IMPACT OF INVASIVE PLANT SPECIES ON NON INVASIVE PLANT SPECIES AROUND JAGDISHPUR RESERVOIR OF KAPILVASTU DISTRICT, NEPAL

A THESIS

SUBMITTED FOR THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER'S DEGREE IN BOTANY

BY

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DECLARATION

I, "Rakshya Pandey", 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 "**Impact of invasive plant species on non invasive plant species around jagdishpur reservoir of Kapilvastu district, Nepal**" is carried out by "Rakshya Pandey" 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 fulfillment of M. Sc. Degree in Botany.

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ACRONYMS AND ABBREVIATIONS

AT - Around tal

ALNT - Agricultural land near tal

BPP - Biodiversity profile project

C - Coverage

C- Simpson`s index of dominance

CBD- Convention on Biological diversity

DFO - District Forest Officer

DFRS- Department of forest research and survey

DPR- Department of Plant Resources

F - Frequency

FNT - Forest near tal

FRA - Forest resource assessment

GoN - Government of nepal

H- Shannon-wiener index

IBAs - Important bird areas

IAPs - Invasive alien plant species

IAS - Invasive alien species

ICIMOD - International centre for integrated mountain development

IPCC – Intergovernmental panel on climate change

ISSG - Invasive species specialist group

IUCN - International union for conservation

IVI - Important value index

MEA - Millennium ecosystem analysis

MOFSC – Ministry of forest and soil conservation

RA- Relative Abundance

RD- Relative Density

RF- Relative Frequency

ABSTRACT

Invasion by the exotic species has become a serious problem in Nepal. Jagdishpur is one of the Ramsar sites and Important Bird Areas of Nepal that drives this study to know if the invasive species are present in the site and its effects. Land use status of the study area was categorized as Grassland Around Reservoir, Agricultural Land and Forest Near Reservoir. Quadrate method (size = 2m * 2m and plot number (n=40) in each land use class) was followed as sampling method. A total of 129 species under 46 families were recorded out of which 20 were invasive alien plant species in Jagdishpur. Important Value Index of each species in Agricultural land, Forest land and Grassland around reservoir showed Grassland rich in biodiversity. It is also found that Agricultural land was rich in invasive species biodiversity. *Ageratina adenophora, Ageratum conyzoides, Amaranthus spinosus, Chromolaena odorata, Eichhornia crassipes, Ipomoea carnea, Mikania micrantha, Mimosa pudica, Parthenium hysterophorus, Senna tora, Xanthium strumarium,* etc. are common invasive species found in the region. Plots with invasive species coverage more than 30 % and less than 30 % were divided in each land use classes and Shannon-Weiner Index and Simpson's Index were computed for differences in the biodiversity index in each land use. Shannon's index in grassland near reservoir is 2.76 that is highest in the area with invasive species coverage less than 30%. Agricultural land with more than 30% invasive species coverage was found to be the lowest Shannon's index (0.87) and lowest Simpson's index (0.35) as well. The impact of invasive species on loss of plant biodiversity is evident in the areas where the coverage of invasive species is more and has been demonstrated with both Simpson diversity index and also Shannon's biodiversity index value. Jagdishpur lake has significant number invasive plant species with potential of invasion are present in the area. The results of this study have shown that the loss of biodiversity in and around Jagdishpur reservoir is in alarming state and need to take necessary action to conserve its biodiversity. Potential risks of IAPs include biodiversity loss and siltation of lakes and reservoirs. Thus, time to time monitoring of aquatic as well as invasive species in and around the reservoir by the concern authority is recommended to take necessary precaution and mitigation measures to conserve biodiversity of this Ramsar site and to stop further expansion of the IAPs in the area.

Keywords: *Jagdishpur, Ramsar, Important Bird Area, Invasive species, Shannon's index, Simpson's index, land-use, and biodiversity loss.*

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CHAPTER 1. INTRODUCTION

1.1 Background

Any species which is not native to a location and tendency to spread and get established in another ecosystem to the extent that can cause serious damage to the biodiversity may be termed as invasive species. Biological invasion worldwide threatens biodiversity, ecosystem dynamics, resource availability, national economy and human health (Ricciadi, 2000). Such invasions can alter native species assemblage and richness and increase biotic homogenization, with replacement of local biotas by non-indigenous species (McKinney and Lockwood, 1999). With steady increase in human movement and global trade, the intensity of biological invasion has been increasing in all ecosystems and landscapes (Shrestha, 2016). The problem of invasive species is prevalent both in developed as well as developing countries, but their impact is likely to be higher in developing countries like Nepal due to lack of expertise and limited resources available for their management (Shrestha, 2016).Invasion by the exotic species has become a serious problem in Nepal. Our country is considered to be one of the countries with the greatest threat (ranked 3 out of 124 countries for the agriculture sector) from biological invasions (Paini*et al.*,2016). Currently, 179 species of flowering plants are known to be naturalized in Nepal (Shrestha et al., 2017a) and 26 of them are considered invasive (Shrestha et al., 2017b). Species like *Lantana camera, Mikania micrantha, Chromolaena orodata, Ageratina adenophora, Parthenium hysterophorus* are invasive alien species (IAS) in Nepal. IAS displaces the native plants by reducing the amount of space, water, sunlight and nutrients that could otherwise be available to native species (IUCN, 2005). *Mikania micrantha* which has been listed as one of the six worst invasive alien species that poses the highest risk to native ecosystem (Tiwari *et al.*, 2005) has invaded major parts of National Park and wetlands suppressing the regeneration and growth of native vegetation.

Many introduced exotic plants have been naturalized in a new environment and form a part of existing landscapes and ecosystems out-competing the native species (IUCN, 2005). However, not all alien species are considered as harmful (IUCN, 2005). There exists a long list of alien species throughout the world introduced intentionally and make a valuable part of the livelihoods and economy of the modern world (IUCN, 2005). Jagdishpur is one of the ten Ramsar sites of Nepal that provide various ecosystem services (MoFE, 2018). Baral, (2008), Bhusal *et al.*, (2020) and Thapa and Saund, (2013) have studied bird diversity in Jagdishpur, Gautam *et al.*, (2010) explored Jagdishpur as suitable habitat for warm water fishes, Chaudahary and Devkota, (2018), Sapkota *et al.*, (2021) and Thapa and Saund, (2013) have assessed water quality and limnological studies of Jagdishpur reservoir and (Sapkota *et al.*, 2021) has recommended the quality of water of the reservoir suiable for drinking and irrigation purposes and the major function of reservoir is irrigation. (Pokhrel *et al.*, 2021) reported 81 algal species in the reservoir. IAPs should be controlled in order to reduce impact and economic loss of ecosystem services of wetlands (Pathak *et al.*, 2021). It negatively affects the natural beauty, biodiversity, recreational activities, tourism activities, fish production in wetlands and disbalance the ecosysem(Pathak *et al.*, 2021). So, this study focuses to know the status of invasive species present in Jagdishpur reservoir, their impact on native vegetation and recommendation for further action.

