NATIVE AND INVASIVE PLANTS IN SOME SELECTED HABITATS OF DHANGADHI SUB-METROPOLITAN CITY, FAR WEST NEPAL

A THESIS

SUBMITTED FOR THE

PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

THE MASTER'S DEGREE IN BOTANY

BY

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KATHMANDU, NEPAL

March, 2024

DECLARATION

I, "Roshni Bhatta" hereby declare that the work enclosed here is entirely my own, except where states otherwise by reference or acknowledgement, and has not been published or submitted elsewhere, in whole or in part, for the requirement for any other degree or professional qualification. Any literature, data or works done by others and cited within this thesis has been given due acknowledgement and listed in the reference section.

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RECOMMENDATION

This is to recommend that the Master's thesis entitled "Native and invasive plants in some selected habitats of Dhangadhi Sub-Metropolitan City, Far West Nepal" is carried out by "Roshni Bhatta" under my supervision. The entire work is based on original scientific investigations and has not been submitted for any other degree in any institutions. I therefore, recommend this thesis work to be accepted for the partial fulfilment of M.Sc. Degree of Science Botany.

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ABBREVIATIONS AND ACRONYMS

IAPS:	Invasive
F:	Frequency
RF:	Relative Frequency
C:	Cover
D:	Density
RD:	Relative density
m:	Meter
Mm:	Millimeter
A:	Abundance
RA:	Relative Density
IVI:	Importance Value index
IUCN:	International Union for Conservation of Nature
ANOVA:	Analysis of Variance
SPSS:	Statistical Package for the Social Science
DPR:	Department of plant Resources
Ha:	Hectares
DFO:	District Forest office

शोध सार

यस अध्ययनमा धनगढी उप महानगरपालिका अर्न्तगत सडक किनारा, बाँझो जमिन, तालको किनारा र जंगलको छेउमा भएका रैथाने तथा मिचाहा प्रजातिका वनस्पतिहरुको अध्ययन गरिएको छ। यस अध्ययनबाट जम्मा ७४ प्रजातिका वनस्पतिहरु संकलन तथा पहिचान गरिएको थियो। यी मध्ये सबैभन्दा बढी वनस्पतिहरु सडक किनारमा त्यसपछि ताल किनारा र बाँझो जमिनमा पाइएका थिए भने जंगलको छेउमा कम वनस्पतिहरु पाइएका थिए। जम्मा १५ प्रजातिका मिचाहा वनस्पतिहरु पाइएका मध्ये यिनिहरुको संख्या सडक किनारामा नै बढी थियो । सडक किनारा र बाँझो जमिनमा पाति झार (*Parthenium hysterophorus*) र तालको किनारा र जंगलको छेउमा भने *Senna tora* को Importance value index (IVI) बढी पाइएको थियो।

शब्दकुंजी :- धनगढी, मिचाहा प्रजाति, सडक किनार, परिस्थितिकि

CHAPTER 1: INTRODUCTION

1.1 Background

Nepal, nestled in the heart of the Himalayas, boasts a diverse array of plant species that contribute to its rich biodiversity. The country's flora includes a mix of native plants that have evolved over millennia to thrive in its varied landscapes, alongside invasive alien species that pose a threat to the delicate ecological balance. Understanding the dynamics between native and invasive plants in Nepal is crucial for conservation efforts and the preservation of the country's unique natural heritage.

The significance of plants, however, outweighs all else. People in rural areas often use many more species, and even city dwellers employ a diverse range of plants for different purposes. A wide variety of wild plant foods play important roles in traditional medicine, and they also help with nutrition and food security. In addition, plants provide the three-dimensional framework for animal movement and survival, as well as the bulk of the food that most terrestrial ecosystems rely on (Corlett, 2016). Moreover, Plants play a crucial role in soil ecosystems by providing organic matter and energy, which in turn promote microbial activity (Sofo *et al*., 2014). It is also found that without relying on tillage techniques, plants also the composition of the microbial community (Vezzani *et al.,* 2018).

The decline in native biodiversity and loss of ecosystem services are primarily due to biological invasion (Kohli *et al*., (2004); Pejchar and Mooney (2009)). According to Richardson and Pysek (2006), biological invasion refers to the process of invasive species being introduced, established, and spread next to their native environment. Due to its diverse and varied elevation gradient and topography, Nepal offers adequate habitats and climatic conditions for species from every part of the world. There are a minimum of 219 non-native species of flowering plants that have been established in Nepal, according to research conducted by Tiwari et al. in 2005, Siwakoti in 2012, and Sukhorukov in 2014. IUCN Nepal conducted an assessment of invasive alien plant species (IAPS) in 2002-2003 and identified 21 naturalized flowering plant species that have established self-sustaining populations and are considered invasive in Nepal (Tiwari *et al*., 2005). They aren't the only naturalized species that have been discovered to be invasive in rangelands and agro-ecosystems; four more include *Erigeron karvinskianus*, *Spermacoce alata* Aubl, *Galinsoga quadriradiata*, and *Ageratum conyzoides* (Shrestha, 2016) as invasive alien plant species (IAPS) in Nepal. According to Shrestha and Shrestha 2021, about 27 alien

plant species have been reported as in invasive in Nepal. The four invasive plant species that are listed among the 100 worst invasive species in the world are *Chromolaena odorata*, *Eichhornia crassipes*, *Lantana camara*, and *Mikania micrantha* (Lowe *et al*., 2000).

According to Rajbhandary *et al*. (2017), a total of 5309 plant species have been recorded belonging to 5309 genera and 193 families in our country. The primary sources of plant resources for humans are cultivated areas, common lands, marshes, and woods. Plant resources are collected and put to a variety of uses, such as fodder essential oils, medicinal or religious purpose, fuel, fiber, construction materials in agroindustry and household goods, and wild genetic resources for enhancing crop plants (Rajbhandary and Winkler, 2015). Plant diversity conservation has been given far less priority than animal diversity conservation, maybe due to the fact that many animal groups find plants unappealing (Goettsch *et al*., 2015). Consequently, compared to animal conservation, plant conservation receives far less funding (Havens *et al*., 2014).

Because of shifts in resource availability, disturbance regime, and propagule pressure brought about by changes in land use, ecosystems become more susceptible to biological invasions (Davis *et al*., 2000; Hobbs, 2000). As a consequence of increased international trade, transportation, and tourism, many developing nations are now at risk of becoming hosts to invasive alien plant species or receiving them from other parts of the globe. Furthermore, this is also true in our nation. The issue of IAPS along roadside, agricultural grounds (whether cultivated or fallow), and wetlands is not limited to rural regions; it is also affecting urban places such as Dhangadhi sub metropolitan city. Since roadsides are often disturbed, they provide an ideal environment for IAPS to thrive in and serve as a pathway for the spread of the plant. Plant invasion is rapidly becoming an issue also in wetland areas.

Since, most of the studies are confined to larger landscapes like forest, the smaller areas with greater impacts like roadsides, fallow areas, margins of forests and wetlands are often neglected. Such areas are also found to be comprising an important ecosystem. So, this study's overarching goal is to understand the vegetation of urban areas. The results of this study would be useful in understanding the importance of native biodiversity, effects of biological invasions and could lay the groundwork for future management initiatives.

1.2 Justification of study

Biodiversity being crucial component of the environment is intricately linked with ecosystem and human welfare. Ecosystem and biodiversity are facing major threats from Invasive alien plant species which needs to be managed and controlled effectively in time. Environment and economy of non-native areas gets highly affected due to the alien plants (Pysek *et al*., 2004). The uncontrolled spread and establishment of IAPS is a serious problem worldwide and in Nepal as well. Some of the alien plant species may be useful and cultivated for food, medicine, fuel or fodder for local communities (Roder *et al*., 2007) while other most of the IAPS have negative impacts on native vegetation, forest regeneration, agriculture production, cattle grazing, ecosystem and human health (Pimentel *et al*., 2000). Biological invasions at the interfaces of roadsides, forest margins, fallow lands, and wetland margins have become a pressing ecological concern due to their significant impacts on biodiversity, ecosystem functions, and socio-economic well-being.

In a world that is becoming more and more urbanized, urban nature is essential to human well. Despite the great diversity of urban greenspaces, parks and the presence of trees in particular have received the majority of attention in prior study. Despite the fact that streets are essential urban constructions and provide a variety of green spaces beyond trees, few researches have been done on how urban dwellers perceive and value different types of roadside flora (Weber *et al*., 2014).

Roadside vegetation varies in structure and content, ranging from artificial landscaping to naturally occurring plant communities, and from regularly mown grass to shrubs and trees. In addition to providing habitat for rare plants and animals, roadside vegetation can also serve as a carbon sink, a barrier against the intrusion of light and noise from traffic, a source of seeds for nearby landscapes, and an aesthetic enhancer for drivers (Lahoti *et al*., 2020).

The two most significant variables affecting the germination and early growth of scattered seeds on fallow land are water level and fertility (Gaujour *et al*., 2012)). Due to our great reliance on food and commodity imports and open border transportation, many IAPS are infiltrating our country from neighboring countries, primarily India. Through direct resource competition or indirect changes to nutrient cycling, invasive alien plant species can suppress or exclude native species, altering the structure and species composition of

ecosystems. In order to minimize the negative repercussions that come with the invasion of IAPS, it is necessary to build and extend them to new places.

1.3 Objectives

1.3.1 General objective

General objective of the study is to enumerate native and invasive flora of different habitats in Dhangadhi Sub-Metropolitan City, Kailali, Far West Nepal.

1.3.2 Specific Objectives

The specific objectives of the study are:

- To document the native and invasive flora of different habitats of the study site.
- To compare and analyze the ecological parameters the native and invasive flora in different habitats of the study site.
- To find out the relationship between native and invasive plants among different habitats in the study site.

1.4 Limitations

- The recording of plant species does not encompass representatives from all seasons, as the study was conducted solely during the pre-monsoon period.
- The study exclusively examines plant diversity within four specific habitats: roadsides, fallow lands, forest margins, and wetland margins, potentially excluding other habitats and land use types from its analysis.
- The study specifically targets the margins of forested areas and wetlands for examination, indicating that the entire forest and interior sections of the wetland were not included in the study's scope.

CHAPTER 2: LITERATURE REVIEW

2.1 Biological invasion

Invasive alien plant species are swiftly encroaching upon native ecosystems worldwide. These species, introduced to new areas through various means, are a significant driver of global environmental change caused by human activity. This invasion leads to substantial economic losses, diminishes biological diversity, and disrupts the functioning of affected ecosystems (Vitousek *et al*., 1997; Mack *et al*., 2000; Pimentel *et al*., 2001). Richardson and Pysek (2000) define biological invasions as the introduction, establishment, and spread of species beyond their native habitats. This phenomenon now operates on a global scale and is expected to undergo rapid increase in the coming years due to interactions with other global changes such as the globalization of markets, explosive rise in global trade, travel, tourism, expansion of road networks, and exchange of goods (Hobbs, 2000).

Biological invasions can arise from human activities or occur naturally. Human-induced invasions in new habitats are rapidly increasing, driven by globalization. The impact of natural invasions closely resembles that of human-mediated invasions, but natural invasions primarily rely on the dispersal abilities of the invading plants themselves. Sources of natural invasions include humans, birds, animals, insects, wind, water, and vehicles. In essence, invasive alien plant species (IAPS) undergo three phases for biological invasions: introduction, colonization, and naturalization to infiltrate the host ecosystem (Mack *et al*., 2000). Successful invasions occur when species introduced beyond their native range through human actions establish self-sustaining populations and spread into new areas (Richardson *et al*., 2000; Richardson & Pysek, 2006).

Biological invasion is mainly influenced by three factors; propagule pressure, biological traits of IAPS and invasibility (Londsale,1999). IAPS have life history traits like fitness homeostasis, smaller seed size and weight for efficient dispersal, allelopathy, vegetative reproduction as an alternative mode of reproduction, phenotypic plasticity, persistent seed bank and successful colonizers of disturbed habitat (Kohli *et al*., 2006; Grice, 2006). Dispersal of IAPS have major role in biological invasion and roads as dispersal corridors promote invasion to adjacent areas (Christen and Matlack, 2009; Sullivan *et al*., 2009). The disturbed nature of roads acts as source areas for biological invasion.

2.2 Origin and Distribution of IAPS

The process of species being transported by people beyond natural barriers to dispersal is continuing to increase in speed. This is a consequence of globalization and the disruption of natural ecosystems. A number of IAPS have expanded into new regions at a rapid pace, impacting ecosystems and human health in major ways (Rai, 2022).

The degree to which a country's economy is open and the specific trade channels it engages in can increase the susceptibility of nations to biological invasions (Perrings *et al*., 2002). In recent years, numerous established and developing countries have emerged as potential origins and destinations for International Aquatic Pathway Species (IAPS) from various countries worldwide. Asian countries such as China, India, Nepal, Bangladesh, and Pakistan are particularly vulnerable to biological invasions (Weber and Li 2008). Several invasive alien plant species (IAPS) have been introduced in Nepal by diverse means in various ecosystems such as wetlands, forests, grasslands, rangelands, crops, and highways. The majority of the IAPS (Invasive Alien Plant Species) in Nepal are unintentionally brought in from the next nation, India, due to the presence of an open border, direct road connections, and a high reliance on basic necessities (Tiwari *et al*., 2005). The majority of the IAPS (Introduced Alien Plant Species) in Nepal have their origins in the neo-tropical region, specifically South America (Bhattarai *et al*., 2014). IAPS has made its debut into India through many channels throughout the course of time. The plant introduction in India can be attributed to its colonial history and historical trading links with many countries such as British, Portuguese, Spanish, French, as well as countries from the Middle East and Central Asia (Khuroo *et al*., 2012). Out of the 225 IAPS in India, a majority (52%) are from South America, while the rest are from Africa (16%), Asia (16%), Europe (9%), North America (4%), and Australia (2%), with a small percentage (1%) being of unknown origin (cryptogenic) (Khuroo *et al*., 2011). In recent decades, India's growing economy has led to the implementation of large-scale infrastructure development projects. Unfortunately, these initiatives have resulted in the destruction of natural habitats and the creation of disturbance corridors. As a consequence, this has facilitated the spread and establishment of numerous invasive alien plant species (Sharma *et al*., 2005).

2.3 Community Invasibility

The ability of a habitat to support the colonization and establishment of new non-native or alien species is known as invasiveness. According to Davis *et al*. (2000), it can be

measured as the likelihood of establishment for each arriving propagule. The invasibility of a community differs between species and throughout time. The presence of resources (Davis *et al*., 2000) and other site characteristics of the new environment, such as the presence or absence of specific predators and pathogens (Shea and Chesson, 2002), as well as the degree to which the physical conditions of the native environment and the new environment match (Kolar and Lodge, 2001), all affect colonizers' capacity to establish themselves in a new community. Ecosystems vary in their natural susceptibility to invasion. Urban-industrial areas, habitats suffering from periodic disturbance, harbors, lagoons, estuaries and the fringes of water bodies, where the effects of natural and anthropogenic disturbances are often linked, are also particularly vulnerable to invasions (Kaur and Arora, 2013).

