0.147	0.883

The presence of barking deer was influenced by invasive cover, the presence of chital, sambar, and the nearest distance to the road. Its presence was increased at lower invasive species coverage, nearer distance to road, and with the presence of chital and sambar (Table 2). The barking deer's presence was found at lower tree canopy percentage, at lower occurrence of wild boar, nearer to water sources and far from the settlement but these were not major influencing factors (Table 2).

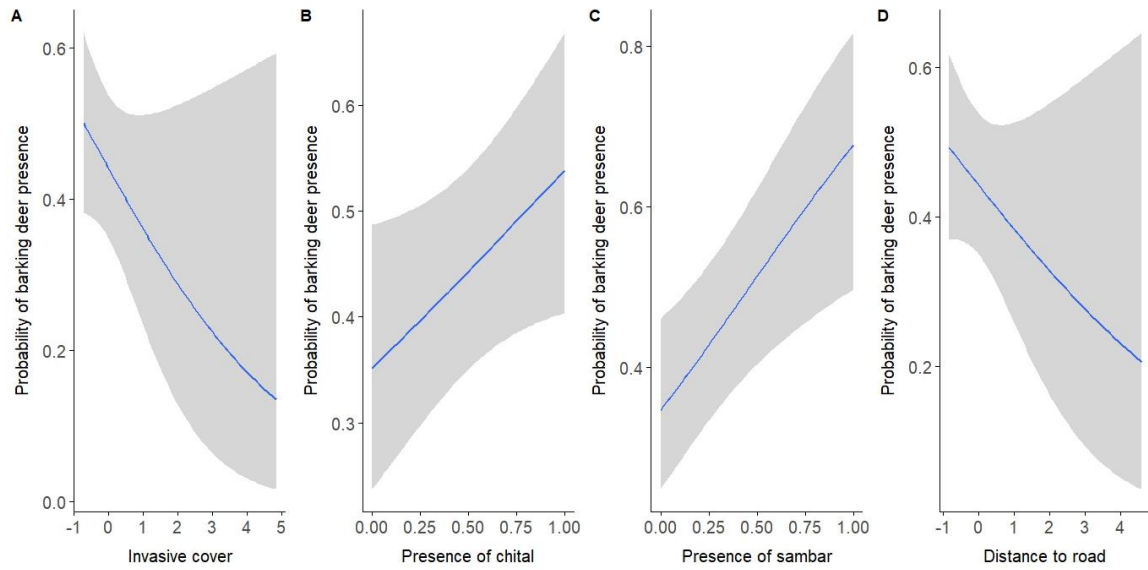


Figure 6. Effect of Invasive cover, presence of chital, presence of sambar and distance to road on barking deer presence in Parsa National Park, Nepal in 2023.

Table 3. Model-average parameter estimates and their Lower Confidence Interval (LCI) and Upper Confidence Interval (UCI) 95% confidence limit (CL) describing the factor affecting the occurrence of chital in Parsa National Park, Nepal during 2023. Model parameters include invasive cover (%), tree canopy cover (%), distance to road (m), distance to water (m), and distance to settlement (m). Estimates were averaged from all models. Significant effects are in bold.

Variables	Estimate	SE	LCI	UCI	z	P
Intercept	-2.474	1.399	-5.482	0.093	-1.769	0.077
Invasive Cover	0.018	0.018	-0.016	0.058	1.000	0.317
Canopy Cover	0.038	0.023	-0.004	0.087	1.654	0.098
Sambar	0.310	0.633	-0.926	1.582	0.489	0.625
Barking deer	0.940	0.490	-0.003	1.931	1.918	0.055
Nilgai	1.145	0.510	0.171	2.189	2.245	0.024
Gaur	0.204	0.607	-0.992	1.415	0.337	0.736
Wild boar	0.266	0.465	-0.643	1.191	0.572	0.567
Distance to road	-0.303	0.325	-0.968	0.313	-0.934	0.350
Distance to water	-0.193	0.344	-0.887	0.476	-0.561	0.575
Distance to settlement	-0.029	0.322	-0.657	0.616	-0.091	0.927

The presence of chital was influenced by the presence of barking deer, and nilgai. Its occurrence was increased with increasing the presence of barking and nilgai. Its presence was found at higher tree canopy percentage, invasive species cover, at higher occurrence of sambar, and wild boar, nearer to water sources, and far from the settlement but these were not influencing factors (Table 3).