According to Convention, Wetlands are defined as "areas of marsh, fen, peatland or water whether natural or artificial, permanent or temporary with water that is static or flowing; fresh, brackish or salty, including areas of marine water, the depth of which low tide does not exceed six meters". There are total of 171 countries, 2416 wetlands that cover an area of 254,551,385 ha in the world (Ramsar,2021). The wetlands with high biodiversity value are categorized as Ramsar site by Ramsar Convention. The convention was entered into Nepal from 1998, 10 sites with an area of 60,561 ha are designated as Wetlands of International Importance (Ramsar, 2021). Jagdishpur Reservior was declared as Ramsar site in 2003 (Bhandari, 2009) that covers an area of 225 ha and is home 45 resident bird species (Bhuju*et al.*, 2007), 18 species of fishes, nine species of herpetofauna and six species of mammals (Baral, 2008). The area has record of 16 vascular plants: one pteridophyte, seven dicots, and eight monocots. The major aquatic plant species are *Ageratum conyzoides, Ceratophyllum demersum, Cyperus spp., Hygroryza aristata, Typha elephantina, Ipomoea carnea ssp., fistulosa, Leersia hexandra, Nelumbo nucifera, Vmphoides hydrophyllum, Oryza rufipogon, Ottelia alismoides, Paspalum distichum, Polygonum hydropiper, Vetiveria zizaanioides,* etc. Plantation of *Dalbergia sissoo* is common along the embankment. The associated species in the plantation areas mainly consist of alien taxa, such as

Cassia occidentalis, *C. tora*, *Hromolaena odorata*, *Croton bonplandianum*, *Hyptis suaveolens*, *Parthenium hysterophorus*, *Xanthium strumarium*, etc (Nepal Biodiversity Resource Book, 2007). Also, it is one of the IBA's identified by researchers that harbor winter migratory birds. Despite of many research activities in Jagdishpur wetland, assessment of invasive species is seen as a gap.

Nepal is a country rich in biodiversity due to its diverse topography and climate. Forest area covers 44.74% of the total area of the country (DFRS, 2015) that is composed of vegetation from tropical region to temperate region. Biodiversity Profile Project (BPP) identified 118 ecosystems in Nepal (BPP, 1995), and Stantion (1972) reported 35 forest types in Nepal. More than three percent of the world's known flora exist here i.e., 6,073 angiosperms; 26 gymnosperms; 534 pteridophytes; 1,150 bryophytes; 365 lichens; 1,822 fungi and 1,001 algae of which 284 flowering plants are endemic to Nepal (GoN, 2014).With increasing globalization of trade and human movement, the number of alien species has been increasing in all continents and climatic regions without any sign of saturation (Seebens *et al.*, 2017), including in high mountains and Polar Regions (Pauchard *et al.*, 2016). At least 13,168 species of plants have become naturalized elsewhere in the world outside their native distribution range (van Kleunen*et al.*, 2015). Similar data for animals and other taxonomic groups is, however, lacking. With worldwide increase in the number of naturalized species, the negative impacts of biological invasion have been considered equally significant in countries with under-developed to developed economy. Biological invasion in Nepal has also emerged as a challenging problem in biodiversity conservation, ecosystem services flow, and agriculture production (MoFSC, 2014). Physiographic and climatic diversity of Nepal is not only supporting wide spectrum of organisms and ecosystems but also providing potential suitable habitats for the species native to anywhere in the world. Furthermore, there is huge imbalance in Nepal's international trade with import to export ratio at about 11 (calculated for fiscal year 2015/2016 from the data available from Trade and Export Promotion Center – www.tepc.gov.np; retrieved on 3 June 2017). Food security and agriculture sector is also increasingly more dependent on imported agriculture products, seeds and seedlings/plantlets. Due to these scenarios, Nepal's agriculture sector has been ranked third among the most threatened countries out of the 124 countries assessed (Paini*et al.*, 2016). To address the emerging threat of invasive alien species. Nepal's National Biodiversity Strategy and Action Plan 2014-2020 has targeted a number of activities including impact assessments of selected invasive alien plant species (IAPS) and release of biological control agents against IAPS (MoFSC, 2014).

1.2 Justification

Jagdishpur wetland is one of the Important Bird Area that habors hundreds of bird species along with herpetofauna, fish species and vegetation. Many studies have prioritized the importance of the wetland as bird habitat but very few attempts have been made to understand the vegetational diversity and their status in the area. This study aims to find out the vegetational features, especially invasive secies that will help in better understanding of overall ecology of an area. Biodiversity loss due to biological invasion is the major global environmental (Bellard *et al.*, 2016, Downey and Rirchardson, 2016) and economic problem (Born *et al.*, 2005), is a direct outcome of human movement and trade across continents. Similar risk is posed at Jagdishpur wetland as the presence of IAPS, favorable condition for its growth and multiplication and the utility of the reservoir in irrigation of large agricultural lands. Thus, this study is valid to know the condition of invasive species and its effect in the area to retain the area as wetland, bird habitat and irrigation reservoir.

1.3 Objectives

General objective

- To assess the problems and potentials of invasive plant species in Jagdishpur Tal.

Specifically, following activities will be performed,

- To study the status and distribution of various invasive plants species in the study area
- To assess the impacts of invasive species on native plant species.

1.4 Limitations

- Sampling is more focused around the reservoir.
- Linear sampling regarding inlet canal and outlet canal is small.
- The data obtained is of short term.

CHAPTER 2: LITERATURE REVIEW

2.1 Invasive species

Invasive Alien Species (IAS) are the species which have the capacity to compete with native species outside their geographical origin (CBD, 1992). IAS is of great concern for conservationists and natural resource managers because of their rapid spreading nature, competitiveness and capability to colonize in new areas within short time period (Rejmánek and Richardson, 1996). These species primarily gain entry into new geographic areas through human activities, environmental disturbances, deforestation and forest degradation, and forest fire which promotes the establishment of the species (Early *et al.*, 2016; McNeely, 2001). IAS have negative consequences to native species and ecosystem services (MEA, 2005) by predation, competition and habitat modification (McGeoch*et al.*, 2010). Invasive species have become a threat for 42% of the native species to fall into endangerment in the United States (Pimentel *et al.*, 2005). Freshwater ecosystems are at high risk of invasion compared to the terrestrial ecosystems as the vulnerability of invasion varies with biotic resistance of ecosystems (Rejmánek and Richardson, 1996).