Disturbance mediated susceptibility to invasion seems particularly pronounced in fertile/eutrophic environments (Burke and Grime, 1996). Deserts, semi-deserts, tropical dry forests and woodlands, artic systems and pelagic marine systems appear to be least susceptible to invasions while mixed island systems, road networks, lake, river, canals and nearshore marine systems appear to be most susceptible to invasions (Heywood, 1995). Similarly, systems with low natural diversity (especially if they are without existing predators or competitors) seem to be more vulnerable to invasion than with high natural diversity (Rejmanek, 2000). But susceptibility also depends on land use type, disturbance level, travel and tourism activities etc. Disturbance caused by any natural or human-mediated events can provide the opportunity for IAPS to colonize new habitat.

A community's susceptibility to invasion is increased by habitat fragmentation, habitat modification, and agricultural disturbance (Williamson, 1999). Building roads makes it easier for IAPS to invade nearby towns. While Thompson *et al*., (2001) acknowledge that invasibility is a byproduct of changes in resource availability, either through increase or reduction of resources, Davis *et al*. (2000) theorize that invasibility is a result of variations in resource availability.

2.4 Dispersal of IAPS

There are many different ways that invasive alien species might enter a region; these methods and channels are referred to as invasion pathways, these routes of invasion act as conduits for the dispersion of IAPS throughout the world using a variety of vectors (Lemke, *et al*., 2021). A species might be unintentionally or purposely introduced to a

new area in a variety of ways. According to Hulme (2009), accidental transportation of species includes the movement of species as contaminants within commercial products. Intentional movement of species includes a wide range of vectors, such as the importation of ornamental plants, crop species, biocontrol, medicinal plants, fodder, etc. Plant distributions are significantly influenced by seed dispersal (Chen *et al.*, 2020). Invasive plant species spread their numbers over large areas after becoming naturalized. Many vectors, including people, cars, wind, water, insects, animals, and others, allow invasive plants to spread into uninfected areas (Sorenson, 1986). The transfer of seeds away from their parent plants by a variety of physical means is referred to as dispersal. For a plant to be a successful invader, it must be able to spread out of the area of introduction into new areas (Singh *et al*., 2008). Plants can spread through seed dispersal or vegetative propagation. Long-distance dispersal of plant seeds, especially those of invasive alien species, is mostly caused by humans, animals, water, birds, wind, etc. While both natural processes and human activities contribute to the subsequent dispersal of naturalized species, human activities are the sole cause of alien species introduction.

The spread of IAPS can be facilitated by various additional vectors. Vehicles, birds, insects, water, and wind are all examples of such things. Depending on the habitat or type of IAPS blooms or seeds, the medium could change at times (Shrestha, 2016). The spread of IAPS throughout several ecosystems has significantly risen due to the acceleration of human trade, transportation, and travel (Vitousek *et al*., 1997; Mack, 2003). An imported plant's ability to successfully invade a new area may be influenced by the quantity of seeds it produces; a larger seed bank means more opportunities for colonisation, which increases the likelihood of successful establishment and expansion. By eliminating native species and supplying fresh soil layers that are conducive to invasion, road construction and maintenance provide safe spaces where IAPS can sprout and establish (Londsale and Lane, 1994). Through the introduction or dispersal of seeds and other viable plant materials, routine building and maintenance operations along transportation corridors can also significantly contribute to the spread of invasive plants. IAPS find that the dense native vegetation along roadsides provides a low-competitive environment, and they typically receive more sunlight, moisture, and soil nutrients that encourage invasion (Parendes and Jones 2000).

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

The present study was carried out in Dhangadhi Sub-Metropolitan city of Kailali district in Province-7, Nepal. The district covers an area of 3, 23,500 ha with an altitude ranging from 109 to 1950 m (DFO, 2021/2022). Around 2, 05,724 hectares of land is covered by forest and 43.38% has been referred to as community forest (DFO, 2021/2022). The study was conducted in four habitats within the sub-metropolitan city which forest margin, wetland margin, fallow lands and roadsides.

Forest margin: The forest margin was a part of Laljhadi - Mohana forest corridor which is linked to Dudhwa National Park, India. The Mohana river separates Nepal and India. The forest is facing human encroachment and deforestation which is highly disturbed.

Wetland margin: The wetland margin is of Jokhar lake which occupies an area of 13.49 ha. It is an oxbow-perennial lake. Most portion of the lake is covered by *Eichhorina crassipies* during rainy season. Surrounding vegetation and lake is also disturbed by visitors. The Tharu community inhabits nearby.

Fallow lands: The fallow lands were abandoned for more than 15 years and seemed mostly covered by *Parthenium hysterophorus*. They are situated in between the residential areas. In some fallow lands grazing cattle can be seen.

Roadsides: The roads for the study were away from the highway that connected inner urban areas. The roads of this study included secondary roads that has access to communities.

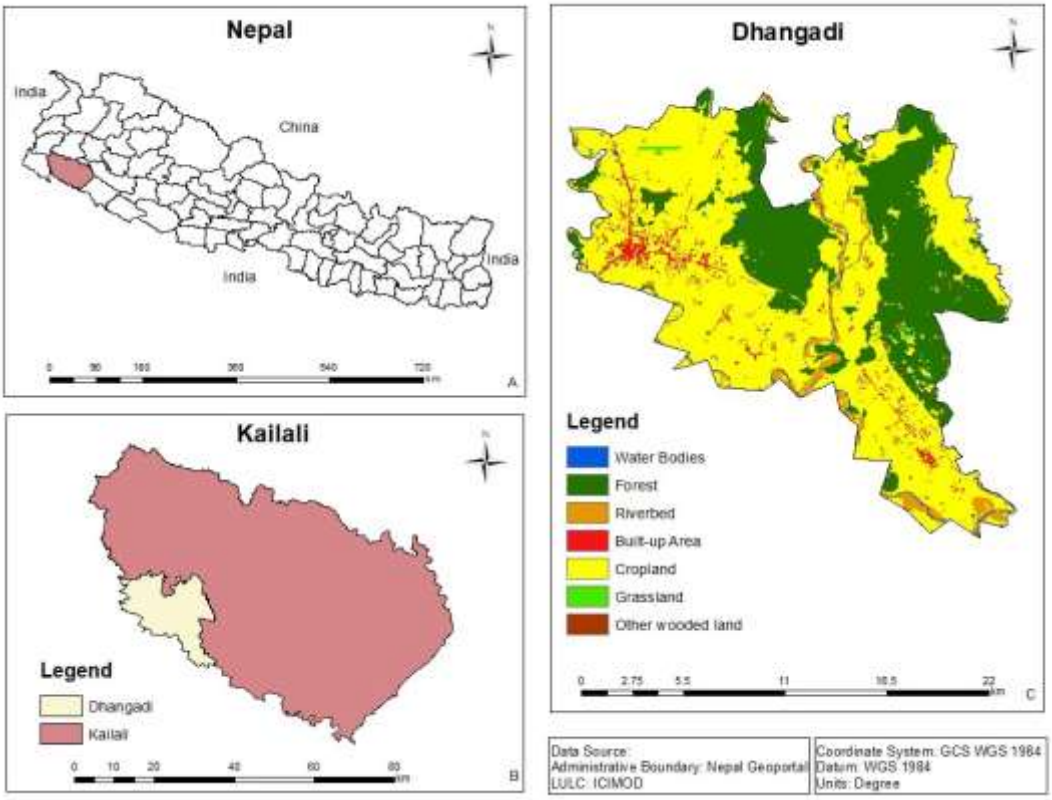

Figure 1: Map of the study area; (A) map of Nepal with districts; (B) Kailali district ;(C) Dhangadhi Sub-Metropolitan City with different land use types (C)

3.2 Climate

The monthly average maximum and minimum temperature of Dhangadhi were 30.60°C and 13.75°C respectively (average data of 22 years) (Figure 2). The highest monthly rainfall was in July (537.24 mm), and the lowest was in November (1.9 mm), with a mean annual rainfall of 1892.88 mm. It experiences a warm summer and a very cold winter with high rainfall in summer and low in winter.

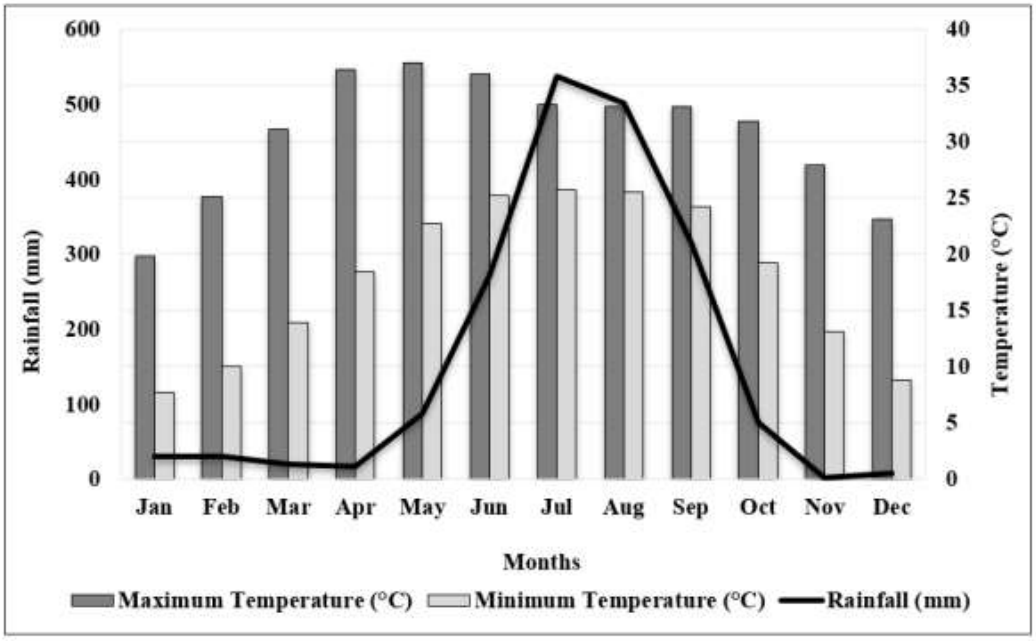

Figure 2: Twenty-two years (2000-2022) monthly average data of average temperature and rainfall recorded at Attariya Station of Kailali district. (Source: Department of Hydrology & Meteorological, Kathmandu).

3.3 Experimental Design

The sampling in the study area differed according to habitats. Total 120 plots of size 1m x1m were sampled in which 30 plots for each habitat. With some modification the roadside sampling was taken from Rahman *et al*. (2015). So, for roadsides, systematic sampling with zigzag plots were taken to maintain variation. Each plot was at distance of 150 m each. While in fallow lands random sampling was done. Along the forest margin and wetland margin a distance of 100 m was maintained between each plot.

3.4 Quantitative analysis

The ecological characteristics, abundance, frequency (%), cover (%), were quantified in accordance with Zobel et *al*. (1987). Abundance (A) refers to the sum total of individuals of a given species within a given unit area. The formula to calculate Abundance is given by

$$\textbf{Abundance (A)} = \frac{total\ no.\ of\ individual\ of\ a\ species\ in\ all\ quadrats}{No.of\ quadrats\ in\ which\ the\ speies\ occured}$$

Relative Abundance (RA) is the percent composition of species relative to total number of individuals in the area and is given by following formula.

$$\textbf{RA (\%)} = \frac{abundance\ of\ a\ individual\ species}{sum\ of\ the\ abundance\ of\ all\ species} x100$$

Frequency (F) describes the degree of dispersion of a specific species within a community. It is the percentage of sampling units in a specific area that contains a species. It is also used to describe how species are distributed throughout a community. It was calculated by the following formula.

$$\textbf{F (\%)} = \frac{number\ of\ plots\ in\ which\ the\ species\ occured}{total\ number\ of\ quadrats\ studied}\ x\ 100$$

The term "relative frequency" (RF) describes the degree of dispersion of a specific species in a given area in relation to the overall number of species that occurred, and it was calculated using the following formula.

$$\textbf{RF (\%)} = \frac{Frequency\ of\ individual\ species}{sum\ of\ all\ frequencies} x\ 100$$

Density (D) refers to the number of distinct species in each area. It displays the species' relative population size within the community. It is calculated by the following formula.

$$\textbf{D} = \frac{total\ number\ of\ plants\ in\ the\ studied\ plots}{number\ of\ plots\ studies\ x\ area\ of\ plot\ (m^2)}$$

Similarly, Relative density (RD) refers to the numerical strength of a species in relation to the total number of individuals of all the species and it was calculated using the following formula.

$$\textbf{RD (\%)} = \frac{density\ of\ a\ individual\ species}{sum\ of\ all\ the\ densities} x100$$

Importance Value index (IVI) is the sum of the relative values of the density, frequency, and abundance. It is used to determine the overall importance of each species in the community structure. IVI was calculated by using the following formula:

IVI = RA +RF+RD

Moreover, scatter plot was created for abundance of native and invasive plants and similar for their as well. The regression was performed to know the relation between the abundance of invasive plants and native plants. Similarly, the relation between the cover of invasive and native plants was also performed through regression.

3.5 Plant identification and herbarium preparation

When I was out in the field collecting samples, I asked people to help us identify the plants by their common names. Nevertheless, plants that could not be recognized were collected, labelled, and compacted using newspapers. Unidentified species were identified using the following methods: herbarium was prepared in accordance with Lawrence (1951), taxonomic specialists were consulted, and references such as "Plant Resources of Kailali, West Nepal" (DPR, 2016) and works by Rajbhandari and Rai (2017) were consulted. Online resources such as the Annotated checklist of flowering plants of Nepal (www.efloras.org),www.gbif.org, and www.theplantlist.org were utilized to verify the most current and widely recognized scientific names, families of the plants and their distribution that had been identified (Press et al., 2000). Also matched with the herbarium specimens were those from the National Herbarium and Plant Laboratories in Godawari (KATH). The Ascol Herbarium in Kathmandu, Nepal, is where the specimens were placed for preservation.

3.6 Statistical analysis

All the ecological parameters were quantitatively analyzed in Microsoft Office Excel program 2019. All the statistical analysis was performed in IBM SPSS 4.0.3. One way analysis of variance (ANOVA), followed by multiple comparisons using Tukey's test. One-way ANOVA was performed to observe the significant difference of invasive cover and native cover as well as native abundance and invasive plant abundance.

CHAPTER 4: RESULTS

4.1 Species richness

In the study area, a total of 74 species belonging to 68 genera were identified, distributed across 31 families and 17 orders. Notably, the Asteraceae family exhibited the highest species richness with 11 species, followed by Malvaceae with 8 species, Fabaceae with 6 species, Amaranthaceae with 5 species, and Poaceae with 5 species (refer to Figure 3). Among these species, 64 were dicots while 10 were monocots, as illustrated in figure 4. Additionally, the study revealed a composition of 49 herb species, 24 shrub species, and one climber species, as depicted in figure 5.