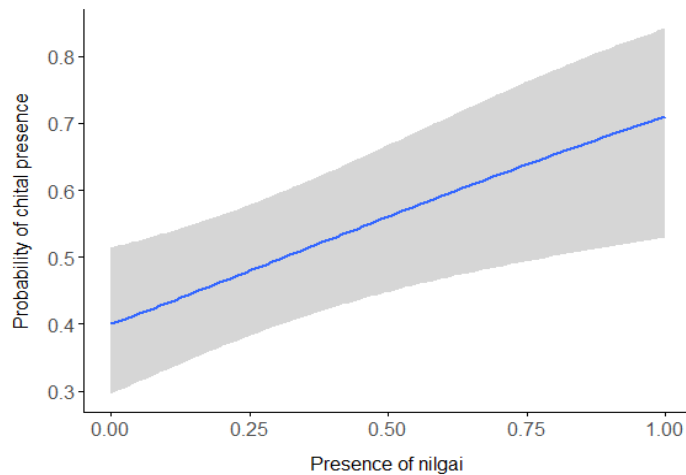


Figure 7. Effect of the presence of nilgai on chital presence in Parsa National Park, Nepal in 2023.

Table 4. Model-average parameter estimates and their Lower Confidence Interval (LCI) and Upper Confidence Interval (UCI) 95% confidence limit (CL) describing the factor affecting the occurrence of sambar deer in Parsa National Park, Nepal during 2023. Model parameters include Invasive cover (%), tree canopy cover (%), distance to road (m), distance to water (m), and distance to settlement (m). Estimates were averaged from all models. Significant effects are in bold.

Variables	Estimate	SE	LCI	UCI	z	P
Intercept	-0.675	1.595	-3.840	2.515	-0.423	<0.001
Invasive Cover	0.053	0.023	0.009	0.100	2.335	0.019
Canopy Cover	-0.078	0.030	-0.143	-0.025	-2.618	0.008
Spotted	0.056	0.658	-1.247	1.370	0.086	0.932
Barking	2.085	0.684	0.828	3.548	3.049	0.002
Nilgai	-0.314	0.705	-1.740	1.067	-0.446	0.656
Gaur	-0.416	0.740	-1.930	1.010	-0.562	0.574
Wild boar	1.712	0.645	0.520	3.082	2.654	0.007

Distance to road	0.720	0.379	0.028	1.529	1.896	0.057
Distance to water	1.347	0.504	0.453	2.471	2.673	0.007
Distance to settlement	-0.953	0.434	-0.884	-0.151	-2.193	0.021

The presence of sambar was influenced by the invasive cover, tree canopy cover, presence of barking deer, wild boar, distance far from road, water resources, and settlement. Its presence was increased at the higher invasive cover, presence of barking deer, far from distance to water, road, and settlement. But low in high tree canopy cover, lower occurrence of gaur, but these were not influencing factor (Table 4).

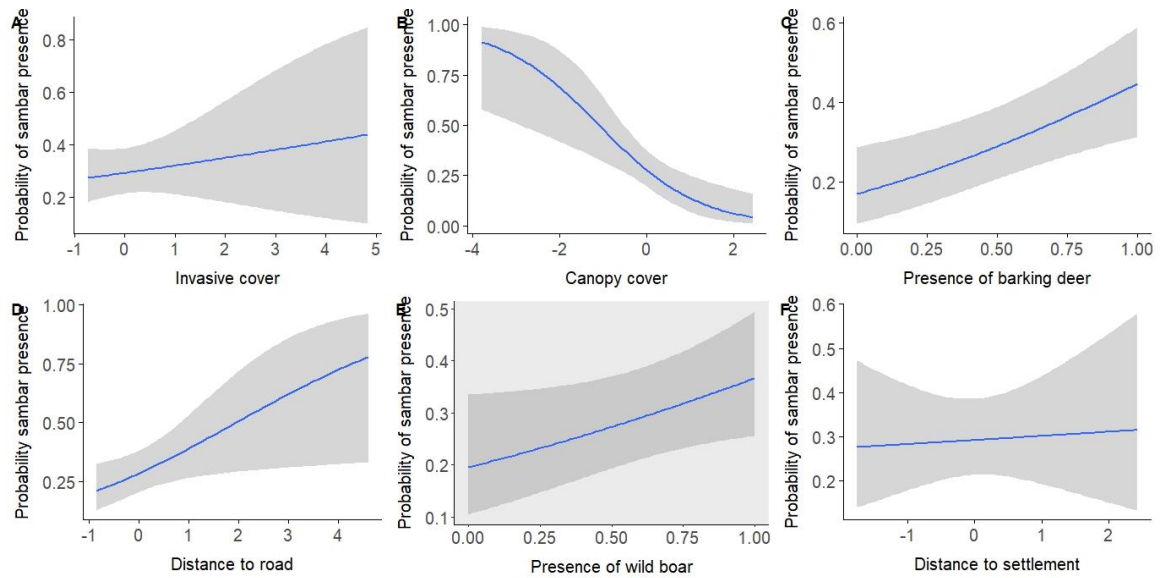


Figure 8. Effect of invasive cover, canopy cover, presence of barking deer, distance to road, presence of wild boar, and distance to settlement and sambar's presence in Parsa National Park, Nepal in 2023.

Table 5. Model-average parameter estimates and their Lower Confidence Interval (LCI) and Upper Confidence Interval (UCI) 95% confidence limit (CL) describing the factor affecting the occurrence of nilgai in Parsa National Park, Nepal during 2023. Model parameters include Invasive cover (%), tree canopy cover (%), distance to road (m), distance to water (m), and distance to settlement (m). Estimates were averaged from all models. Significant effects are in bold.