Half of the world's wetlands have been lost, and the remaining are degraded due to large-scale water diversion, introduction of invasive species, overharvesting, industrial pollution and climate change (Carpenter *et al.*, 2011). In Nepal, wetlands occupy approximately 5% of the total area of the country (DoFD, 2012). These wetlands are converting into unproductive land due to exotic plant species, expansion of cropland, siltation, overharvesting, land use change, and climate change. Out of the total 219 alien species of flowering plants (Siwakoti, 2012; Sukhorukov, 2014; Tiwari *et al.*, 2005), 26 plant species including 6 species in wetlands are invasive in Nepal (Shrestha, 2017).

Invasive species has been considered as an important component of global environmental changes (Vitousek *et al.*, 1997) and a leading cause of decline and/or loss of native biodiversity (Ricciardi *et al.*, 1998, Kohli *et al.*, 2004) and ecosystem services (Pejchar and Mooney, 2009). With steady increase in human movement and global trade, the intensity of biological invasion has been increasing in all ecosystems and landscapes. The negative impact of invasive species is further exacerbated by ongoing climate change because the later has been projected to increase both frequency and intensity of biological invasion (Simberloff, 2000). The problem of invasive species is prevalent both in developed as well as developing countries, but their impact is likely to be higher in developing countries like Nepal due to lack of expertise and limited resources available for their management.

There are at least 219 alien species of flowering plants (Tiwari *et al.*, 2005, Siwakoti, 2012 and Sukhorukov, 2014) and 64 species of animals (Budha, 2015) that are naturalized in Nepal. An assessment of invasive alien plant species (IAPS) was undertaken for the first time by IUCN Nepal during 2002-2003 and reported 21 naturalized (i.e. alien species with self sustaining population) flowering plant species to be invasive in Nepal (Tiwari *et al.*, 2005).

In an assessment undertaken by IUCN Nepal during 2002-2003, 21 naturalized plant species have been reported as invasive in Nepal (Tiwari *et al.*, 2005). In addition to them, four naturalized species Ageratum conyzoides, Erigeron karvinskianus, Galinsoga quadriradiata and Spermacoce alata Aubl (Syn. Borreria alata) have been also found to be invasive in agro-ecosystems and rangelands (BB Shrestha, personal observation). A. haustonianum is spreading rapidly in Terai, Siwalik and Mid Hills from east to west while E. karvinskianus is problematic mainly in Mid Hills and Low Mountains of western Nepal (e.g., Darchula district). G. quadriradiata is a serious weed of agro-ecosystem in Mid Hills and Low Mountains from east to west. S. alata is commonly invading agro-ecosystems and rangelands of Siwalik and Mid Hills, and, according to the local community of Begnas lake area of Kaski district, it has significantly reduced forage production. Therefore, the total number of IAPS in Nepal becomes 27 which belong to 13 families. Asteraceae is the largest family with 10 species, followed by Amaranthaceae (2 species) and Caesalpiniaceae (2 species); remaining 11 families are represented by single species.

Among 27 IAPS, four species (Chromolaena odorata, Eichhornia crassipes, Lantana camara and Mikania micrantha) are included in world's 100 worst invasive species (Lowe *et al.*, 2000). In addition, six plant species found in Nepal are also included in the list. However, five of them (Arundo donax L., Hedychium gardnerianum Sheppard ex. Ker Gawl., Hiptage benghalensis (L.) Kurz., Imperata cylindrica (L) P. Beauv. and Rubus ellipticus Sm.) are native to Nepal. The remaining one

Leucaena leucocephala (Lam.) de Wit., a medium sized tree, was introduced as fodder plant in Nepal and now it is naturalized within agro-ecosystem. Invasive status of this species in natural habitat has not been reported yet.

After introduction, the dispersal and establishment of IAPS at local scale depend on resources availability and human activities. Frequent availability of unused resources increases vulnerability of a habitat to invasion (Davis *et al.*, 2000) while human activities increase propagule pressure of invasive species (Simberloff, 2009). Therefore, most of the IAPS in Nepal are concentrated in anthropogenic landscape such as agro-ecosystem, residential area and rangeland (e.g., shrub land, degraded forests) while they are less common in intact forests. For example, Parthenium hysterophorus was present in 80% of the sampling locations in fallow and grazing land while it was present only in 24% of the sampling locations in forests (Shrestha BB, unpublished data). Out of 27 IAPS found in Nepal, 4 species are found in wetland and Eichhornia crassipes is the most problematic among them. Species like *Ageratum conyzoides*, A. *houstonianum*, *Erigeron karvinskianus* and *Oxalis latifolia* are problematic in agro-ecosystems. In forest and shrublands, the major problematic species include *Ageratina adenophora*, *Chromolaena odorata*, *Lantana camara* and *Mikania micrantha* while the species like *Parthenium hysterophorus* is threatening grass/grazing lands.

Climate change and invasive species present two of the greatest threats to biodiversity and the provision of valuable ecosystem services (Burgiel and Muir, 2010). Climate change contributes to erratic rainfall, drying up of local springs and streams, adjustment of species distribution, phenology and morphology, shift in agriculture calendar, emergence of invasive species and outbreak of diseases and pests, etc (IPCC, 2007). Precisely, climate change impacts, such as warming temperatures and changes in CO2 concentrations, are likely to increase opportunities for introduction of invasive species because of their adaptability to disturbance and to a broader range of biogeographic conditions and environmental controls (Mooney and Hobbs, 2009). Warmer temperature may also facilitate the movement of invasive species along previously inaccessible pathways of spread in both natural and human-made environments (Engel *et al.*, 2011), because invasive species have a broader range of tolerance (Walther *et al.*, 2009)

It is estimated that biological invasions can have strong effects on structure and function of ecosystems that are responding to a changing climate and climate change is also changing the context in which potential invasive species succeed or fail (Husain and Agnihotri, 2009). However, relationship of biological invasion of alien plant species and climate change and their management are hitherto unknown in Nepal, despite Article 8(h) of CBD urged parties to prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats and species (CBD, 1992).