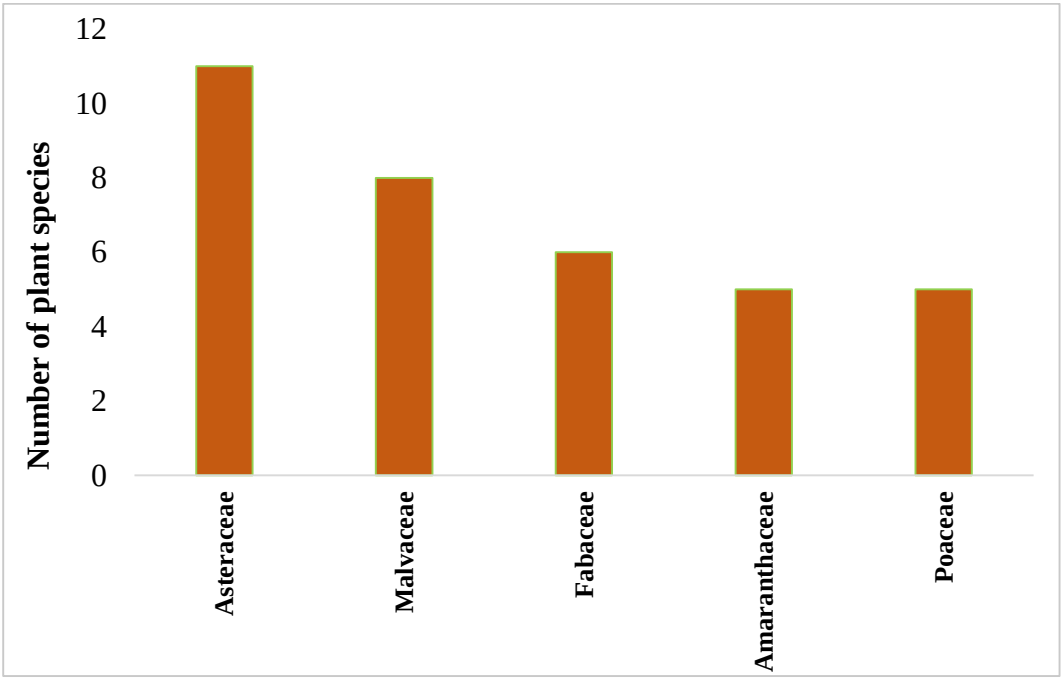

Figure 3: Dominant plant families in the study site

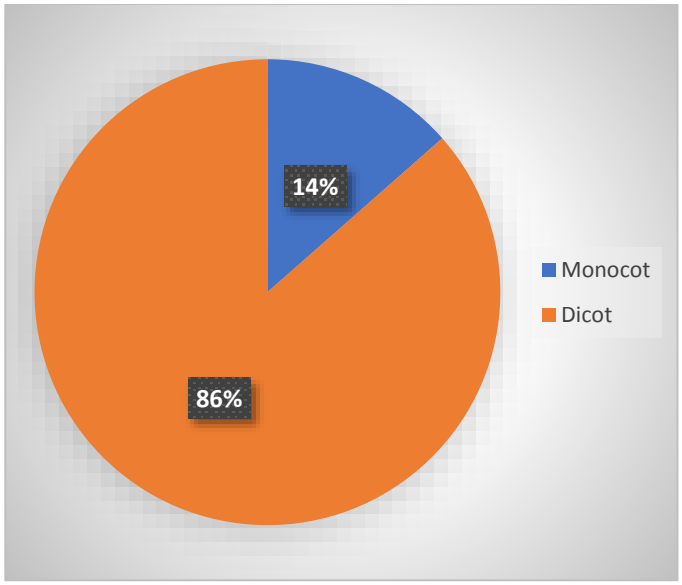

Figure 4: Dicots and Monocots

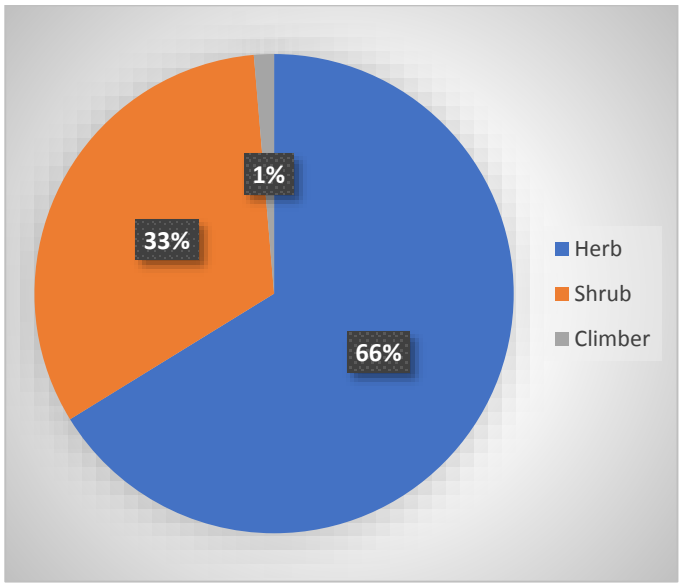

Figure 5: Habit of plants in the study area

When comparing sites, the roadside exhibited the highest diversity, hosting 54 species ($p>0.05$) across 30 families and multiple genera. In contrast, fallow land supported 33 species spanning 18 families. Similarly, the forest margin area harbored 28 species from 13 families, while the wetland margin contained 34 species belonging to 17 families.

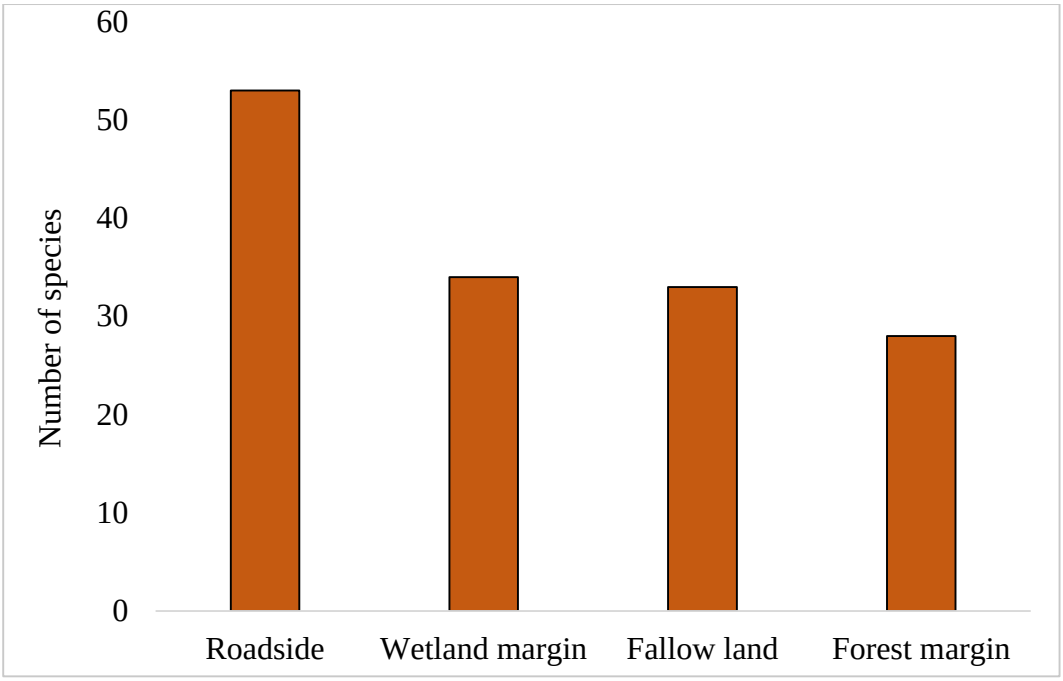

Figure 6: Number of plants in different habitats

Among the four habitats studied, the roadside exhibited the greatest species richness, followed by the wetland margin, forest margin, and fallow lands, in descending order. However, the differences in species richness among these habitats were not statistically significant ($p > 0.05$). Interestingly, the mean species richness of the wetland margin, forest margin, and fallow land significantly differed from that of the roadside. Nevertheless, there was no significant distinction in species richness among the wetland margin, forest margin, and fallow land, as illustrated in figure 7.

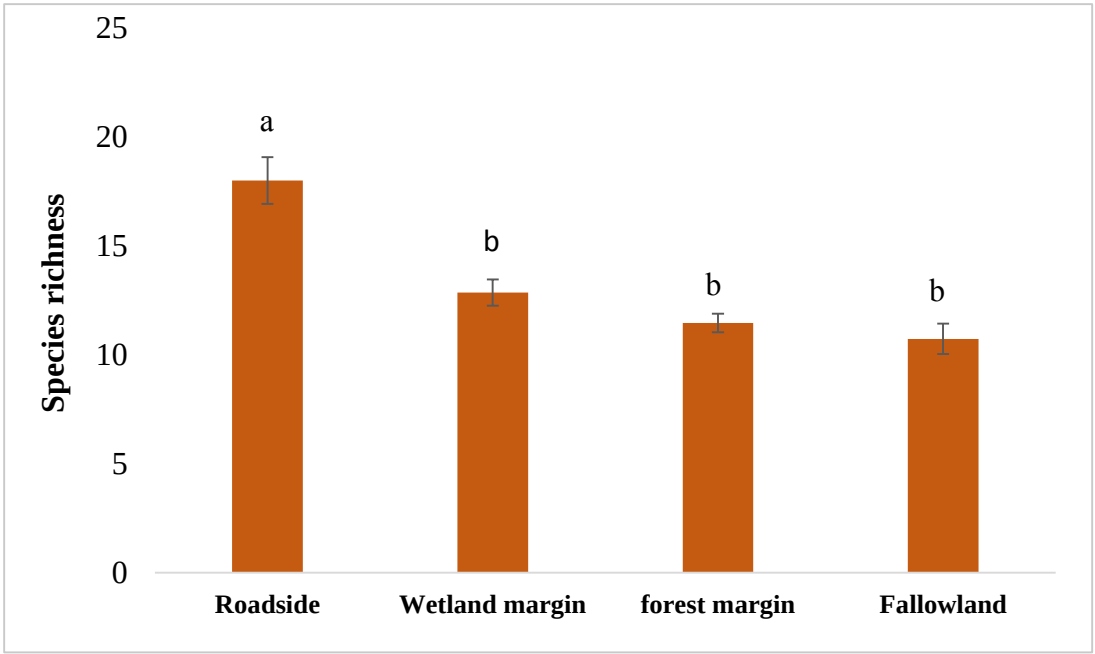

Figure 7: Mean species richness in different habitats ($p > 0.05$)

4.2 Native and invasive flora

In the four study sites, roadside exhibited the highest number of invasive alien plant species (13), whereas the forest margin had the fewest (5). Fallow land contained 9 invasive alien plant species, while the wetland margin had 8. Notably, *Xanthium strumarium* and *Ageratum houstonianum* were observed in all four habitats surveyed. *Bidens pilosa*, *Ageratum conyzoides* and *Galinsoga quadriradiata* were observed only in roadsides (Table 2).

Similarly, the distribution of native plant species across the surveyed habitats varied: roadside supported 8 native species, forest margin had 7, fallow land contained 3, and wetland margin harbored 4. On the other hand, naturalized species were most abundant in the roadside habitat (32), followed by wetland margin (22), fallow land (21), and forest margin (16) as illustrated in table 1 and figure 8.

Table 1: Number of naturalized, native and invasive species

	Roadside	**Fallow land**	**Forest margin**	**Wetland margin**
Naturalized	32	21	16	22
Invasive	13	9	5	8
Native	8	3	7	4

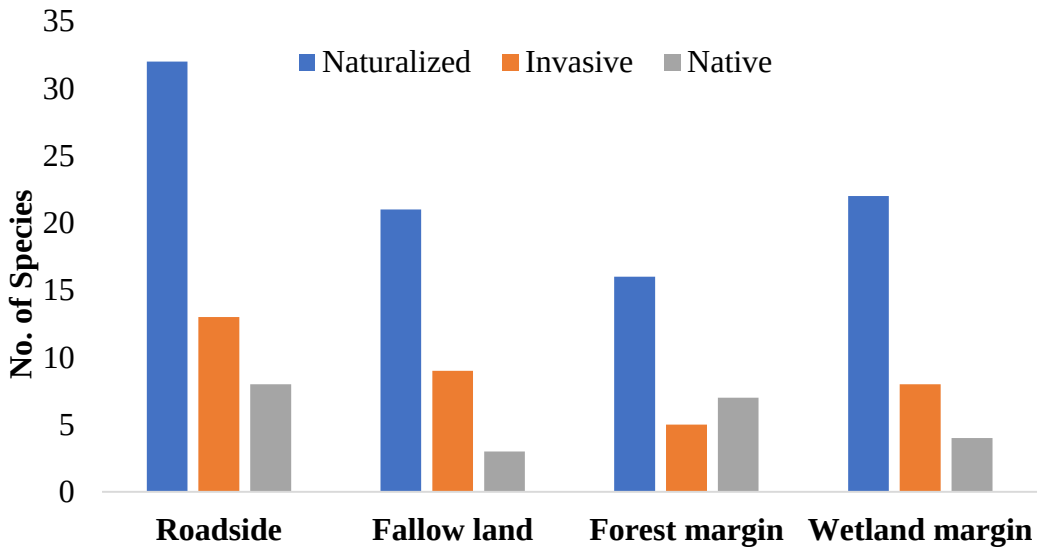

Figure: 8: Number of species according to their distribution in different habitats.

Table 2: List of IAPS found in different habitats

S.N	Name of IAPS	Habitat
1	*Alternanthera philexeroides*	R, FL, WM
2	*Amaranthus spinosus*	R, FL, WM
3	*Argemone Mexicana*	R, FL
4	*Bidens Pilosa*	R
5	*Ipomea carnea*	R, WM
6	*Oxalis latiflolia*	R, WM
7	*Parthenium hysterophorus*	R, FL, FM,
8	*Xanthium stumarium*	R, FL, FM, WM
9	*Lantana camara*	R, FL, FM
10	*Eichhornia crassipies*	FL
11	*Ageratum haustonianum*	R, FL, FM, WM
12	*Galinsoga quadriradiata*	R
13	*Ageratum conyzoides*	R
14	*Senna tora*	FL, FM, WM
15	*Mimosa pudica*	WM

R-Roadside, FL- Fallow land, FM- Forest margin, WM- Wetland margin

4.3 Frequency and cover

Along the roadside, Cannabis sativa dominated with a frequency of 96.67%, closely trailed by *Parthenium hysterophorus* at 93.33%. Conversely, in fallow lands, *Parthenium hysterophorus* exhibited the highest frequency at 83.33%, followed by *Cannabis sativa* at 76.67% and *Ageratum houstonianum* at 66.67%.

In forest margins, *Senna tora* stood out with a frequency of 86.67%, followed by *Murraya koenigii* at 76.67%. *Senna tora* also claimed the highest cover at 18.33%. At the wetland margins, *Cyperus haspan* and *Euphorbia hirta* shared the highest frequency at 73.33%, followed by *Ageratum houstonianum* at 60% and *Xanthium strumarium* at 53.33%.