Variables	Estimate	SE	LCI	UCI	z	P
Intercept	-3.160	1.699	-6.794	-0.109	-1.860	0.063
Invasive Cover	0.014	0.017	-0.020	0.049	0.833	0.405
Canopy Cover	0.036	0.028	-0.015	0.094	1.285	0.199
Sambar	-0.444	0.699	-1.863	0.911	-0.636	0.525
Chital	1.173	0.507	0.205	2.210	2.313	0.020
Barking deer	-0.023	0.541	-1.096	1.041	-0.042	0.966
Gaur	0.876	0.624	-0.352	2.131	1.404	0.160
Wild boar	0.041	0.496	-0.929	1.029	0.084	0.933
Distance to road	0.304	0.337	-0.373	0.962	0.904	0.366
Distance to water	0.499	0.346	-1.201	0.173	-1.440	0.150
Distance to settlement	0.019	0.336	-0.642	0.692	0.059	0.953

The presence of nilgai was influenced by the presence of Chital. Nilgai's presence was increased with increasing the presence of chital. Its presence was found at high tree canopy cover, invasive cover, far from water bodies, settlement, and roads, and at lower presence of barking deer and sambar but these were not influencing factors (Table 5).

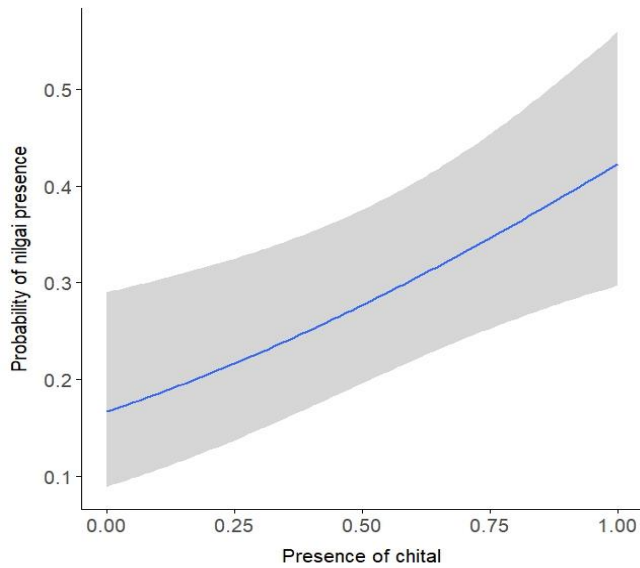


Figure 9. Effect of presence of chital on nilgai presence in Parsa National Park, Nepal in 2023.

Table 6. Model-average parameter estimates and their Lower Confidence Interval (LCI) and Upper Confidence Interval (UCI) 95% confidence limit (CL) describing the factor affecting the occurrence of gaur in Parsa National Park, Nepal during 2023. Model parameters include invasive cover (%), tree canopy cover (%), distance to road (m), distance to water (m), and distance to settlement (m). Estimates were averaged from all models. Significant effects are in bold.

Variables	Estimate	SE	Lower CI	Upper CI	z	P
Intercept	-4.229	1.696	-7.956	-1.200	-2.493	0.013
Invasive Cover	0.012	0.020	-0.033	0.052	0.593	0.553
Canopy Cover	0.006	0.028	-0.047	0.064	0.200	0.842
Sambar	-0.256	0.684	-1.648	1.066	-0.374	0.708
Chital	0.023	0.621	-1.209	1.263	0.037	0.971
Barking deer	0.224	0.636	-1.030	1.496	0.353	0.724
Wild boar	0.495	0.574	-0.610	1.669	0.863	0.388
Nilgai	0.863	0.650	-0.407	2.187	1.328	0.184
Distance to road	-0.237	0.331	-0.938	0.387	-0.717	0.474
Distance to water	1.010	0.419	0.242	0.920	2.410	0.015
Distance to settlement	0.242	0.405	-0.583	1.039	0.598	0.550

The presence of gaur was influenced by the nearest distance to water bodies. Gaur presence was decreased at the nearest distances to water bodies. In addition, its occurrence was high in invasive cover, high tree canopy cover, at the high occurrence of chital, barking deer, wild boar, nilgai, and its presence was found at the lower occurrence of sambar, far from the road, water, and settlement but these were not influencing factor (Table 6).