IUCN (2000) defines IAS as an alien species, which becomes established in natural or seminatural ecosystems or habitat, an agent of change, and threatens native biological diversity. IAS occurs in all major taxonomic groups. Within each taxon, numerous species including perhaps as many as 10 per cent have potential to invade other ecosystems (Rejmanek*et al.*, 2000). IAS can transform the structure and species composition of ecosystems (Ricchardi*et al.*, 2000) by establishing viable populations with growth rates enough to displace elements of native biota (Rejmanek, 1999) or to modify disturbance regimes (Brooks *et al.*, 2004), thereby potentially changing ecosystem structure and functioning (Dukes and Mooney, 2004), or by outcompeting native denizens for resources by changing the way nutrients are cycled through the system.

IAS endangers the environment, economy and human welfare (Lodge *et al.*, 2006). It also reduces biodiversity, replaces important native species and increases investment in agriculture and silviculture (Ricchardi *et al.*, 2000), disrupting prevailing vegetation dynamics and nutrient cycling (Richardson, 1998). The estimated damage from invasive species worldwide totals more than US $1.4 trillion a year (5 percent of the global economy) with impacts across a wide range of sectors, including agriculture, forestry, aquaculture, transportation, trade, power generation and recreation (Stern, 2006)

A list of invasive alien plant species is available for most regions, though the list is to be updated and reviewed routinely. Nepal is not exempt and there are handful studies of invasive species. Though the first study of invasive alien species of Nepal was carried out for over five decades (Banerji, 1958), impacts and management studies of IAS at species, ecosystem and socioeconomic levels through eco-friendly approaches were parsimoniously carried out. Poudel and Thapa (2012) reviewed 43 studies so far conducted in Nepal related to invasive plant species, and they recommended for more researches on documentations and impacts of invasive alien plant species. A total of 166 invasive alien plants species of Nepal were noted by IUCN (Tiwari *et al.*, 2005). However, in a milieu of changing climate, introduction and aggressiveness of invasive alien species is being increased, urging more researches and updates on IAS.

The world's 100 worst invasive aliens (Lowe *et al.*, 2000) include 11 plant species (*Arundo donax, Chromolaena odorata, Eichhornia crissepes, Hedychium gardnerianum, Hiptage benghalensis, Imperata cylindrica, Lantana camara, Leucaena leucocephala, Mikania micrantha, Opuntia stricta and Rubus ellipticus*) that are found in Nepal. However, they are not equally invasive. Seven toppers alien invasive in the list for Asia Pacific region include: *Ageratina adenophora, Ageratum conyzoides, Chromolaena odorata, Eichhornia crissepes, Lantana camara, Mikania micrantha and Parthenium hysterophorus* (Sankaran *et al.*, 2005). All these seven species are problematic in Nepal.

The impacts of those invasive plant species may be more severe as they increase both in numbers and extent, and as they compete for diminishing resources such as water and soil minerals. Invasive alien plant species can threaten those basic needs and compromise ecosystem functions by taking advantage of habitat disturbance, species under stress and other chinks in the armor of otherwise healthy systems. This affects the multiple roles of ecosystems in providing provisioning, regulating, supporting and cultural services (MEA, 2005 and Vila *et al.*, 2009). Therefore, global efforts are being made to control these invaders. Whatever the cost may be, the unintended spread of invasive species continues unabated, despite the earnest efforts are being made to manage them (Sankaran *et al.*, 2005).

2.2 Wetland

Wetlands, according to Wetlands Policy (NWP, 2012) of Nepal defines as "perennial water bodies that originate from underground sources of water or rainfall. It means swampy areas with flowing or stagnant fresh or salt water that is natural or man-made, or permanent or temporary. Wetlands also mean marshy lands, riverine floodplains, lakes, ponds, water storage areas and agricultural lands"

Wetland dependent species covers about 25 percent of the total vascular plant species (Bhandari, 1992). IUCN (2004) have reported 318 wetland dependent plant species in Terai's wetlands. Similarly, the eastern plain region of Nepal is reported to have 141 wetland-dependent plant species (Siwakoti and Varma, 1998).

Marcin and Jagodzinski (2020) have found that the invasive species have negative impact on the natural regeneration of the species in the invaded region. Gaudel *et al.*, (2016) have also recommended that the invasive species effects on the regeneration of the existing species due to carpeting nature of such species like *Mikania micrantha, Ageratina adenophora, Chromolaena odorata* etc. Also, IS invaded region face severe biodiversity loss. According to Tiwari *et al.*, (2005), *Ipomoea carnea ssp. fistulosa, Ipomoea aquatica, Paspalum distichum, Eichhornia crassipes,* etc. have dominated the Jagdishpur Reservior (a Ramsar site). According to Baral and Thapa (2008), the Jagdishpur Wetland is being polluted due to the invasive alien species like *Mikania micrantha* and use of excessive agricultural fertilizers, insecticides, and pesticides.

As Jagdishpur Ramsar site is a man made reservoir which is important for the migratory birds and also provides irrigation facilities to the agricultural lands. Besides, this the reservoir is also attracting tourists from Nepal and abroad broadens its importance from ecotourism point of view. Biodiversity around it need to be protected for maining the ecosystem services that it has provided. But in recent years the invasive species around it is increasing and creating a threat to the biodiversity. Hence the present work will help understand the impact of invasive species at different land use around the Jagdishpur reservoir.