Notably, *Xanthium strumarium*, an invasive alien plant species, occupied the highest cover.

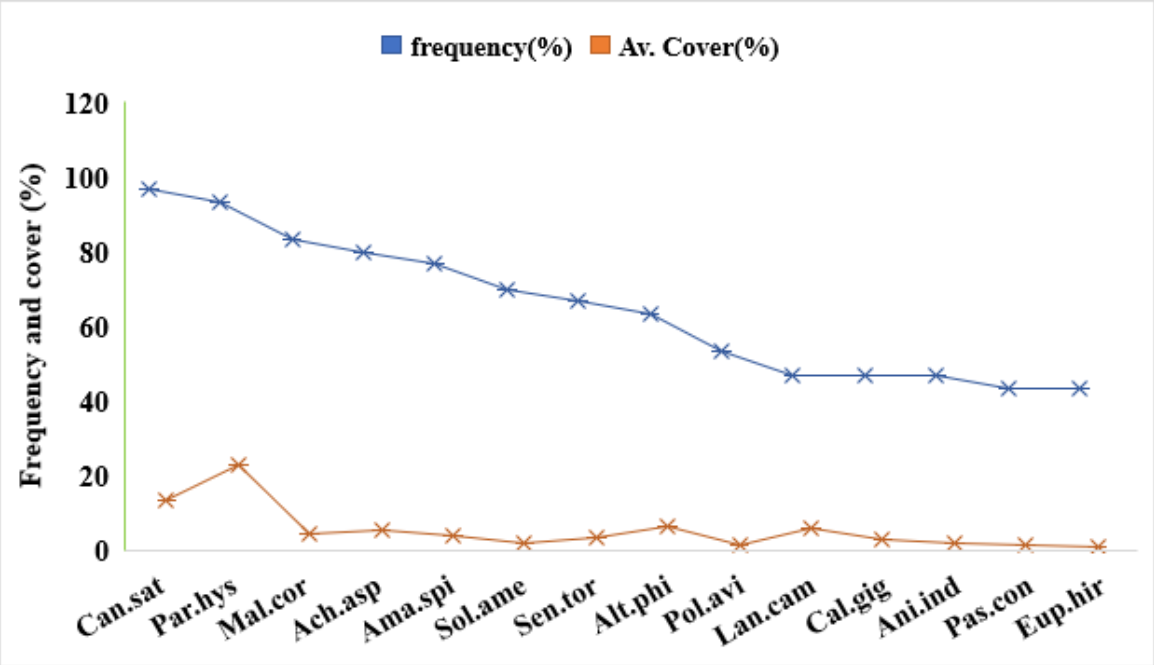

Figure 9: Frequency and cover of dominant plant species at roadside (Full name of plants are given in Appendix 5).

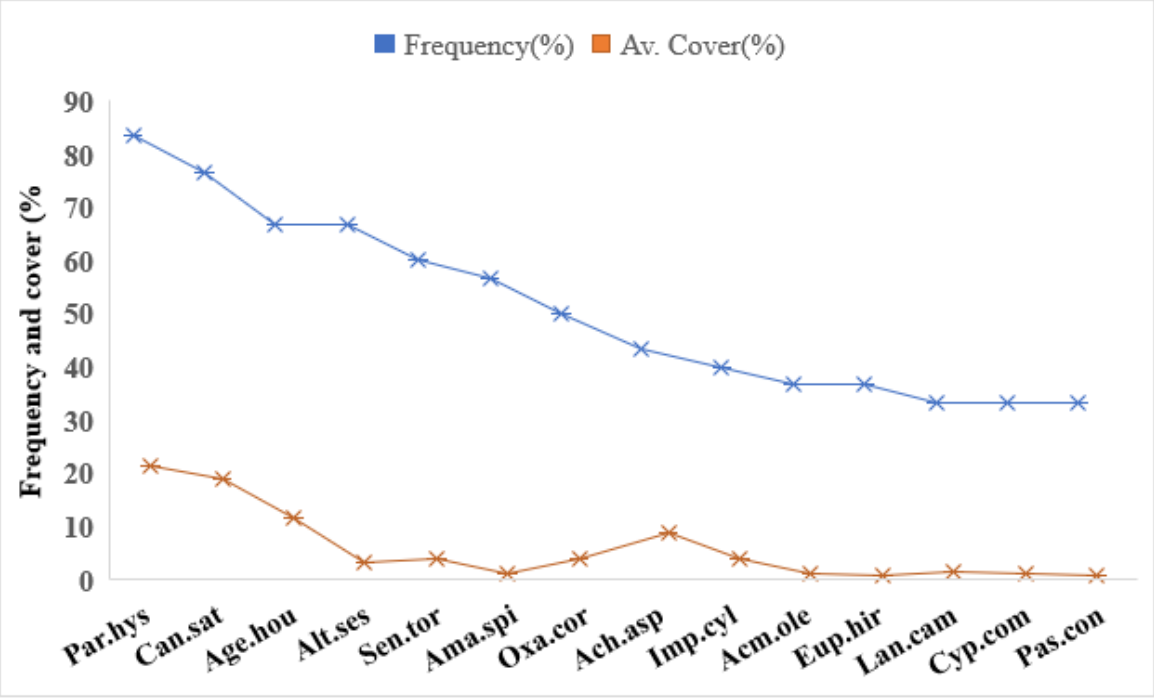

Figure 10: Frequency and Cover of dominant plant species at Fallow lands (Full name of plants are given in Appendix 3).

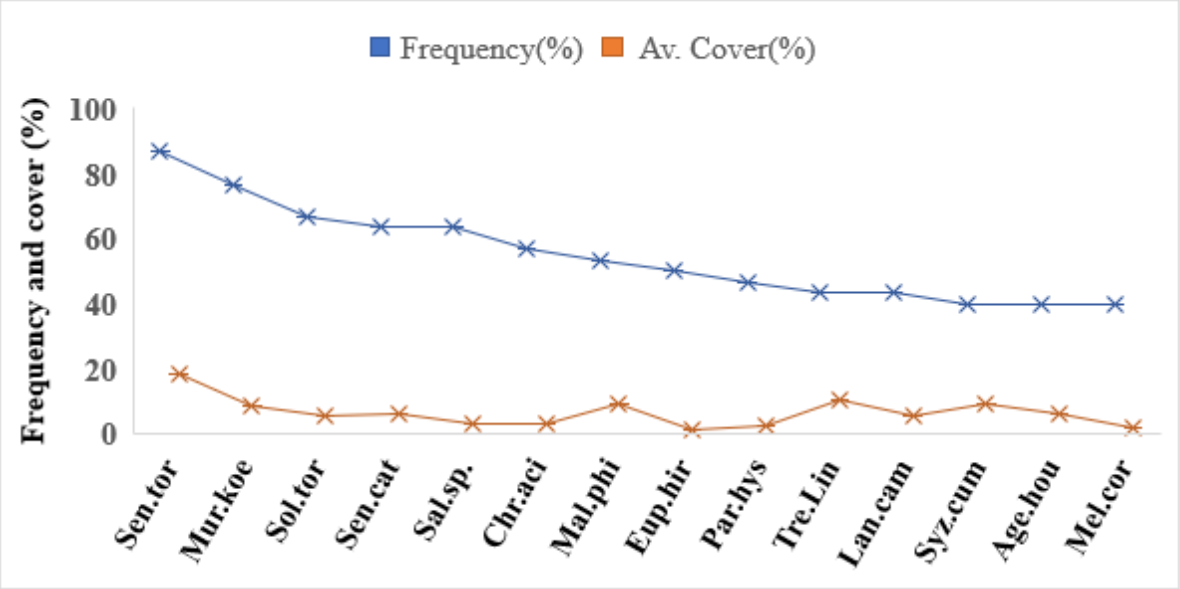

Figure 11: Frequency and Cover of first 15 plant species at forest margin (Full name of plants are given in Appendix 4).

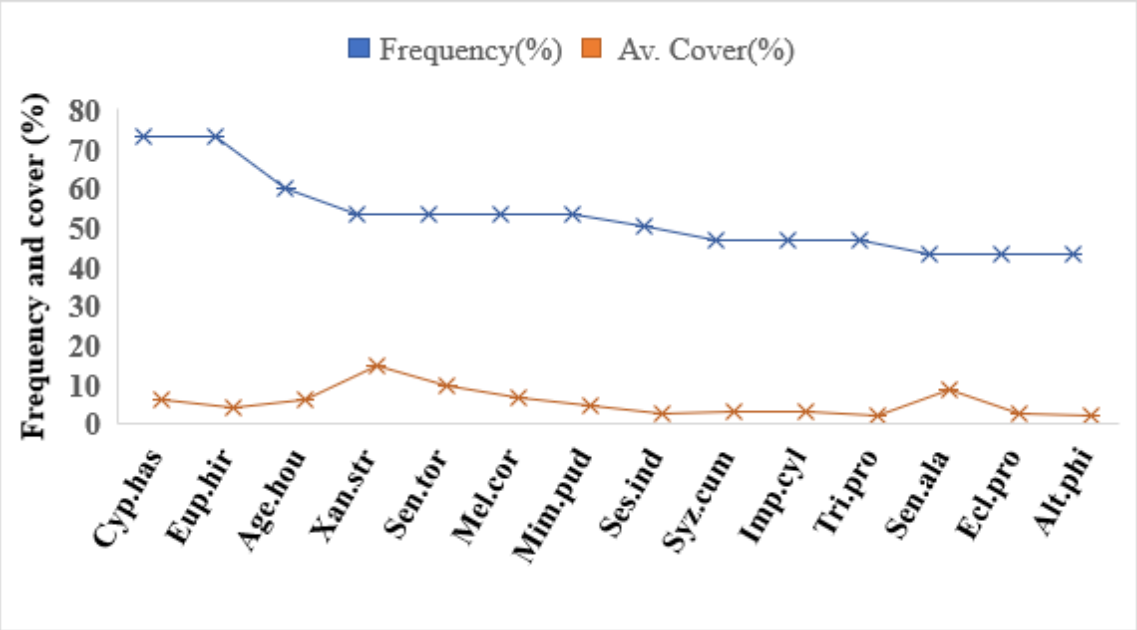

Figure: 12: Frequency and Cover of dominant plant species at wetlands ((Full name of plants are given in Appendix 1).

4.3.1 Frequency of IAPS

At roadside, among the 13 IAPS, *Parthenium hysterophorus* showed the highest frequency (93.33%) followed by *Amaranthus spinosus* (76.67%), *Senna tora* (66.67%), *Alternanthera philoxeroides* (63.33%) and *Lantana camara* (46.67%) as well. While the most frequent species in fallow land and wetland margin was *Ageratum haustonianum*

with (66.67%) and (60%) respectively but in the forest margin *Senna tora* (86.67%) was the most frequent species. Following figures show the frequencies of IAPS in different habitats (Figure 13 to Figure 16).

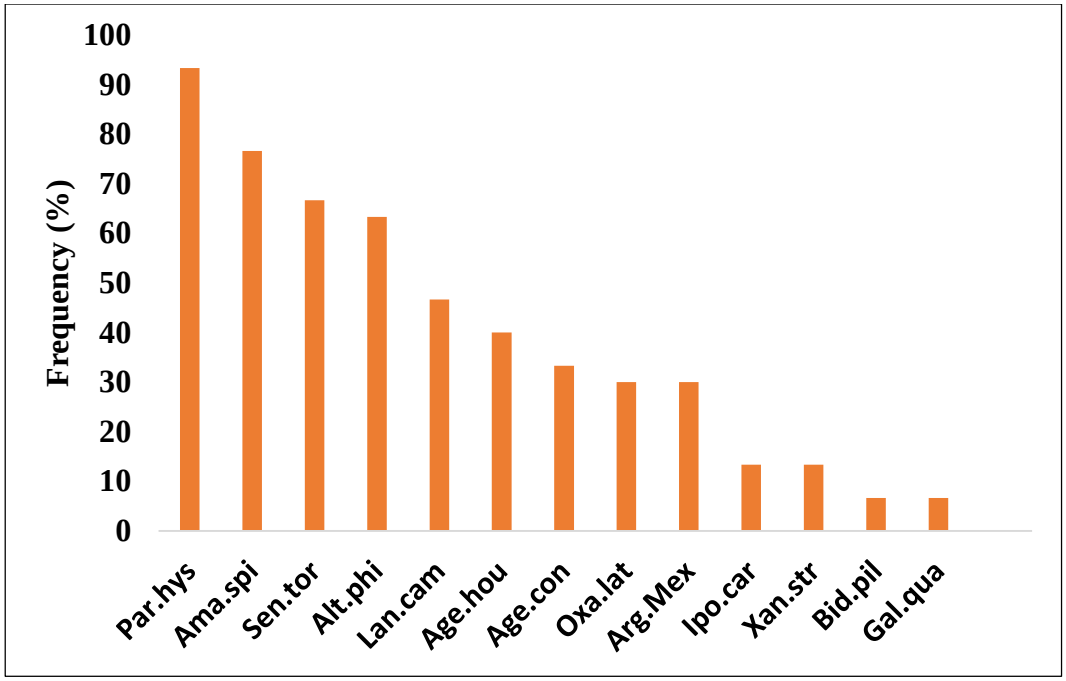

Figure 13: Frequency of IAPS at roadside (full name of plant species are given in Appendix 6).

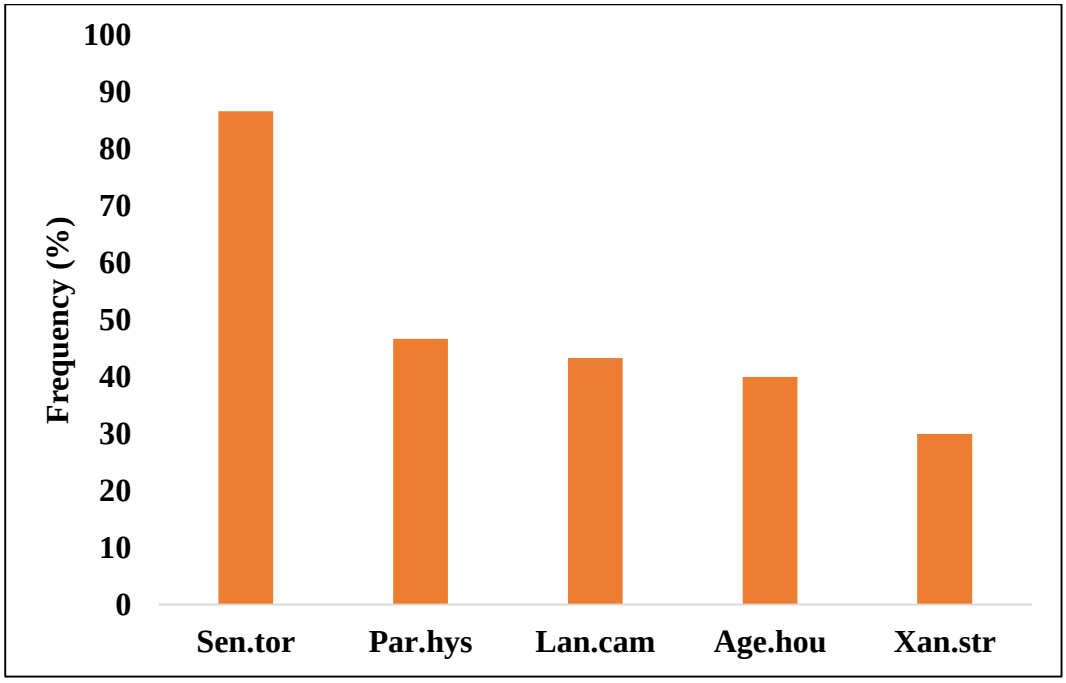

Figure 14: Frequency of IAPS at forest margin(full name of plant species are given in Appendix 6).