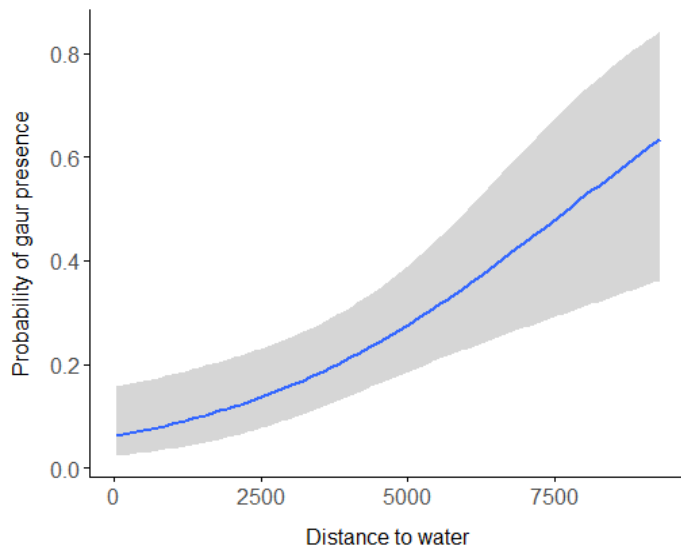


Figure 10. Effect of distance to water on gaur presence in Parsa National Park, Nepal in 2023.

Table 7. Model-average parameter estimates and their Lower Confidence Interval (LCI) and Upper Confidence Interval (UCI) 95% confidence limit (CL) describing the factor affecting the occurrence of wild boar in Parsa National Park, Nepal during 2023. Model parameters include invasive cover (%), tree canopy cover (%), distance to road (m), distance to water (m), and distance to settlement (m). Estimates were averaged from all models. Significant effects are in bold.

Variables	Estimate	SE	LCI	UCI	z	P
Intercept	-0.462	1.192	-2.911	1.836	-0.387	0.699
Invasive cover	-0.025	0.017	-0.061	0.008	-1.440	0.150
Canopy cover	0.015	0.020	-0.023	0.056	0.750	0.453
Sambar	1.584	0.595	0.468	2.821	2.665	0.007
Chital	0.257	0.458	-0.643	1.164	0.560	0.576
Barking deer	-0.150	0.467	-1.077	0.764	-0.320	0.749
Gaur	0.652	0.582	-0.465	1.842	1.121	0.263
Nilgai	0.048	0.496	-0.922	1.038	0.096	0.923
Distance to road	-0.320	0.276	-0.884	0.216	-1.157	0.247
Distance to water	-0.485	0.324	-0.147	0.135	-1.495	0.135
Distance to settlement	0.304	0.310	-0.294	0.933	0.979	0.328

The presence of wild boar was influenced by the presence of sambar. Its presence was increased with increasing the presence of sambar. But their occurrence was increased in lower invasive species coverage, high tree canopy percentage, at the presence of chital, gaur, and nilgai, far from the distance to road, water, and settlement and lower in the occurrence of barking deer, but these were not influencing factors (Table 7).

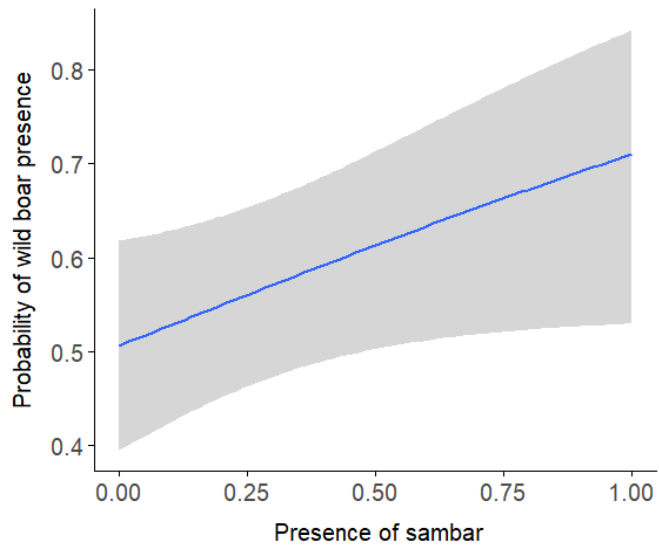


Figure 11. Effect of presence of sambar on wild boar presence in Parsa National Park, Nepal in 2023.

5. Discussion

This study investigated 20 IAPS in PNP with seven new species for PNP. These new recorded species were crofton weed (*Ageratina adenophora*), bush morning glory (*Ipomoea carnea*), broadleaf weed (*Spermacoce alata*), water hyacinth, lead tree (*Leucaena leucocephala*), water lettuce (*Pistia stratiotes*), shaggy soldier (*Galinsoga quadriradiata*). These newly recorded invasive species suggest that these IAPS are at the initial invasion stage in PNP. Crofton weed, bush morning glory and water hyacinth are recorded from Chitwan National Park (Bhatta et al., 2021) and Urban Forest of Hetauda (Pandey et al., 2021), these species are more problematic in the Terai region near to PNP. Therefore, these might be the reason of the dispersion of these IAPS in PNP. However, only the effect of eight IAPS coverage (that was recorded in the survey plots) was seen in the habitat of wild ungulates. Among them the highest coverage was found for siam weed which might be due to the quick adaptation of this species in the deciduous forest supporting habitat (Ahrestani et al., 2012; Chaudhary et al., 2020), which is appropriate at PNP (Chaudhary et al., 2020). Siam weed forms monoculture stands which affect the germination of native species and drive for imbalance ecosystem process (Shrestha, 2016).