CHAPTER 3: MATERIALS AND METHOD

3.1 Study area

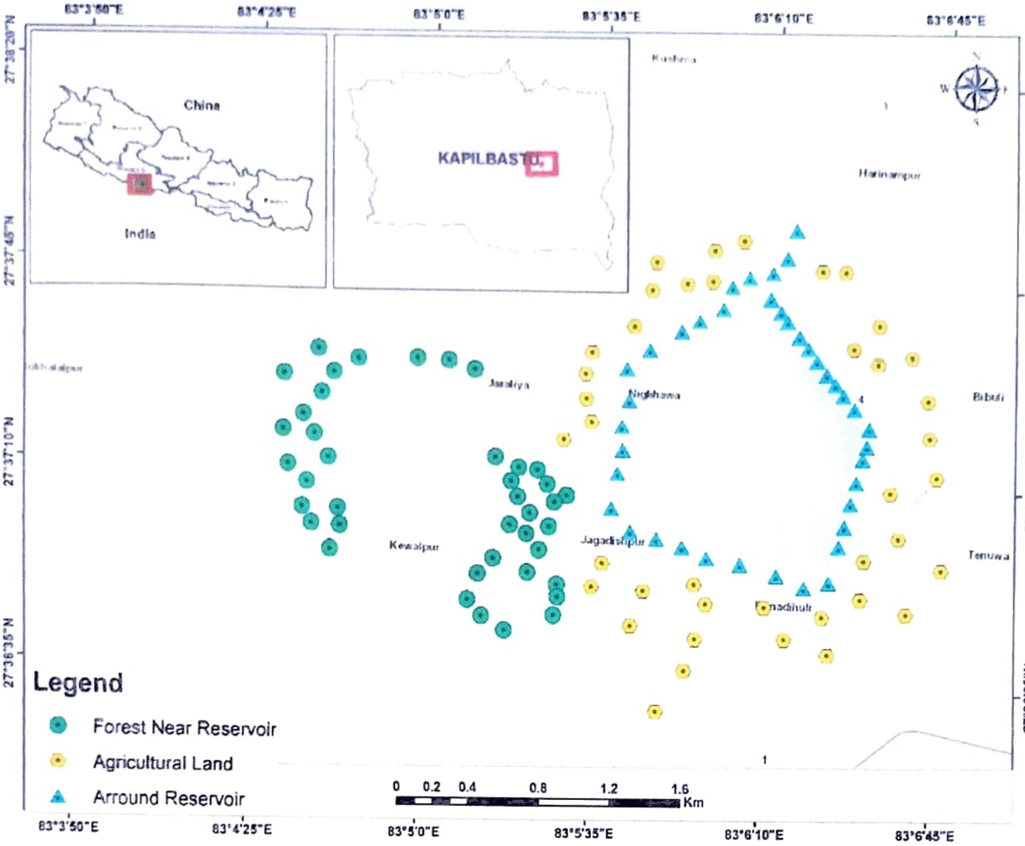


Figure 1: Map of study area

Jagadispur reservoir is located in Jagadi village development committee, in Kapilvastu District of Western Nepal. With a surface area of 225 ha, it is the largest reservoir in the country and important wetland sites and it is situated at an altitude of 197 m. The maximum water depth varies between 2m in the dry season n 7m in monsoon season. It was declared as Ramsar sites on 13 August 2003, and is also highlighted in the directory of Asian wetland (NBRB, 2007). Jagdishpur Tal is included in Ramsar site due to its fundamental ecological functions and their economic, cultural, scientific and recreational value.

Sal Forest (*Shorea robusta*) and *Acacia catechu - Dalbergia sissoo* forest as major forest types associated with *Terminallia tomentosa, Terminallia beleria, Anogeisus latifolia,* and *Penta gyna* while other riverine forest includes small strips of forest. The site provides shelter for an assembly of rare and endangered species (K.C *et al.*, 2012) including plants such as the endangered Serpentina (*Rauvolfia serpentina*), rare

Pond weed (*Potamogeton lucens*), threatened Lotus (*Nelumbo nucifera*). Biological aspects of the Reservoir cover species and habitat, including ecosystem conservation and management (NBRB, 2007).

The Reservoir's aquatic vegetation is represented by extensive coverage of floating leaf species, mainly lotus (*Nelumbo nucifera*), followed by wild rice (*Hygrorhyza aristata*), and pond weed (*Potamogeton nodosus*), free floating species include water velvet (*Azolla imbricata*) and Duckweed (*Lemna*spp) (NBRB, 2007).

3.1.1 Climatic characeristics:

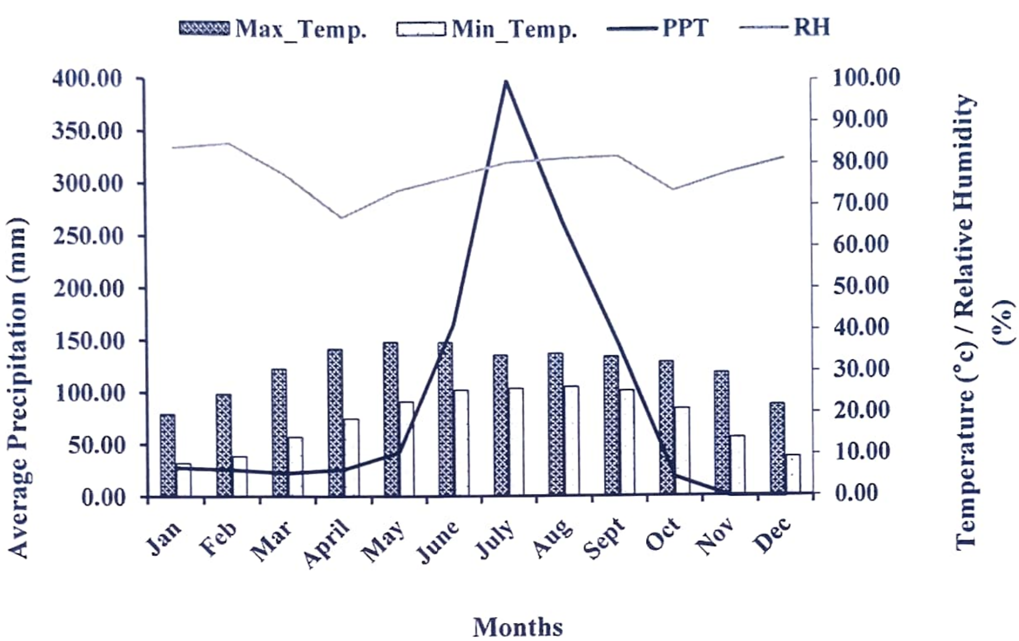


Figure 2: Ten year (2011-2020) average of minimum and maximum temperature, precipitation and relative humidity recorded at nearby station of Kapilvastu. (Source: DHM, 2020).

The yearly average maximum temperature ranges from 29.325 degree centigrade to 32.07 degree centigrade while the yearly average minimum temperature in Kapilvastu ranges from 18.091 degree centigrade to 19.15 degree centigrade.

The maximum rainfall in the study area was observed in 2013 AD and the minimum rainfall in the area was observed in 2013 AD in last ten years. The total average rainfall of last ten years in 122.558 mm.

3.2 Methods

3.2.1 Sampling

Quadrat sampling method was followed for field data collection. 2m*2m plots were laid on the sampling points and the herbs, shrubs and seedlings of trees were counted and noted along with coverage of each species (Baxter, 2014).

Three land-use type*viz.* Grassland, Agricultural land, and Forest land were the sampling sites with 40 plots in each category of land-use. Number of individuals and coverage percentage were recorded.