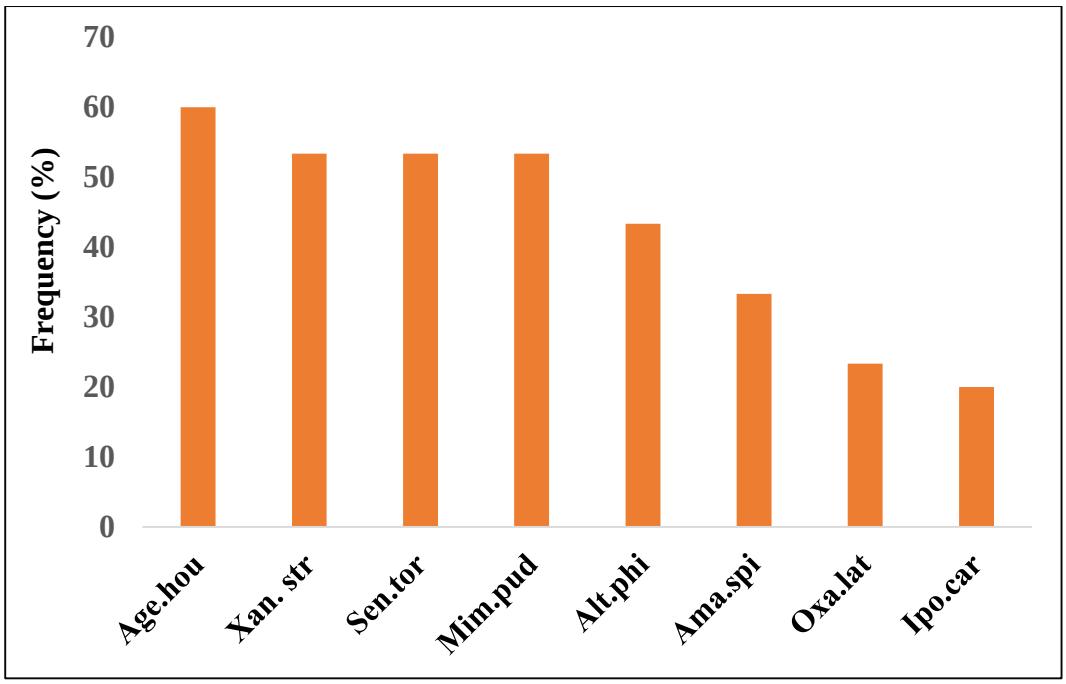

Figure 15: Frequency of IAPS at wetland margin (full name of plant species are given in Appendix 6).

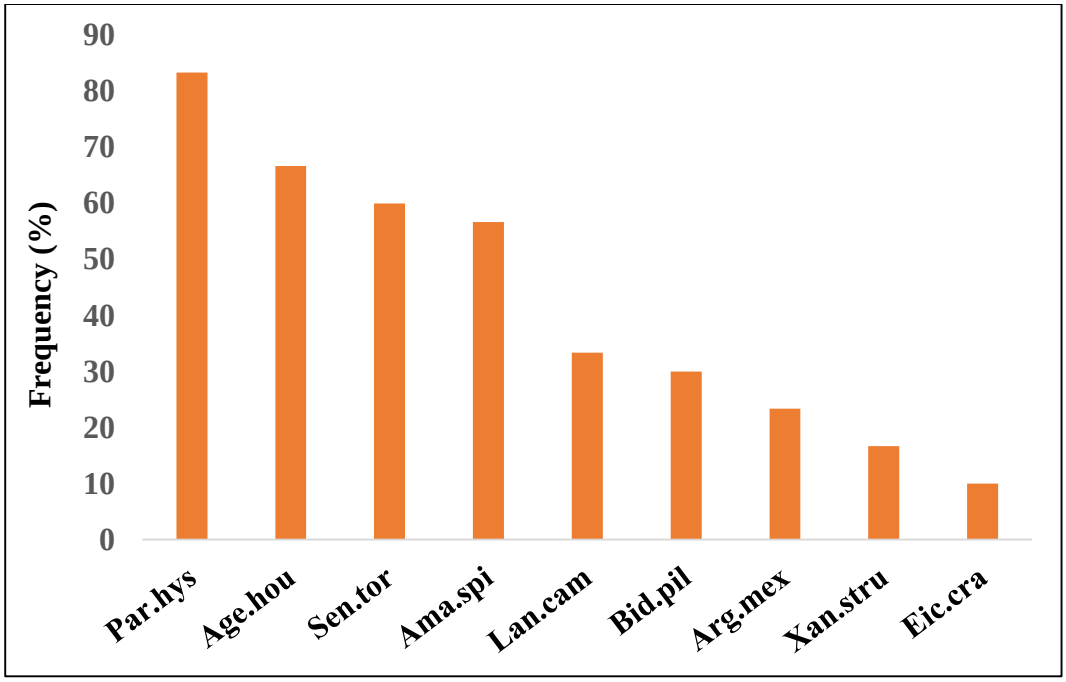

Figure 16: Frequency of IAPS at fallow land (full name of plant species are given in Appendix 6).

4.3.2 Mean Invasive Cover

Among the four habitats, roadside had the highest mean invasive cover followed by fallow land, wetland margin and forest margin. The invasive cover (%) across these habitats was

not statistically significant ($p > 0.05$). There is no significant difference between the mean invasive cover of fallow land, wetland margin and forest margin but the mean invasive cover of roadside differs from other three habitats (Figure 17).

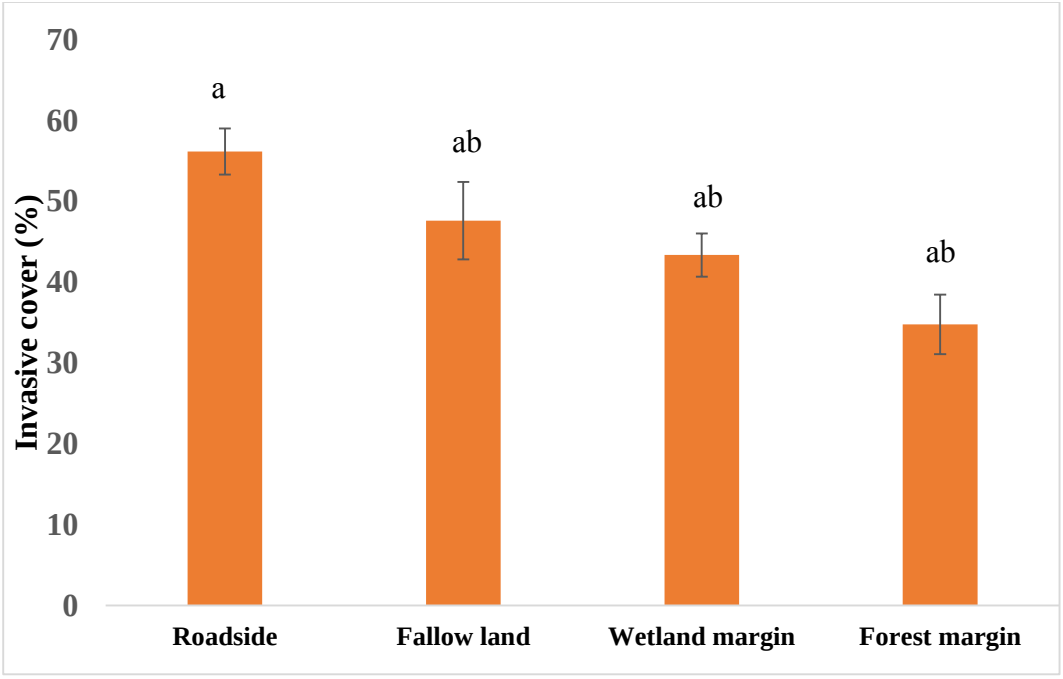

Figure 17: Mean cover of IAPS (%) in different habitats. The vertical bars represent error bars. Mean values were compared by ANOVA followed by Tukey test.

4.3.2 Mean native cover

Among the four habitats, forest margin had the highest mean native cover followed by wetland margin, roadside and fallow lands. The native cover (%) across these habitats was not statistically significant ($p > 0.05$). There is no significant difference between the mean native cover of wetland margin and forest margin but the mean native cover of fallow land significantly differs from other three habitats (Figure 18).

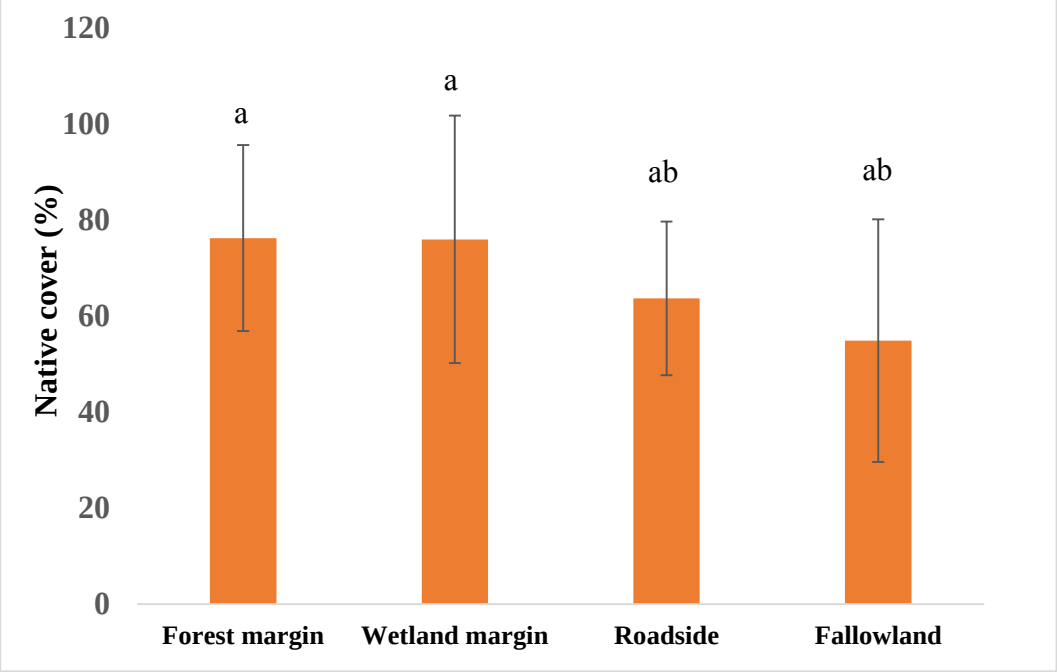

Figure 18 : Mean native cover (%) in different habitats. The vertical error bars represent the standard errors. The mean values were compared by ANOVA followed by Tukey test.

4.4. Relationship between native and invasive plants

4.4.1 Relationship between abundance of native and invasive plants

The abundance relation of native and invasive plants shows that the abundance of invasive plants has a linear effect on the abundance of native plants. A linear regression is obtained in between them. The increase in abundance of invasive species decreased the abundance of native species. The value of R^2 indicates the goodness of fit of the regression line to the data. The lower value of R^2 shows that's the abundance effect of invasive plants on native plants is not statistically significant in all the four habitats (Figure 19.).

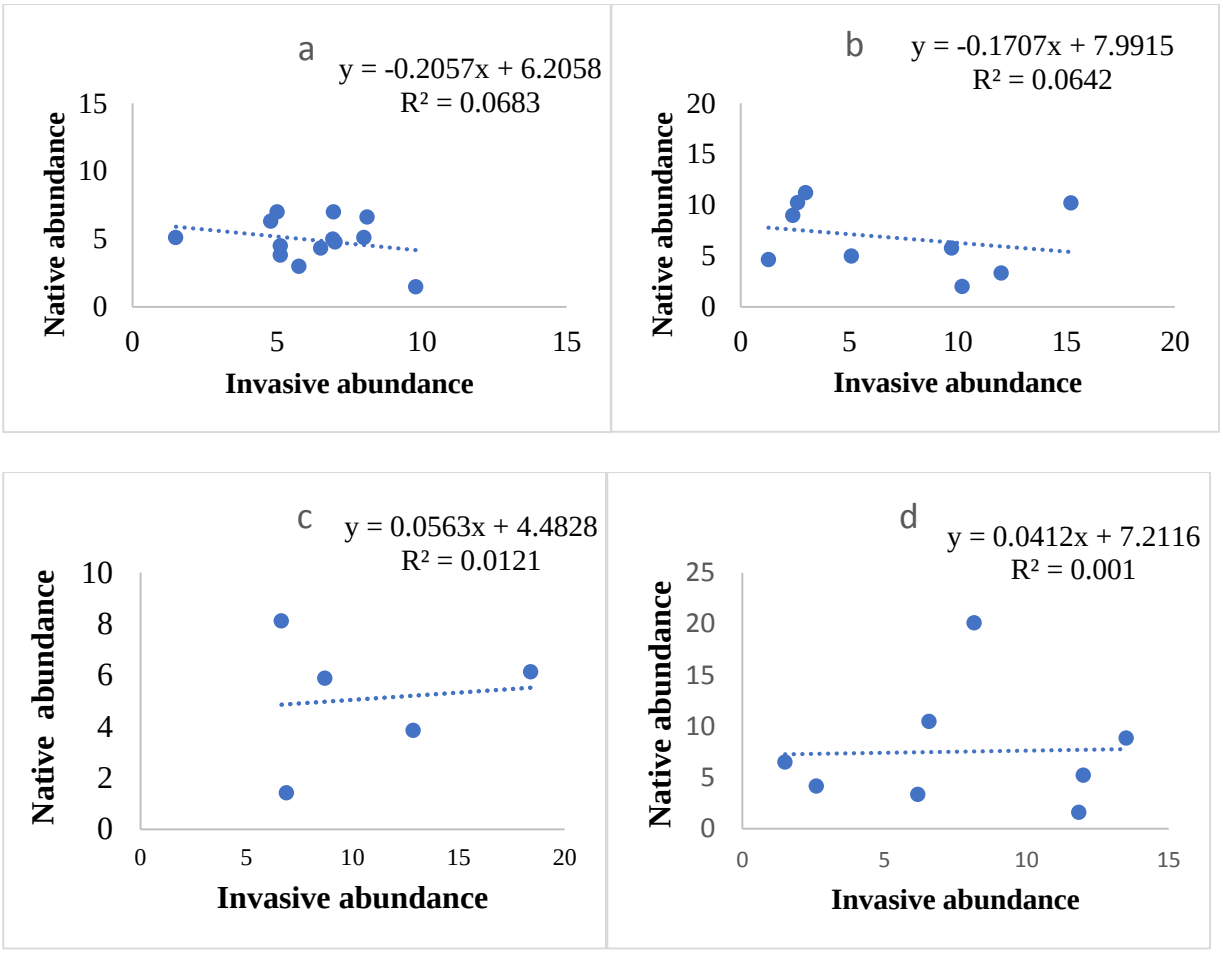

Figure 19 : Relationship between abundance of native and invasive species roadside b) fallow land c) forest margin d) wetland margin

4.4.2 Relationship between cover of native and invasive plants

The relationship between cover of native and invasive plants shows that the cover of invasive plants has a linear effect on the cover of native plants. A linear regression is obtained in between them. The increase in the cover of invasive species suppresses the cover of native species. Along roadsides (a), the effect of cover of invasive plants on the other native plants is not statistically significant. While in the other habitats the effect of invasive cover is statistically significant. The value of R^2 suggests that approximately, 91.57%,66.73%,78.76% of the variability in native cover can be explained by linear relationship with invasive cover in the habitats of fallow lands, forest margins and wetland margins respectively (Figure 20).