The IAPS coverage varies among the species and is influenced by canopy cover, the nearest to roads, settlements, and water bodies in PNP. The number and coverage of IAPS are lower in dense tree canopy cover than in open. This might be due to low light penetration in dense canopy cover (Baret et al., 2008), which might be unfavorable for the spreading of invasive species. Open area is highly invaded by the IAPS than dense areas (Adhikari et al., 2022). Invasion disperse more in open areas like ventenata (*Ventenata dubia*) in China (Averett et al., 2016), because their germination and growth were facilitated by the openness of the canopy cover (Charbonneau & Fahrig, 2004).

The cover of individual IAPS species is higher near the settlement areas, probably due to the expansion of IAPS through global trade and human activities (IPBES, 2023). During this study, local people use ban silam for fencing houses or agricultural land, and later it becomes more problematic in croplands, or near settlements (Personal observation). Due to human activities like livestock, grazing assists IAPS more near settlements (Chaudhary

et al., 2020), for example, parthenium was used as animal bedding in many parts of Nepal (Shrestha, 2015).

The IAPS seems to be most abundant nearer the road, this might be due to transportation through vehicles because the road is one of the major drivers for invasive species transportation (Adhikari et al., 2021) and the road edges provide a suitable microhabitat and also serving as a corridor for species (Shrestha, 2018). Road has enhanced the rapid spread of the IAPS like crofton weed (Sang et al., 2010), which are abundant near and along the roadsides (Wang & Wang, 2006). As PNP is connected with highways, it might be the reason for more IAPS presence in road areas and roadsides.

During the study wild boar was frequently recorded among other ungulate because it forages over long distances (Dovrat et al., 2012), and is selective prey of predators (Wegge et al., 2009). Parsa National Park is the place for many top predators, such as tigers, leopards, and nationally threatened wild ungulates like barking deer, chital, sambar, nilgai, gaur, least concern ungulates wild boar, and Endangered Asian elephant (Jnawali et al., 2011). The population of ungulates needs to be protected for the conservation of top predation like tigers, leopards (Wegge et al., 2008). Otherwise, the ecosystem will demonstrate the trophic cascade (Fortin et al., 2005). Therefore, for the ecosystem balance, the presence of prey species is crucial, and their conservation will be secured if their grazing habitat is protected.

Ungulates, including chital, barking deer, sambar, nilgai, wild boar, and gaur, plays significant roles in ecosystem dynamics, and their occurrence is influenced by food choice (Keane & Crawley, 2002). The niche breadths of larger animal species are higher in the dry season, and they overlap with other species' habitats (Ahrestani et al., 2012). As the study was conducted in the dry season, the ground layer was dry, and vegetation was mainly covered with grass species, such as cogon grass (*Imperata cylindrica*) and cynodonts (*Clade cynodontia*), and the buffer zone was highly invaded by IAPS. However, the IAPS effect is not remarkable but ungulates avoid the IAPS invaded area like in Chitwan National Park (Murphy et al., 2013), Bardiya National Park (Bhatta et al., 200). Species avoid space that is invaded by IAPS as it causes a lack of palatable plant and habitat loss (Murphy et al., 2013). This might be the reason species richness is higher in IAPS non-invaded habitats (Dumalisile & Somers, 2017), because IAPS provides less food than native species (Utz et al., 2020).

The occurrence of barking deer was higher at low IAPS coverage and the presence of chital and sambar. Barking deer is mainly found in open canopy cover habitats and grasslands, possibly due to the availability of shrubs, which help them avoid predators. They are browsers and are usually found in grasslands (Habiba et al., 2022). However, the chital usually grazes but increases browsing during the dry season, preferring riverine forests during the hot-dry season and sal forests during the cool-dry season (Moe & Wegge, 1994; Ahrestani et al., 2012). Barking deer were mostly observed in riverine forests (Pokharel, 2012), near the edge of forests (Singh et al., 2022). Similarly, sambar prefers dense forest mainly for shelter (Wegge et al., 2009; Adhikari et al., 2021), they coexist with barking deer. In addition, barking deer were found more in the core area of PNP, and these are near roads (Wang & wang, 2006), as roads are covered with IAPS, which affects the food habitat of barking deer.

The occurrence of chital was influenced by the presence of wild boar in this study. It was probably due to low competition in the similar food between these two species. The wild boar is a gregarious animal that prefers open habitats and wet riverine forests, avoiding forested areas (Bhattarai, 2003). In open habitats, ungulates prefer larger groups to protect themselves from predators (Bhattarai & Kindlmann, 2012). Signs of larger predators are more evident in grasslands (Bhattarai & Kindlmann, 2012). The dominance of IAPS over habitat decreases available resources for herbivores and omnivores (Brooks et al., 2004), reducing habitat and indirectly decreasing grass biomass, on which herbivores feed (Arandhara et al., 2021). Deer species are affected by the introduction of IAPS into open grasslands (Arandhara et al., 2021). The consumption of palatable plant species allows siam weeds to colonize all the space in pasturage and render native species useless (McFadyen, 2000).