3.2.2 Identification of the species:

Following steps were followed for species identification:

1. The morphology of the species was taken as a main feature for identification of the species.
2. Local people familiar with the local vegetation were asked showing plants, herbarium and photo plates of the respective species.
3. Field biologist and officials at Godavari Botanical Garden were consulted for further identification of the species.
4. Importnt Value Index of each species in Agricultural land, Forest land and Grassland around reservoir was calculated.

3.2.3 Measuring impact of the IAPS in native plants species:

1. First of all, the plots with invasive species coverage more than 30 percent and less than 30 percent were identified.
2. Then the plots were divided into two categories.
3. Later, Shanon-Weiner Index and Simpson's Index were computed for differences in the biodiversity index in each land use.
4. Then, the biodiversity indices of plots with invasive species coverage more than 30 percent and less than 30 percent were compared in each landuse.

3.2.4 Statistical analysis of the data

Diversity Indices

Simpson's index was calculated using followingformula Simpson's Index of diversity (Simpson 1949 as described by Krebs 1989) was appliedfor measuring floral diversity.

$1 - D = 1 - \sum (pi)^2$

where,

D = Simpson Index of diversity

Pi = Proportion of individual species in the community i.

Simpson's Index (D)

Simpson index measures the probability that two individuals randomly selected from a sample into the same species (or some category other than species).

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

Where, n = the total number of organisms of a particular species

N = the total number of organisms of all species

The value of D ranges between 0 and 1. With this index, 0 represents infinite diversity and 1, nodiversity. That is, the bigger the value of D, the lower the diversity. This is neither intuitive norlogical, so to get over this problem, D is often subtracted from 1 to give the species diversity.

Simpson's Index of Diversity (1 – D)

The value of this index also ranges between 0 and 1, the greater the value, the greater the samplediversity. This makes more sense. In this case, the index represents the probability that twoindividuals randomly selected from a sample long to different species.

Shannon-Weiner index

Shannon-Weiner (S-W) provides a means of comparing the diversity between two or morenecosystems which go beyond the most basic species-per-unit-area metric. While this simplermetric is useful, in some cases it is desirable to evaluate the equitability of the distribution of thespecies.

H'= index of species diversity

S= species richness (total # of species present)

Pi = proportion of total sample belonging to the ith species

ln= natural log (base e = not the same of log!)

3.3 Important value Index (IVI)

The important value index (IVI) of each species was calculated by summing the percentage ofrelative dominance, relative density and relative frequency, each weighted equally for a speciesrelative to a stand as a whole.

IVI= RD+RF+ RC

where,

RD= Relative density

RF= Relative frequency

RC = Relative coverage

i) Density and Relative density:

Density refers to the number of individuals per unit area. Density is usually used for largeplants that have discrete individuals (Zobel et al. 1987).

Relative density:

Total number of individuals of a species / (Total number of quadrates sampled × size of a quadrate)

ii) Frequency and Relative frequency:

Frequency of a species is the percentage of quadrates in which the particular species occurs. Itgives an index on the spatial distribution of a species and is a measure of relative abundance.

Relative frequency:

(Individual frequency of a species* 100) / Total frequency

iii) Coverage and Relative coverage:

The extent of ground covered by vegetation or plant species is known as coverage. Relative coverage is the ratio of individual coverage of a species to the total coverage expressed in percentage..

$$\text{Relative coverage} = \frac{(\text{Coverage of individual plant species* } 100)}{\text{Total coverage of all species}}$$

CHAPTER 4. RESULTS

4.1 Plant diversity

Altogether 129 species under 46 families of plants were recorded during the study. The detailed description of vegetation is given in Appendix 1. The species like *Cynodon dactylon, Parthenium hysterophorous, Sida cordifolia, Imperata cylindrica,* etc. were very common in the study area and scored highest IVI value. The plant species with highest IVI value around the reservoir is given in Figure 3. The number of herbs and shrubs species recorded are quite higher in comparison to trees species. Cosmopolitan distribution of grass species might be the reason for higher IVI value of herbs (mainly grass) species. *Senna tora, Parthenium hysterophorous,* and *Chromolaena odorata* are some of the common invasive species found in the study area.

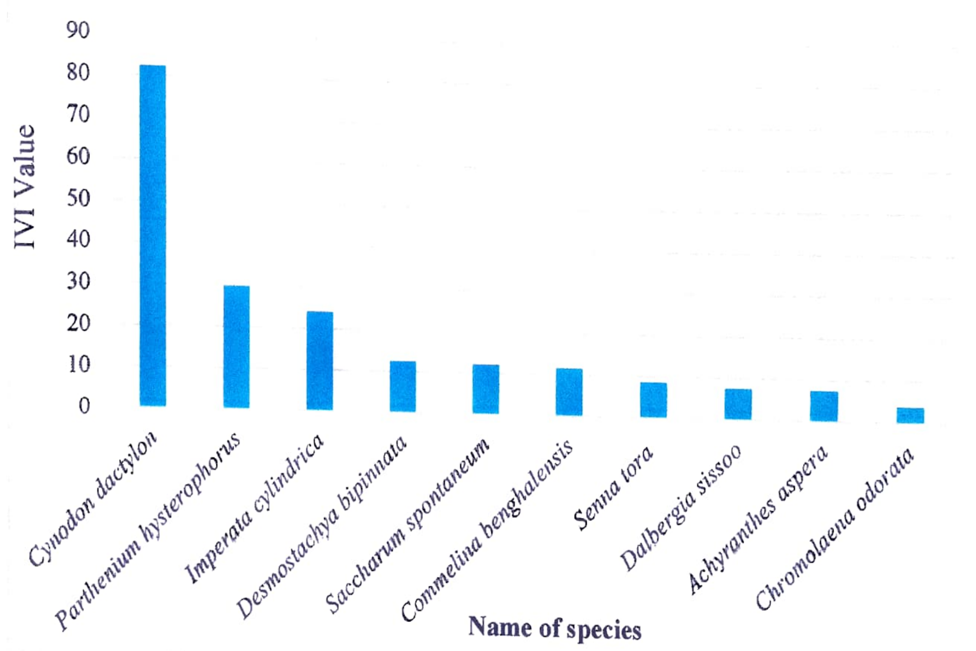


Figure 3: IVI of dominant 10 species in the study area.

4.2 Plant diversity in grassland around reservoir:

Grassland vegetation around reservoir includes *Parthenium hysterophorous, Cynodon dactylon, Tridax procumbens, Sachharum spontaneum, Mimosa pudica,* etc. List of some of the common species available at east, west, north and south directions are given in table 1 and the IVI of all species are given in Annex 2.