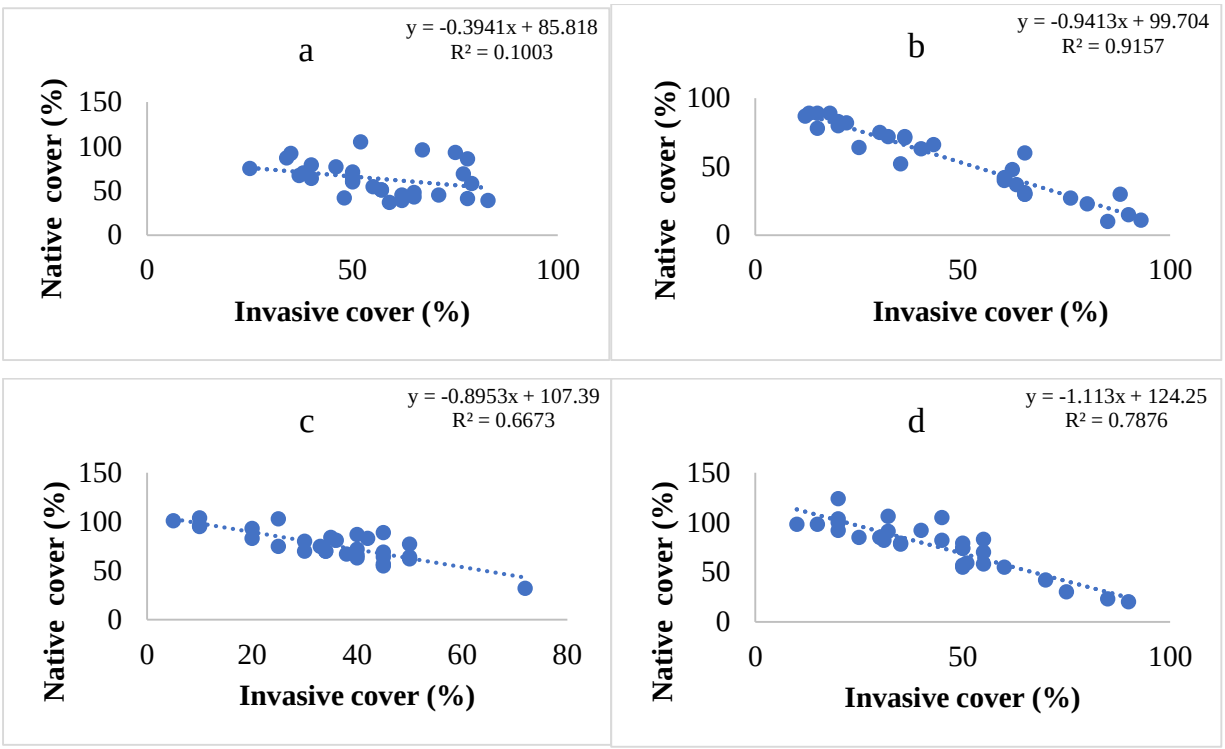

Figure 20: Relationship between native and invasive cover ; a) roadside b) fallow land c) forest margin d) wetland margin

4.5 Importance Value Index (IVI)

Among the four studied habitats, *Parthenium hysterophorus* had the highest IVI in fallow land and roadside while in forest margin and wetland margin *Senna tora* had the highest IVI as shown in figures (21, 22, 23, 24).

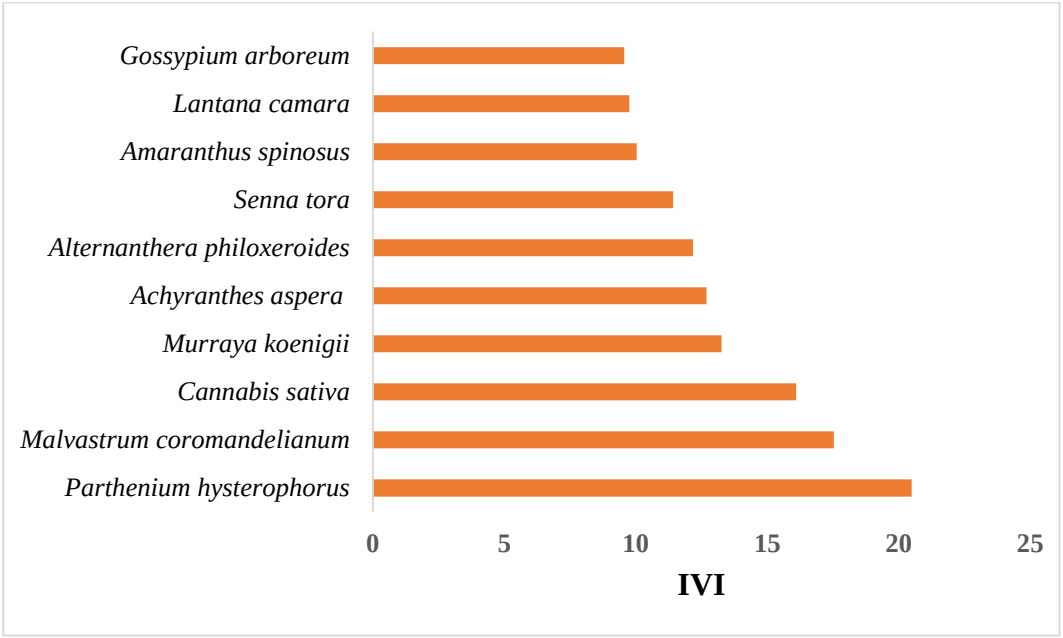

Figure 21: IVI at roadside

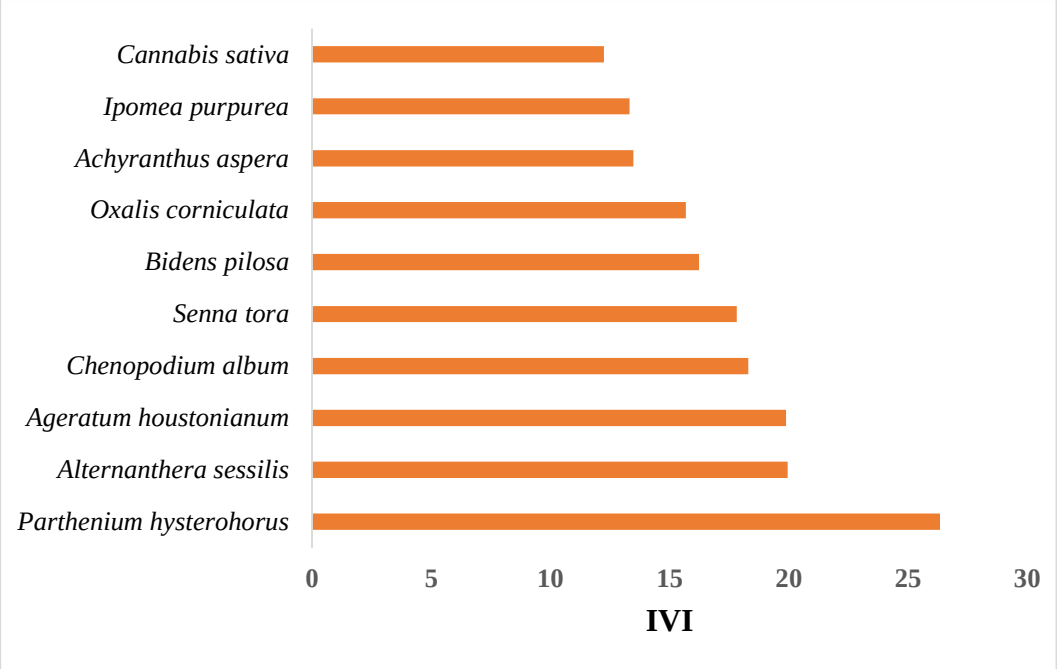

Figure 22: IVI at fallow land

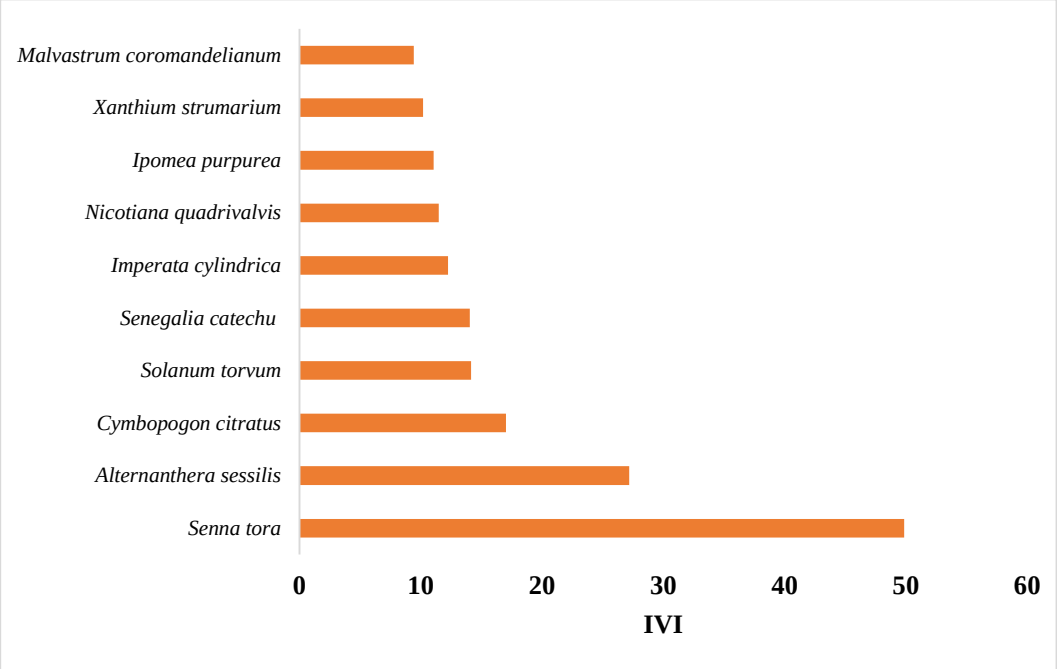

Figure 23: IVI at forest margin

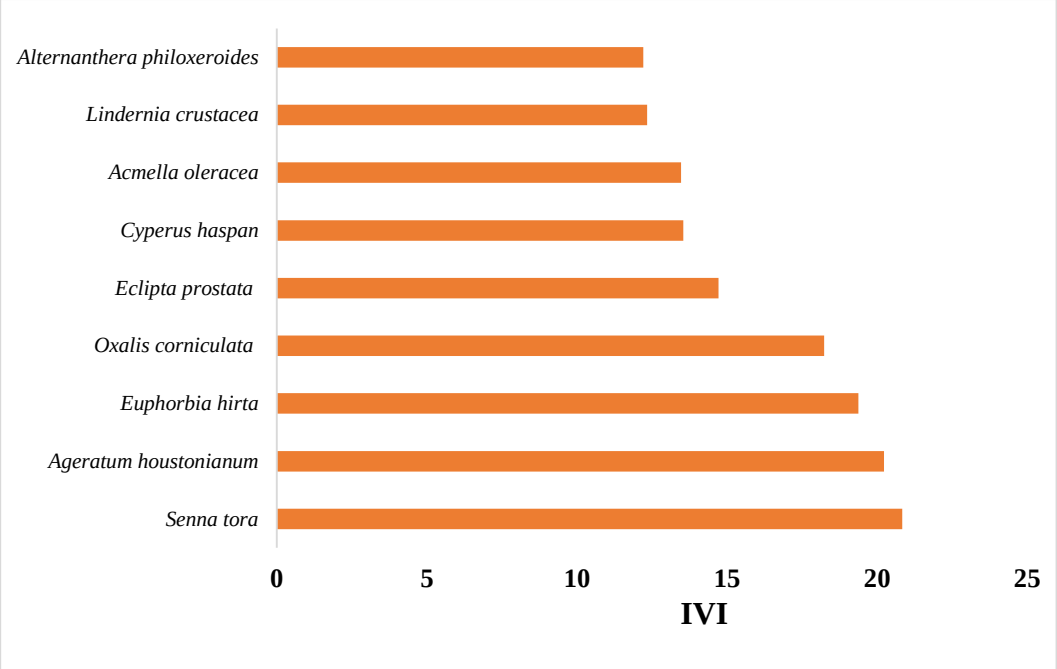

Figure 24: IVI at wetland margin

CHAPTER 5: DISCUSSION

5.1 Species richness

The results of the study indicate a diverse composition of plant species within the study area, encompassing various taxonomic groups and ecological characteristics. The findings highlight the significance of different plant families in contributing to the overall species richness and diversity. The dominance of the Asteraceae family, followed by other prominent families such as Malvaceae, Fabaceae, Amaranthaceae, and Poaceae, underscores the importance of these taxa in the local flora. This distribution of species richness among families is may be due to ecological significance and adaptive capabilities of these plant groups in the study area (Smith *et al*., 2017).

Furthermore, the prevalence of dicot species over monocots suggests a potential preference or adaptation of dicots to the local environmental conditions. This observation aligns with broader ecological patterns indicating the prevalence of dicotyledonous plants in many terrestrial ecosystems (Friedman, 2020). The presence of a diverse array of herb, shrub, and climber species indicates varied habitat structures and ecological niches within the study area. Such diversity of growth forms contributes to the overall complexity and resilience of the local ecosystem (Paine *et al*., 1998). Overall, the results underscore the importance of understanding plant diversity at various taxonomic and ecological levels for effective conservation and management of natural ecosystems.

The findings of the study reveal intriguing patterns of species richness across different habitats, shedding light on the ecological dynamics within the study area. The observed ranking of habitats by species richness, with roadside exhibiting the highest richness followed by wetland margin, forest margin, and fallow lands, suggests varying levels of habitat suitability and ecological heterogeneity.