Sambar is found in dense habitats and can survive in different environments, using dense forests for shelter (Wegge et al., 2009). Nilgai is social and mostly found in groups (Bhattarai, 2003), mainly using open grasslands for grazing (Aryal, 2007). Sambar is found far from settlements, which may be due to the presence of IAPS near the settlement. Sambar is found in areas with less canopy cover, possibly due to changes in their food habits and feeding on shrubs during the dry season. The findings were opposite to those of Comte et al. (2022), who mentioned that the sambar prefers habitats close to roads with dense tree cover. Sambar is mostly distributed at dense tree and shrub densities

(Singh et al., 2022). Although, the presence of IAPS has a positive influence on the presence of sambar, which might be due to suitable habitat for sambar, as the presence of lantana in the Manohari site helps to hide sambar from larger predators observed during the study. Lantana provides space to hide from predators to sambar (Adhikari et al., 2022). The availability of habitat and resources significantly affects the abundance and distribution of mammal species (Ogutu & Owensmith, 2003).

Gaur are grazers, but they switch to browsing on plants during the dry season, when there is a lack of grasses (Ahrestani et al., 2012). In this study, nearest water bodies with sambar and gaur have a negative influence. The occurrence of gaur increases when they move far from the water bodies. However, observation was opposite to the findings in the study (Bhattarai & Kindlmann, 2013), gaur prefers proximity to water (Rich et al., 2016). During the dry times, to avoid waterholes and larger predators like elephants, they adjust their feeding schedules (Valeix et al., 2007).

6. Conclusions and recommendations

6.1 Conclusions

This study confirms the presence of 20 invasive alien plant species within Parsa National Park, with major siam weed emerging as the most abundant IAPS. IAPS coverage was significantly influenced by the variables, including canopy cover, distance to road, and distance to settlement. And, the consequential impact of IAPS coverage on the habitat of wild ungulates. So, understanding and effect of IAPS not only preserve integrity of parks ecosystem but also contributes to the conservation efforts aimed at maintaining the biodiversity and ecological balance essential for the wild population.

6.2 Recommendations

The following recommendations are highlighted based on the above observation and result of the entire study:

- Regular monitoring to avoid the spread of IAPS in the foraging habitat of Nationally Vulnerable ungulates species.
- Extent research area
- Extending the study to multiple seasons.

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Appendices

Appendix 1. List of Invasive alien plant species in Parsa National Park

S.N	Scientific name	Common name	Family
1	<i>Mimosa pudica</i>	Sensitive plant (Lajjawati)	Fabaceae
2	<i>Mikania micrantha</i>	Mile-A Minute Weed (Lahare Banmara)	Asteraceae
3	<i>Pontederia crassipes</i>	Water hyacinth (Jal kumbhi)	Pontederiaceae
4	<i>Ipomoea carnea spp fistulosa</i>	Bush Morning glory	Convolvulaceae
5	<i>Ageratina adenophora</i>	Crofton weed (Kalo banmara)	Asteraceae
6	<i>Senna tora</i>	Sickle pod senna (Sano tapre)	Fabaceae
7	<i>Senna occidentalis</i>	Coffee senna (Thulo tapre)	Fabaceae
8	<i>Spermacoce alata</i>	Broadleaf weed (Alu pate)	Rubiaceae
9	<i>Ageratum houstonianum Mill</i>	Blue Billy goat weed (Nilo gandhe)	Asteraceae
10	<i>Mesosphaerum suaveolens</i>	Bushmint (Ban silam)	Lamiaceae
11	<i>Biden pilosa</i>	Hairy Beggar-tick (kalo kuro)	Asteraceae
12	<i>Chromolaena odorata</i>	Sima weed (Seto banmara)	Asteraceae
13	<i>Parthenium hysterophorus</i>	Parthenium (Pati jhar)	Asteraceae
14	<i>Xanthium strumarium</i>	Rough cockle-bur (Bhede kuro)	Asteraceae
15	<i>Ageratum conyzoides</i>	Billy goat (Gandhe)	Asteraceae
16	<i>Lantana camara</i>	Lantana (Ban Fanda)	Verbenaceae
17	<i>Amaranthus spinosus</i>	Spiny pigweed (Kande lude)	Amaranthaceae
18	<i>Galinsoga quadriradiata</i>	Shaggy soldier (Jhuse Chitlange)	Asteraceae
19	<i>Leucaena leucocephala</i>	Lead tree	Fabaceae
20	<i>Pistia stratioties</i>	Water lettuce	Araceae