Table 1: Plant species around Jagdishpur reservoir in four directions and their IVI

Species name	Family	IVI (E)	IVI (W)	IVI (N)	IVI (S)
Dalbergia sissoo (seedling)	Fabaceae	9.56	3.33	9.70	5.31
Saccharum spontaneum	Poaceae	6.89	22.53	10.99	2.70
Aegle marmelos (seedling)	Rutaceae		1.27	2.03	
Croton bonplandianum	Euphorbiaceae	6.31	5.94	5.48	8.38
Achyranthes aspera	Amaranthaceae	9.62	8.95	19.21	6.33
Sida cordifolia	Malvaceae	8.06	5.21	5.10	11.55
Cyperus iria	Cyperaceae	2.14	6.06	2.93	1.68
Sida acuta	Malvaceae	2.53	1.62	1.99	4.77
Kyllinga brevifolia	Cyperaceae	3.24	1.39	1.72	5.23

Invasive species like *Senna tora, Parthenium hysterophorus, Ipomea carnea, Amaranthus spinosus, Mimosa pudica, Chromolaena odorata, Alyernanhera philoxeroides, Ageratum conyzoides, Xanthium strumarium, Oxalis latifolia, Eichornia crassipes, Mikania micarantha,* and *leersia hexandra* etc were also recorded in each direction around the reservoir. The IVI value of invasive plants are summarized in Table 2

Table 2: Invasive species and around reservoir and their IVI

Species name	Family	IVI(E)	IVI(W)	IVI(N)	IVI(S)
Senna tora	Fabaceae	1.74	1.50	5.28	1.27
Parthenium hysterophorus	Asteraceae	84.52	109.81	69.69	83.54
Ipomoea carnea	Convolvulaceae	3.56	5.41	4.72	1.68
Amaranthus spinosus	Amaranthaceae		5.50	3.10	1.68
Mimosa pudica	Fabaceae	7.25	6.01	3.69	
Chromolaena odorata	Asteraceae	6.72		10.91	
Alternanthera philoxeroides	Amaranthaceae	3.56	1.66	4.24	4.14
Ageratum conyzoides	Asteraceae	3.34	1.71	3.70	3.88
Xanthium strumarium	Asteraceae	3.52	1.45	8.58	2.93
Oxalis latifolia	Oxalidaceae	5.63	3.46	1.71	3.98
Eichhornia crassipes	Pontederiaceae	2.43			
Mikania micrantha	Asteraceae	1.23	2.06	0.62	
Leersiahexandra	Poaceae		1.48		1.48

4.3 Plant diversity in agricultural land near reservoir:

Major agricultural land around the reservoir are paddy fields. Plants like *Cynodon dactylon, Sida cardifolia, Parthenium hysterophorous, Achyranthes spinosus,* etc.were common species recorded around the agricultural land near reservoir. IVI of different plant species around the agricultural fields recorded in the study is shown in Annex 3 and some of the common plants are given in Table 3.

Table 3: Plant species in agricultural land in four direction and their IVI

Species name	Family	IVI (E)	IVI (W)	IVI (N)
Dalbergia sissoo	Fabaceae			4.74
Saccharum spontaneum	Poaceae	7.03	6.71	5.63
Croton bonplandianum	Euphorbiaceae			1.50
Achyranthes aspera	Amaranthaceae	11.61	1.92	8.44
Sida cordifolia	Malvaceae	1.73	3.84	1.51
Cyperus iria	Cyperaceae		3.01	
Cynodon dactylon	Poaceae	98.11	117.23	146.43
Bothriochloa ischaemum	Poaceae	1.89	2.19	
Commelina benghalensis	Commelinaceae	10.09		7.43

Senna tora, Parthenium hysterophorus, Ipomoea carnea, Amaranthus spinosus, Mimosa pudica, Chromolaena odorata, Ageratum conyzoides, Xanthium strumarium, Eichhornia crassipes, Mikania micrantha, Ageratina adenophora, Ageratum haustonium, Galinsoga quadriradiata, Spermacoce alata, Senna occidentalis, and *Erigeron karvinskianus* are the invasive species recorded around the agricultural land of the study area. The IVI value of invasive species around the agricultural land is given in Table 4

Table 4: Invasive species in agricultural land near reservoir and their IVI

Species name	Family	IVI (E)	IVI (W)	IVI (N)	IVI (S)
Senna tora	Fabaceae	24.49	12.21	4.77	15.49
Parthenium hysterophorus	Asteraceae	22.67	9.84	19.86	9.20
Ipomoea carnea	Convolvulaceae	3.67		1.75	1.84
Amaranthus spinosus	Amaranthaceae		3.84	1.50	0.92
Mimosa pudica	Fabaceae	1.97	5.39	4.84	

Chromolaena odorata	Asteraceae	9.80	2.23	3.81	4.24
Ageratum conyzoides	Asteraceae	7.15		1.76	6.19
Xanthium strumarium	Asteraceae		1.92	4.96	5.78
Eichhornia crassipes	Pontederiaceae			1.50	
Mikania micrantha	Asteraceae				5.16
Ageratina adenophora	Asteraceae			4.35	8.68
Ageratum haustonium	Asteraceae	3.93	2.17		15.32
Galinsoga quadriradiata	Asteraceae				1.09
Bidens pilosa	Asteraceae				0.93
Spermacoce alata	Rubiaceae	5.48	9.13		4.68
Senna occidentalis	Fabaceae	3.09			2.41
Erigeron karvinskianus	Asteraceae	2.25	4.40		3.30

4.4 Plant diversity in forest edge near the reservoir:

Cynodon dactylon, Desmostachya bipinnata, Commelina benghalensis, Saccharum spontaneum, Imperata cylindrica, Parthenium hysterophorus, etc. are common species recorded during study in the forest near the reservoir. IVI of different species recorded in the forest near reservoir are shown in Annex 4 and some of the common species is given in Table 5

Table 5: Plant species and their IVI in the forest near the reservoir

Species name	**Family**	**IVI**
Dalbergia sissoo	Fabaceae	13.28
Saccharum spontaneum	Poaceae	20.31
Aegle marmelos	Poaceae	0.33
Croton bonplandianum	Euphorbiaceae	3.06
Achyranthes aspera	Amaranthaceae	3.59
Sida cordifolia	Malvaceae	0.67
Cyperus iria	Cyperaceae	1.69
Sida acuta	Malvaceae	1.13
Kyllinga brevifolia	Cyperaceae	0.52
Cynodon dactylon	Poaceae	70.21