Despite the observed differences in species richness among habitats, the lack of statistical significance indicates that these differences may not be substantial or consistent across sampling locations. This could be attributed to factors such as habitat disturbance, historical land use patterns, or stochastic processes influencing species assemblages (Magurran and McGill, 2010).

The significant difference in mean species richness between the roadside and other habitats highlights the importance of roadside habitats as reservoirs of biodiversity. Roadside

habitats often experience unique environmental conditions, such as increased light availability and disturbances from human activities, which can favor the establishment and persistence of a diverse array of plant species (Clergeau *et al*., 2001).

On the other hand, the absence of significant differences in species richness among wetland margin, forest margin, and fallow land suggests potential similarities in habitat characteristics or species composition across these habitats. This may indicate the presence of common ecological processes or environmental filters shaping plant community structure in these areas (Chiarucci *et al*., 2005).

5.2 Native and invasive flora

The findings from the study highlight the differential distribution of invasive alien plant species across various habitats, with implications for ecosystem management and conservation efforts. Roadside habitats emerged as hotspots for invasive species, hosting the highest number of invasive alien plant species compared to other habitats. Conversely, forest margins exhibited the lowest invasion intensity, with the fewest invasive species recorded.

The prevalence of invasive alien species in roadside habitats could be attributed to factors such as human disturbance, habitat fragmentation, and the introduction of non-native species through human-mediated activities (McKinney, 2006). These habitats often experience high levels of disturbance and habitat degradation, creating favorable conditions for the establishment and spread of invasive species (Clergeau *et al*., 2001).

Interestingly, certain invasive species, such as *Xanthium strumarium* and *Ageratum houstonianum*, were ubiquitous across all surveyed habitats, indicating their wide ecological amplitude and adaptability to diverse environmental conditions (Pysek *et al*., 2008).

In contrast, the distribution of native plant species varied among habitats, with roadside supporting the highest number of native species. This could be attributed to the presence of remnant native vegetation in roadside habitats or the availability of suitable microhabitats that support native plant communities (Clergeau *et al*., 2001). Naturalized species are typically found in more disturbed areas, such as grasslands and fallow lands, across the country and are spreading to nearby disturbed land use types. According to Tiwari et al. (2005), these species thrive in places like roadside grazing lands and

agricultural fields, where resources such as light, water, and nutrients are more abundant. This abundance of resources can facilitate the invasion process (Davis *et* al., 2000).

Furthermore, the abundance of naturalized species followed a similar pattern to invasive species, with roadside habitats exhibiting the highest abundance of naturalized plants. This underscores the need for effective management strategies to mitigate the spread of invasive species and promote the conservation of native biodiversity in roadside habitats and other vulnerable ecosystems (Pysek *et al*., 2012).

Overall, the study highlights the importance of understanding the distribution patterns of invasive alien, native, and naturalized plant species across different habitats for informing targeted conservation and management interventions.

5.3 Frequency and cover

Along the roadside, *Cannabis sativa* and *Parthenium hysterophorus* emerge as the dominant species, with high frequencies of 96.67% and 93.33%, respectively. This dominance reflects the ability of these species to thrive in disturbed habitats and outcompete native vegetation (Gelbard and Belnap, 2003). Furthermore, among the 13 IAPS identified, *Parthenium hysterophorus* maintains the highest frequency, indicating its successful establishment and spread in roadside environments (McKinney, 2006).

In fallow lands, *Parthenium hysterophorus* remains the most frequent species, followed by *Cannabis sativa* and *Ageratum houstonianum*. This suggests the colonization of fallow agricultural fields by invasive species, potentially disrupting ecosystem processes and reducing habitat suitability for native flora and fauna (Bogale and Tolossa, 2021).

Forest margins are dominated by *Senna tora*, indicating its preference for edge habitats and potential encroachment into adjacent natural ecosystems. This dominance could alter understory vegetation dynamics and threaten native plant diversity in forest margins (Chitnis *et al*., 2019).

At wetland margins, *Cyperus haspan* and *Euphorbia hirta* share the highest frequency, suggesting their adaptation to wetland habitats. However, *Xanthium strumarium*, an invasive alien species, occupies the highest cover, highlighting its potential threat to native wetland plant communities and ecosystem functioning (Richardson *et al*., 2000).

Overall, the distribution patterns of IAPS across different habitats underscore the importance of effective management strategies to control their spread and mitigate their ecological impacts on native biodiversity.

5.4 Relationship between native and invasive species

The observed relationship between the cover and abundance of invasive plants and their impact on native plant communities aligns with established ecological principles and has been documented in numerous studies. The linear effect of invasive plant cover on native plant cover suggests competitive interactions between invasive and native species, wherein an increase in the cover of invasive plants leads to a corresponding decrease in the cover of native plants. This phenomenon is commonly referred to as competition-mediated displacement, where invasive species outcompete native species for limited resources such as light, water, and nutrients (Levine *et al*., 2003).

Similarly, the linear relationship between the abundance of invasive plants and the abundance of native plants further supports the notion of competitive exclusion, wherein invasive species negatively impact native species through resource competition, allelopathy, or habitat modification (Vilà *et al*., 2011). As the abundance of invasive plants increases, they can directly suppress the growth and reproduction of native plants, leading to declines in native plant abundance and diversity.

These findings are consistent with broader ecological theories, such as the competitive exclusion principle and the niche differentiation hypothesis, which suggest that invasive species can alter ecosystem dynamics and community structure by displacing or suppressing native species (Schoener, 1983; Levine *et al*., 2003).

Overall, the observed linear relationships between the cover and abundance of invasive plants and their impact on native plant communities highlight the importance of understanding and managing invasive species to mitigate their negative effects on native biodiversity and ecosystem functioning.

5.5 Importance value Index (IVI)

The observation that *Parthenium hysterophorus* exhibited the highest Importance Value Index (IVI) in fallow land and roadside habitats, while *Senna tora* had the highest IVI in forest margin and wetland margin habitats, provides insights into the differential habitat preferences and competitive abilities of these plant species.

Parthenium hysterophorus, commonly known as parthenium weed, is renowned for its aggressive invasive behavior and ability to colonize disturbed habitats such as fallow lands and roadsides (Evans, 1997). Its high IVI in these habitats suggests its successful establishment and dominance, potentially outcompeting native vegetation and altering ecosystem dynamics with its small sized seed with prolific seed production capacity (Bhattarai and Vetaas, 2006). Thapa *et al*. (2015) also noted that *Ageratum houstonianum*, *Senna tora* along with *A*. *conyzoides*, were particularly troublesome in the far-western region of Nepal. Conversely, *Senna tora*, also known as sicklepod, exhibits a preference for forest edge and wetland habitats, where it may have evolved to thrive in partially shaded environments or moist conditions (Munasinghe *et al*., 2020). Its high IVI in forest margin and wetland margin habitats suggests its ability to outcompete other species and dominate plant communities in these specific ecological niches. These findings underscore the importance of habitat-specific factors in shaping the distribution and dominance of plant species and highlight the ecological impacts of invasive species like *Parthenium hysterophorus* on native biodiversity and ecosystem functioning (Pyšek *et al*., 2012).

Overall, the differential IVI values of *Parthenium hysterophorus* and *Senna tora* across different habitats reflect their niche specialization and competitive abilities, providing valuable insights into their ecological roles and potential impacts on native plant communities.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study on plant species diversity and invasive plants in different habitats revealed significant insights into the distribution, richness and composition of plant species. It can be concluded that that there was varying diversity across habitats, with the roadside exhibiting the highest species richness, followed by wetland margin, forest margin, and fallow lands. Invasive alien plant species were most prevalent along roadsides. The notable IAPS species observed were *Parthenium hysterophorus*, *Xanthium strumarium*, *Senna tora* and *Ageratum houstonianum* observed across all habitats. The study emphasized the need for conservation measures to protect native biodiversity and ecosystems from the threats posed by invasive species.

6.2 Recommendations

a) Resources can be allocated and efforts should be prioritized to control and eradicate high risk invasive species by using mechanical, chemical or biological control methods tailored to each species and habitat.

b) Certain invasive species such as *Parthenium* hysterophorus, *Ageratum houstonianum*, and *Eichhornia crassipes* can be repurposed as fertilizers, offering a dual benefit of aiding agriculture while managing their population growth.

c) Biosecurity measures should be enhanced at borders to prevent the introduction and spread of invasive species through trade and travel. Regulations, inspections, and quarantine procedures should be improved to minimize the risk of accidental introductions.

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APPENDICES

Appendix I. Data sheets used during sampling

Data sheet for ecological assessment

Size of quadrat: Establish plots of 1m × 1m Square plot.

Quadrat no: .....Altitude: ..... Site: .....

S.N.	Scientific name of plant	Local name	Number of individuals	Cover (%)
1				
2				
3				
4				

Appendix 2. Density (D), relative density (RD), frequency (F), relative frequency (RF), average cover (C) abundance(A) relative abundance (RA) and important value index (IVI) of wetland margin

S.N	Name of species	F	A	D	C	RF	RA	RD	IVI
1	Ach.asp	20.00	4.17	0.83	2.50	1.55	2.02	1.15	4.73
2	Acm.ole	30.00	20.11	1.00	4.73	2.33	9.76	1.38	13.47
3	Age.hau	60.00	11.83	7.33	6.00	4.66	5.74	10.15	20.56
4	Alb.leb	33.33	1.60	0.53	1.50	2.59	0.78	0.74	4.11
5	Alt.phi	43.33	8.15	3.53	2.20	3.37	3.96	4.89	12.21
6	Ama.spi	33.33	2.60	0.87	1.33	2.59	1.26	1.20	5.05
7	Cal.gig	40.00	3.33	1.33	7.00	3.11	1.62	1.85	6.57
8	Cyp.com	33.33	6.50	2.17	2.50	2.59	3.15	3.00	8.74
9	Cyp.has	73.33	5.23	3.83	5.83	5.70	2.54	5.31	13.54
10	Ecl.pro	43.33	10.46	4.53	2.43	3.37	5.07	6.28	14.72
11	Euc.ter	73.33	1.18	0.87	4.03	5.70	0.57	1.20	7.47
12	Eup.hir	46.67	13.93	6.50	3.00	3.63	6.76	9.00	19.38
13	Imp.cyl	20.00	3.17	0.63	2.83	1.55	1.54	0.88	3.97
14	Ipo.car	36.67	3.36	1.23	2.00	2.85	1.63	1.71	6.19
15	Lin.cru	30.00	11.11	3.33	1.17	2.33	5.39	4.61	12.34
16	Mal.cor	53.33	2.06	1.10	6.37	4.15	1.00	1.52	6.67
17	Mel.cor	53.33	2.50	1.33	4.67	4.15	1.21	1.85	7.20
18	Mim.pud	33.33	2.40	0.80	1.73	2.59	1.16	1.11	4.86
19	Nic.qad	33.33	4.20	1.40	3.67	2.59	2.04	1.94	6.57
20	Oxa.cor	10.00	28.00	2.80	1.00	0.78	13.58	3.88	18.24

21	Oxa.lat	30.00	4.00	1.20	1.55	2.33	1.94	1.66	5.93
22	Per.mit	20.00	7.00	1.40	0.77	1.55	3.40	1.94	6.89
23	Phy.nod	23.33	2.57	0.60	1.07	1.81	1.25	0.83	3.89
24	Sco.dul	43.33	1.46	0.63	8.50	3.37	0.71	0.88	4.95
25	Sen.ala	53.33	2.25	1.20	9.67	4.15	1.09	1.66	6.90
26	Sen.tor	50.00	14.40	7.20	2.47	3.89	6.98	9.97	20.84
27	Ses.ind	23.33	7.43	1.73	1.43	1.81	3.60	2.40	7.82
28	Sid.rho	46.67	1.00	0.47	3.07	3.63	0.49	0.65	4.76
29	Syz.cum	46.67	1.29	0.60	2.00	3.63	0.62	0.83	5.08
30	Tri.pro	23.33	6.29	1.47	2.00	1.81	3.05	2.03	6.89
31	Tri.rho	16.67	2.20	0.37	1.00	1.30	1.07	0.51	2.87
32	Ure.lob	33.33	2.10	0.70	3.33	2.59	1.02	0.97	4.58
33	Xan.stu	53.33	6.56	3.50	14.67	4.15	3.18	4.85	12.17
34	Ziz.juj	23.33	1.71	0.40	1.33	1.81	0.83	0.55	3.20

Appendix 3. Density (D), relative density (RD), frequency (F), relative frequency (RF), average cover (C) ,abundance(A) relative abundance (RA) and important value index (IVI) of fallow lands.

S.N.	Plants	F	A	D	Av. C	RF	RD	RA	IVI
1	Aca.ind	30.00	2.00	0.60	0.97	2.80	0.75	1.02	4.56
2	Ach.asp	43.33	9.00	3.90	8.77	4.04	4.87	4.57	13.48
3	Acm.ole	36.67	4.64	1.70	1.17	3.42	2.12	2.35	7.90
4	Age.hau	66.67	10.20	6.80	11.67	6.21	8.50	5.18	19.89
5	Alt.ses	66.67	10.25	6.83	3.17	6.21	8.54	5.21	19.96
6	Ama.spi	56.67	2.41	1.37	1.30	5.28	1.71	1.22	8.21
7	Ani.ind	10.00	5.00	0.50	0.37	0.93	0.62	2.54	4.10
8	Arg.mex	23.33	1.29	0.30	0.77	2.17	0.37	0.65	3.20
9	Bid.pil	30.00	15.22	4.57	2.53	2.80	5.71	7.73	16.23
10	Can.sat	76.67	5.78	1.73	3.70	7.14	2.17	2.93	12.24
11	Che.alb	20.00	11.22	8.60	18.80	1.86	10.75	5.70	18.31
12	Cle.vis	20.00	3.33	0.67	0.63	1.86	0.83	1.69	4.39
13	Col.esc	26.67	2.83	0.57	0.47	2.48	0.71	1.44	4.63
14	Cyp.com	33.33	5.50	1.47	1.57	3.11	1.83	2.79	7.73
15	Eic.cra	10.00	5.50	1.83	1.00	0.93	2.29	2.79	6.02
16	Euc.ter	16.67	2.63	0.70	3.77	1.55	0.87	1.33	3.76
17	Eup.hir	36.67	1.80	0.30	0.33	3.42	0.37	0.91	4.71
18	Gos.arb	13.33	6.82	2.50	0.70	1.24	3.12	3.46	7.83
19	Imp.cyl	40.00	3.75	0.50	0.37	3.73	0.62	1.90	6.26
20	Ipo.pur	3.33	12.92	5.17	3.93	0.31	6.46	6.56	13.33