Appendix 2. List of mammals recorded in camera trap in Parsa National Park

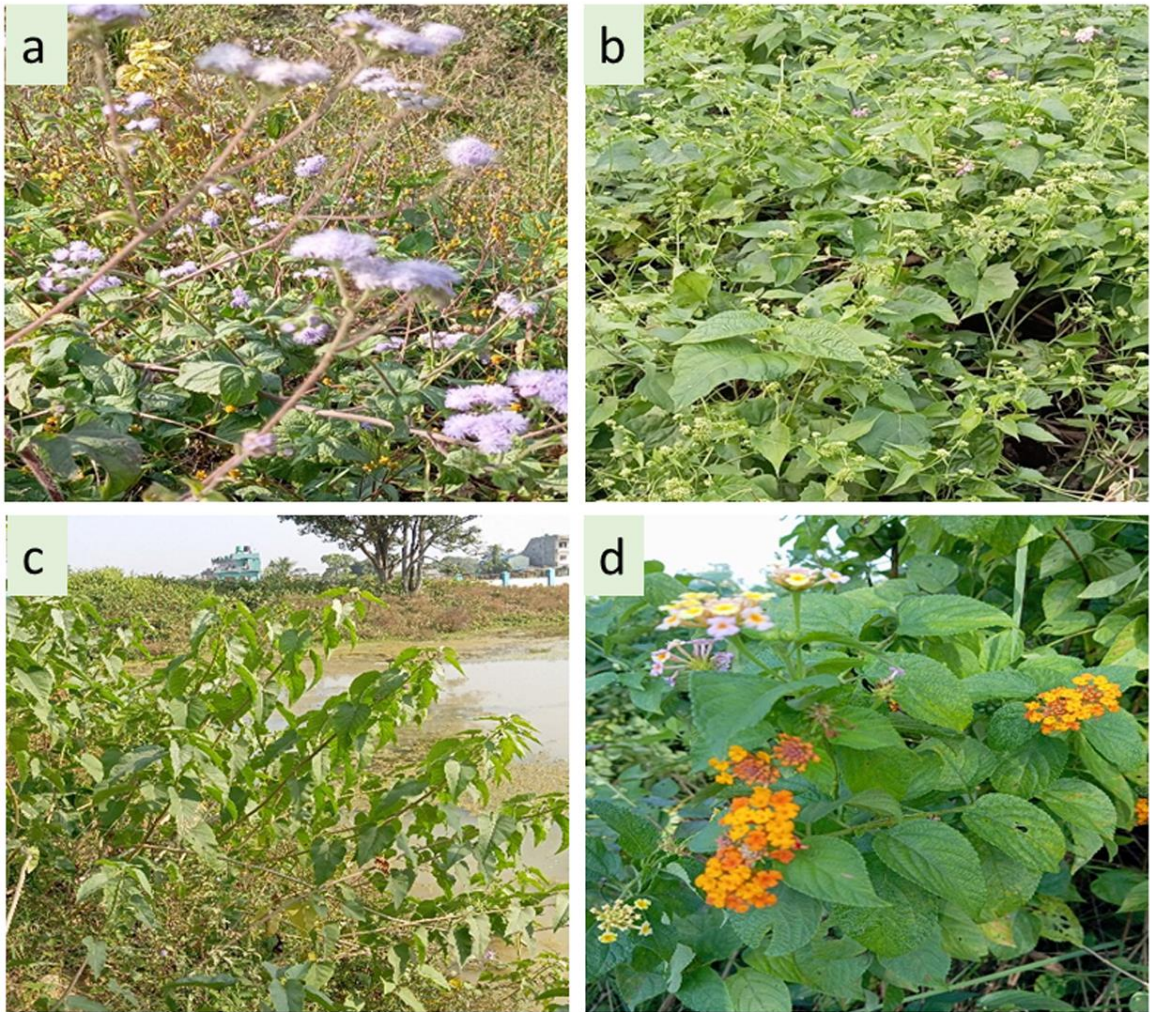
S N	Common Name	Scientific name	IUCN status	Order	Family	Feeding guild
1	Barking deer	<i>Muntiacus vaginalis</i>	LC	Artiodact yla	Cervidae	Herbivor ous
2	Chital	<i>Axis axis</i>	LC	Artiodact yla	Cervidae	Herbivor ous
3	Sambar	<i>Rusa unicolor</i>	VC	Artiodact yla	Cervidae	Herbivor ous
4	Tiger	<i>Panthera tigris tigris</i>	EN	Carnivor a	Felidae	Carnivor ous
5	Leopard	<i>Panthera pardus</i>	VU	Carnivor a	Felidae	carnivoro us
6	Wild boar	<i>Sus scrofa</i>	LC	Artiodact yla	Suidae	Omnivor ous
7	Sloth bear	<i>Melursus ursinus</i>	VU	Carnivor a	Ursidae	Omnivor ous
8	Indian crested porcupine	<i>Hystrix indica</i>	LC	Rodentia	Hystri cidae	Omnivor ous
9	Gaur	<i>Bos gaurus</i>	VC	Artiodact yla	Bovidae	Herbivor ous
10	Nilgai	<i>Boselaphus tragocamelus</i>	LC	Artiodact yla	Bovidae	Herbivor ous
11	Golden jackal	<i>Canis aureus</i>	LC	Carnivor a	Canidae	Omnivor ous
12	Jungle cat	<i>Felis chaus</i>	LC	Carnivor a	Felidae	Carnivor ous
13	Leopard cat	<i>Prionailurus bengalensis</i>	LC	Carnivor a	Felidae	Carnivor ous
14	Rhesus	<i>Macaca mulatta</i>	LC	Primates	Cercopith	Herbivor

4					ecidae	ous
1	Tarai grey	<i>Semnopithecus</i>	NT	Primates	Cercopith	Herbivor
5	langur	<i>hector</i>			ecidae	ous
1	Nepali grey	<i>Semnopithecus</i>	LC	Primates	Cercopith	Herbivor
6	langur	<i>schistaceus</i>			ecidae	ous
1	Small Indian	<i>Viverricula indica</i>	LC	Carnivor	Viverridae	Omnivor
7	civet			a		ous
1	Large Indian	<i>Viverra zibetha</i>	LC	Carnivor	Viverridae	Omnivor
8	civet			a		ous
1	Masked palm	<i>Paguma larvata</i>	LC	Carnivor	Viverridae	Omnivor
9	civet			a		ous
2	Asian palm	<i>Paradoxurus</i>	LC	carnivora	Viverridae	Omnivor
0	civet	<i>hermaphroditus</i>				e
2	Crab eating	<i>Urva urva</i>	LC	carnivora	Hyaenidae	Omnivor
1	mongoose					e
2	Yellow throated	<i>Martes flavigula</i>	LC	Carnivor	Mustelida	Omnivor
2	marten			a	e	e
2	Indian hare	<i>Lepus nigricollis</i>	LC	Lagomor	Leporidae	Herbivor
3				pha		ous
2	Honey badger	<i>Mellivora capensis</i>	LC	Carnivor	Mustelida	Carnivor
4				a	e	ous
2	Striped hyena	<i>Hyaena hyaena</i>	NT	Carnivor	Hyaenidae	Carnivor
5				a		ous
2	Asian elephant	<i>Elephas maximus</i>	EN	Probosci	Elephanti	Herbivor
6				dea	dae	ous
2	greater one	<i>Rhinoceros</i>	VU	Perissod	Rhinocero	Herbivor
7	horned rhino	<i>unicornis</i>		actyla	tidae	ous
2	Bengal fox	<i>Vulpes bengalensis</i>	LC	Carnivor	Canidae	Carnivor
8				a		ous

Appendix 3. The technique involves visually designating different six cover classes to each quadrat. Each species within the quadrat. Each species within the quadrat is usually assessed separately. Canopy cover is typically considered as ground cover.

Cover-class	Cover mid value
2-5	3.5
5-25	15
25-50	37.5
50-75	62.5
75-95	85
95-100	97.5

Appendix 4. Photoplates



(a) *Ageratum houstonianum* (b) *Mikania micrantha* (c) *Ipomoea carnea* new for PNP (d) *Lantana camara* dominated in grassland habitat, in PNP.



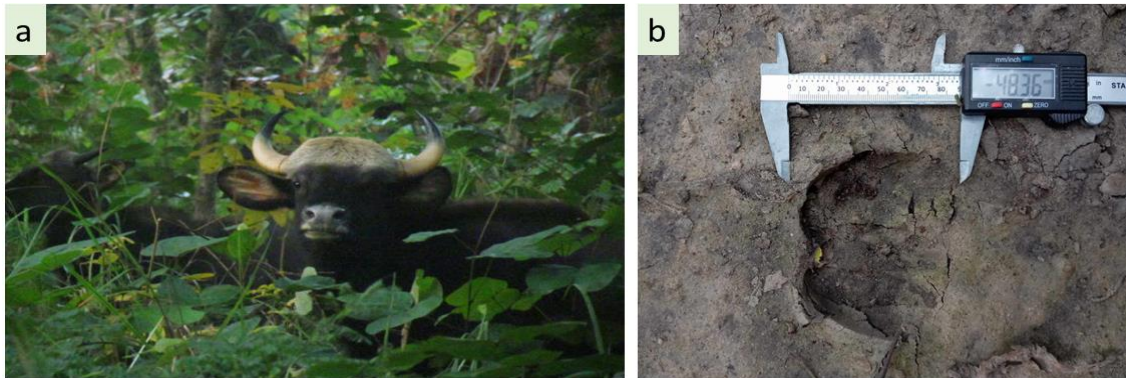
(a) *Chromolaena odorata*, (b) *Mesosphaerum suaveolens*, (c) *Ageratum conyzoides* (d) *Senna tora*



(a) Chital (b) pellet of chital (c) Footprint



(a) Barking deer (b) Footprint (c) Pellet



(a) Gaur (b) Footprint of gaur