21	Jat.cur	23.33	7.00	0.23	0.67	2.17	0.29	3.56	6.02
22	Lan.cam	33.33	2.00	0.47	0.93	3.11	0.58	1.02	4.70
23	Luz.syl	13.33	5.10	1.70	1.60	1.24	2.12	2.59	5.96
24	Mal.cor	26.67	4.50	0.60	0.23	2.48	0.75	2.29	5.52
25	Mel.cor	30.00	6.00	1.60	1.13	2.80	2.00	3.05	7.84
26	Nic.qua	20.00	5.67	1.13	0.43	1.86	1.42	2.88	6.16
27	Oxa.cor	50.00	9.73	4.87	3.83	4.66	6.08	4.94	15.68
28	Par.hys	83.33	12.00	10.00	21.37	7.76	12.50	6.09	26.35
29	Pas.con	33.33	6.10	2.03	0.73	3.11	2.54	3.10	8.74
30	Sen.ala	10.00	2.00	0.20	0.83	0.93	0.25	1.02	2.20
31	Sen.tor	60.00	9.72	5.83	3.90	5.59	7.29	4.94	17.82
32	Sol.ame	13.33	2.00	0.27	0.14	1.24	0.33	1.02	2.59
33	Xan.stu	16.67	3.00	0.50	0.73	1.55	0.62	1.52	3.70

Appendix 4. Density (D), relative density (RD), frequency (F), relative frequency (RF), average cover (C), abundance (A) relative abundance (RA) and important value index (IVI) of forest margin

S.N.	Plants	Av.C	A	F	D	RF	RD	RA	IVI
1	Age.hau	6.10	19.00	40.00	7.60	3.49	11.11	12.59	27.19
2	Alt.ses	0.93	6.14	23.33	1.43	2.03	2.10	4.07	8.20
3	Can.sat	2.57	5.89	30.00	1.77	2.62	2.58	3.90	9.10
4	Chr.aci	2.77	8.12	56.67	4.60	4.94	6.73	5.38	17.05
5	Cym.cit	0.83	3.86	23.33	0.90	2.03	1.32	2.56	5.91
6	Dal.sis	2.97	1.38	26.67	0.37	2.33	0.54	0.91	3.77
7	Dic.cla	0.47	6.60	16.67	1.10	1.45	1.61	4.37	7.44
8	Eup.hir	1.23	5.67	50.00	2.83	4.36	4.14	3.76	12.26
9	Imp.cyl	0.77	9.00	23.33	2.10	2.03	3.07	5.96	11.07
10	Ipo.Ipo	1.20	1.88	26.67	0.50	2.33	0.73	1.24	4.30
11	Jat.cur	2.07	1.50	33.33	0.50	2.91	0.73	0.99	4.63
12	Lan.cam	5.80	2.92	43.33	1.27	3.78	1.85	1.94	7.57
13	Mal.Mal	1.40	2.10	33.33	0.70	2.91	1.02	1.39	5.32
14	Mal.Mul	9.03	3.31	53.33	1.77	4.65	2.58	2.20	9.43
15	Mel.Mel	1.73	1.83	40.00	0.73	3.49	1.07	1.21	5.78
16	Mur.koe	8.53	2.70	76.67	2.07	6.69	3.02	1.79	11.49
17	Nic.qua	1.43	6.00	30.00	1.80	2.62	2.63	3.98	9.22
18	Par.Par	2.23	3.79	46.67	1.77	4.07	2.58	2.51	9.16
19	Sal.Sal	3.03	5.37	63.33	3.40	5.52	4.97	3.56	14.05
20	Sen.cat	6.20	1.42	63.33	0.90	5.52	1.32	0.94	7.78

21	Sen.tor	18.33	21.92	86.67	19.00	7.56	27.78	14.53	49.86
22	Sol.ame	1.10	3.22	30.00	0.97	2.62	1.41	2.14	6.16
23	Sol.tor	5.53	5.10	66.67	3.40	5.81	4.97	3.38	14.16
24	Syz.Ske	9.33	3.25	40.00	1.30	3.49	1.90	2.15	7.54
25	Tre.Lin	10.50	3.00	43.33	1.30	3.78	1.90	1.99	7.67
26	Tri.pro	1.37	4.63	26.67	1.23	2.33	1.80	3.06	7.19
27	Vit.tri	1.23	4.43	23.33	1.03	2.03	1.51	2.93	6.48
28	Xan.Xan	2.33	6.89	30.00	2.07	2.62	3.02	4.57	10.20

Appendix 5. Density (D), relative density (RD), frequency (F), relative frequency (RF), average cover (C), abundance(A) relative abundance (RA) and important value index (IVI) of wetland margin

S.N.	Plants	F	Av.C	A	D	RF	RA	RD	IVI
1	Abu.gra	20.00	0.70	4.33	0.87	1.11	1.74	0.92	3.76
2	Ach.asp	80.00	5.33	6.63	5.30	4.44	2.66	5.60	12.69
3	Acm.ole	40.00	2.15	6.33	2.53	2.22	2.54	2.68	7.43
4	Age.con	33.33	0.80	5.11	1.53	1.85	2.05	1.62	5.52
5	Age.hau	40.00	4.33	6.50	2.60	2.22	2.61	2.75	7.57
6	Alb.leb	36.67	2.67	3.82	1.40	2.03	1.53	1.48	5.04
7	Alt.phi	63.33	6.60	8.11	5.13	3.51	3.25	5.42	12.18
8	Alt.ses	3.33	0.17	7.00	0.23	0.18	2.81	0.25	3.24
9	Ama.spi	76.67	3.97	4.78	3.67	4.25	1.92	3.87	10.04
10	Ani.ind	46.67	1.70	4.50	2.10	2.59	1.80	2.22	6.61
11	Arg.mex	30.00	2.13	5.11	1.53	1.66	2.05	1.62	5.33
12	Bid.pil	6.67	0.39	5.00	0.33	0.37	2.00	0.35	2.73
13	Blu.lac	3.33	0.03	3.00	0.10	0.18	1.20	0.11	1.49
14	Boe.dif	40.00	0.97	3.42	1.37	2.22	1.37	1.44	5.03
15	Cal.gig	46.67	0.87	3.36	1.57	2.59	1.35	1.65	5.59
16	Can.sat	96.67	2.97	7.55	7.30	5.36	3.03	7.71	16.10
17	Che.alb	3.33	13.43	4.00	0.13	0.18	1.60	0.14	1.93
18	Cle.vis	10.00	0.07	6.00	0.60	0.55	2.41	0.63	3.59
19	Com.ben	43.33	0.27	5.31	2.30	2.40	2.13	2.43	6.96
20	Cya.dac	10.00	0.90	6.67	0.67	0.55	2.67	0.70	3.93

21	Dic.cla	10.00	0.57	4.00	0.40	0.55	1.60	0.42	2.58
22	Ecl.pro	43.33	0.27	0.69	0.30	2.40	0.28	0.32	3.00
23	Eri.bon	43.33	0.27	3.15	1.37	2.40	1.26	1.44	5.11
24	Eup.hir	33.33	0.73	6.40	2.13	1.85	2.57	2.25	6.67
25	Fic.pal	6.67	1.10	13.00	0.87	0.37	5.21	0.92	6.50
26	Gal.qua	33.33	0.60	1.40	0.47	1.85	0.56	0.49	2.90
27	Gos.arb	6.67	0.30	19.50	1.30	0.37	7.82	1.37	9.56
28	Imp.cyl	13.33	0.70	4.00	0.53	0.74	1.60	0.56	2.91
29	Ipo.car	26.67	0.33	2.88	0.77	1.48	1.15	0.81	3.44
30	Ipo.pur	6.67	2.33	6.00	0.40	0.37	2.41	0.42	3.20
31	Jat.cur	46.67	0.27	0.14	0.07	2.59	0.06	0.07	2.72
32	Lan.cam	26.67	0.03	12.13	3.23	1.48	4.86	3.41	9.75
33	Luz.syl	83.33	6.13	0.80	0.67	4.62	0.32	0.70	5.65
34	Mal.cor	20.00	0.43	26.83	5.37	1.11	10.76	5.67	17.53
35	Mel.cor	33.33	4.40	2.70	0.90	1.85	1.08	0.95	3.88
36	Mur.koe	3.33	0.70	30.00	1.00	0.18	12.03	1.06	13.27
37	Nic.qua	26.67	3.00	0.13	0.03	1.48	0.05	0.04	1.56
38	Oxa.cor	30.00	0.03	7.22	2.17	1.66	2.90	2.29	6.85
39	Oxa.lat	93.33	2.07	2.57	2.40	5.18	1.03	2.53	8.74
40	Par.hys	43.33	2.53	21.08	9.13	2.40	8.45	9.64	20.50
41	Pas.con	53.33	22.77	4.25	2.27	2.96	1.70	2.39	7.06
42	Pol.avi	30.00	1.27	9.33	2.80	1.66	3.74	2.96	8.36
43	Por.ole	30.00	1.23	4.22	1.27	1.66	1.69	1.34	4.69
44	Sal.sp.	13.33	0.83	11.25	1.50	0.74	4.51	1.58	6.83

45	Sco.dul	66.67	1.00	2.15	1.43	3.70	0.86	1.51	6.07
46	Sen.tor	13.33	0.17	2.25	0.30	0.74	0.90	0.32	1.96
47	Sid.rho	70.00	3.53	6.62	4.63	3.88	2.65	4.89	11.43
48	Sol.ame	43.33	0.83	0.92	0.40	2.40	0.37	0.42	3.20
49	Syz.cum	20.00	1.90	12.67	2.53	1.11	5.08	2.68	8.86
50	Tri.pro	36.67	0.53	1.82	0.67	2.03	0.73	0.70	3.47
51	Ure.lob	13.33	0.27	9.50	1.27	0.74	3.81	1.34	5.89
52	Xan.stu	13.33	0.57	1.50	0.20	0.74	0.60	0.21	1.55
53	Ziz.juj	40.00	1.53	1.67	0.67	2.22	0.67	0.70	3.59

Appendix 6. List of all plants found with their families and abbreviation.

S.N.	Name of plant species	Abbreviation	Family
1	*Abutilon grandifolium*	Abu.gra	Malvaceae
2	*Acalypha indica*	Aca.ind	Euphorbiaceae
3	*Achyranthes aspera*	Ach.asp	Amaranthaceae
4	*Acmela oleracea*	Acm.ole	Asteraceae
5	*Ageratum conyzoides*	Age.con	Asteraceae
6	*Ageratum haustonianum*	Age.hau	Asteraceae
7	*Albizia lebbeck*	Alb.leb	Fabaceae
8	*Alternantera philoxeroides*	Alt.phi	Amaranthaceae
9	*Alternanthera sessile*	Alt.ses	Amaranthaceae
10	*Amaranthus spinosus*	Ama.spi	Amaranthaceae
11	*Anisomeles indica*	Ani.ind	Lamiaceae
12	*Argemone mexicana*	Arg.Mex	Papaveraceae
13	*Bidens pilosa*	Bid.pil	Asteraceae
14	*Blumea lacera*	Blu.lac	Asteraceae
15	*Boerhavia diffusa*	Boe.dif	Nyctaginaceae
16	*Calotropis gigantea*	Cal.gig	Apocyaceae
17	*Cannabis sativa*	Can.sat	Cannabaceae
18	*Chenopodium album*	Che.alb	Amaranthaceae
19	*Chrysopogon aciculatus*	Chr.aci	Poaceae
20	*Cloeme viscosa*	Clo.vis	Cleomaceae
21	*Colocasia esculenta*	Col.esc	Araceae

22	*Commelina benghalensis*	Com.ben	Commelinaceae
23	*Cyanodon dactylon*	Cya.dac	Poaceae
24	*Cymbopogon citratus*	Cym.cit	Poaceae
25	*Cyperus compressus*	Cyp.com	Cyperaceae
26	*Cyperus haspan*	Cyp.has	Cyperaceae
27	*Dalbergia sisoo*	Dal.sis	Fabaceae
28	*Dicanthelium clandestium*	Dic.cla	Poacae
29	*Eclipta prostata*	Ecl.pro	Asteraceae
30	*Eichhornia crassipes*	Eic.cra	Pontederiaceae
31	*Erigeron bonareansis*	Eri.bon	Asteraceae
32	*Eucalyptus tereticornis*	Euc.ter	Myrtaceae
33	*Euphorbia hirta*	Eup.hir	Euphorbiaceae
34	*Ficus palmata*	Fic.pal	Moracae
35	*Galinsoga quadriradiata*	Gal.qua	Asteraceae
36	*Gossypium arboreum*	Gos.arb	Malvaceae
37	*Imperata cylindrica*	Imp.cyl	Poaceae
38	*Ipomea purpurea*	Ipo.pur	Convulvulacae
39	*Ipomoea carnea*	Ipo.car	Convulvulacae
40	*Jatropha curcas*	Jat.cur	Euphorbiaceae
41	*Lantana camara*	Lan.cam	Verbenaceae
42	*Lindernia crustacea*	Lin.cru	Linderniaceae
43	*Luzula sylvatica*	Luz.syl	Juncaceae
44	*Mallotus philippensis*	Mal.phi	Euphorbiaceae
45	*Malvastrum coromandelianum*	Mal.cor	Malvaceae

46	*Melochia corchorifolia*	Mel.cor	Malvaceae
47	*Mimosa pudica*	Mim.pud	Fabaceae
48	*Murraya koenigii L.*	Mur.koe	Rutaceae
49	*Nocotiana quadrivalvis*	Noc.qua	Solanaceae
50	*Oxalis corniculata*	Oxa.cor	Oxalidaceae
51	*Oxalis latiflolia*	Oxa.lat	Oxalidaceae
52	*Parthenium hysterophorus*	Par.hys	Asteraceae
53	*Paspalum conjugatum*	Pas.con	Poaceae
54	*Persicaria mitis*	Per.mit	Polygonaceae
55	*Phyla nodiflora*	Phy.nod	Verbenaceae
56	*Polygonum aviculare*	Pol.avi	Polygonaceae
57	*Portulaca oleracea*	Por.ole	Portulaceae
58	*Salvia sp.*	Sal.sp.	Lamiaceae
59	*Scoparia dulcis*	Sco.dul	Plantaginaceae
60	*Senegalia catechu*	Sen.cat	Fabaceae
61	*Senna alata*	Sen.ala	Fabaceae
62	*Senna tora*	Sen.tor	Fabaceae
63	*Sesamum indicum*	Ses.ind	Pedaliaceae
64	*Sida rhombifolia*	Sid.rho	Malvaceae
65	*Solanum americanum*	Sol.ame	Solanaceae
66	*Solanum torvum*	Sol.tor	Solanaceae
67	*Syzygium cumini*	Syz.cum	Myrtaceae
68	*Trewia nudiiflora*	Tre.nud	Euphorbiaceae
69	*Tridex procumbens*	Tri.pro	Asteraceae

70	*Triumfetta rhomboidea*	Tri.rho	Malvaceae
71	*Urena lobata*	Ure.lob	Malvaceae
72	*Vitex trifolia*	Vit.tri	Malvaceae
73	*Xanthium stumarium*	Xan.stu	Asteraceae
74	*Ziziphus jujuba*	Ziz.juj	Rhamnaceae

PHOTOPLATES

1. Roadside covered with *Parthenium hysterophorus*

2. *Lantana camara* L.

3. Jakhor lake area

4.Cannabis sativa

5. Xanthium strumarium