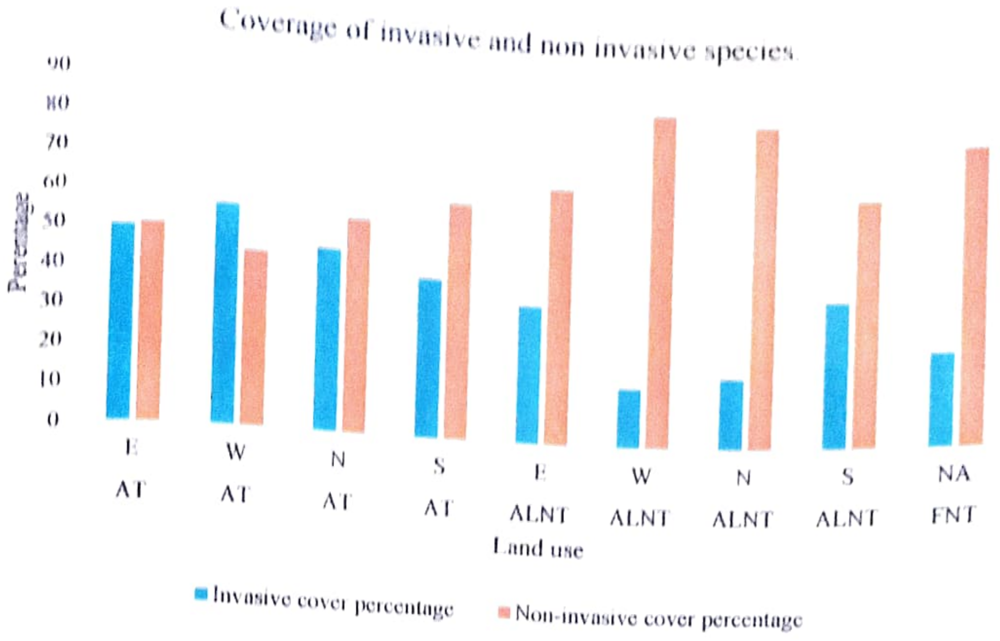
Invasive plant species recorded at the forest edge near reservoir are *Senna tora, Parthenium hysterophorus, Ipomoea carnea, Amaranthus spinosus, Mimosa pudica, Chromolaena odorata, Ageratum conyzoides, Xanthium strumarium, Oxalis latifolia, Mikania micrantha, Ageratum haustonium, Bidens pilosa, Spermacoce alata,* and *Senna occidentalis*. The IVI value of invasive plants found at the forest edge are summarized in Table 6.

Table 6: Invasive plant species recorded in forest near reservoir and their IVI

Species name	Family	IVI
Senna tora	Fabaceae	11.27
Parthenium hysterophorus	Asteraceae	15.32
Ipomoea carnea	Convolvulaceae	1.60
Amaranthus spinosus	Amaranthaceae	2.03
Mimosa pudica	Fabaceae	2.71
Chromolaena odorata	Asteraceae	2.47
Ageratum conyzoides	Asteraceae	0.40
Xanthium strumarium	Asteraceae	1.91
Oxalis latifolia	Oxalidaceae	5.98
Mikania micrantha	Asteraceae	2.11
Ageratum haustonium	Asteraceae	1.14
Bidens pilosa	Asteraceae	0.45
Spermacocealata	Rubiaceae	1.72
Senna occidentalis	Fabaceae	1.42

4. 5 Impact of invasive alien plant species in existing plant diversity

To understand the impact of invasive species on existing native plants, the plots were categorized as uninvaded (i.e. coverage of invasive species less than 30 %) and invaded plots(i.e. the coverage of invasive species more than 30 %).



AT= Around Jagdishpur Reservoir (Taal); ALNT = Agricultural Land Near Reservoir (Taal); FNT = Forest Near Reservoir (Taal)

Figure 4: Coverage of invasive species and non-invasive species in the study area

The figure shows the coverage of invasive and non-invasive species at different sites of the reservoir. Non-invasive plant species have dominated the coverage of the study area at most sites but at grassland around the reservoir in the east has more or less same coverage and in the west the coverage of invasive is higher than non-invasive plants (fig 4.) Invasive species is recorded.

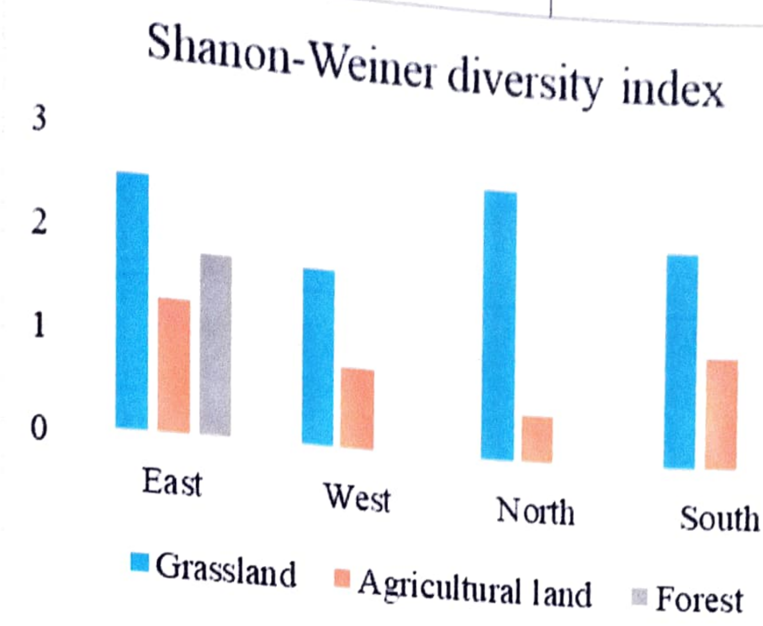
in all the three observational sites of the study area.Also, the differences in the coverage of invasive species at different sites is seen.The coverage of invasive species is more seen in western and southern part of the reservoir in agricultural land. In the forest, coverage of invasive species was more in the peripheral region than in the larger canopy region.

4.6 Comparison of biodiversity indices:

The values of biodiversity index in each land use and their respective directions is tabulated in table 7.

Table 7: Biodiversity indices in different land use

Biodiversity index	Land use	East	West	North	South
Shanon-Weiner Index	Grassland	2.51	1.75	2.71	2.17
Simpson's index	Grassland	0.8	0.65	0.85	0.76
Shanon-Weiner index	Agricultural land	1.33	0.82	0.5	1.13
Simpson's index	Agricultural land	0.59	0.5	0.17	0.51
Shanon-Weiner index	Forest	1.79			
Simpson's index	Forest	0.75			



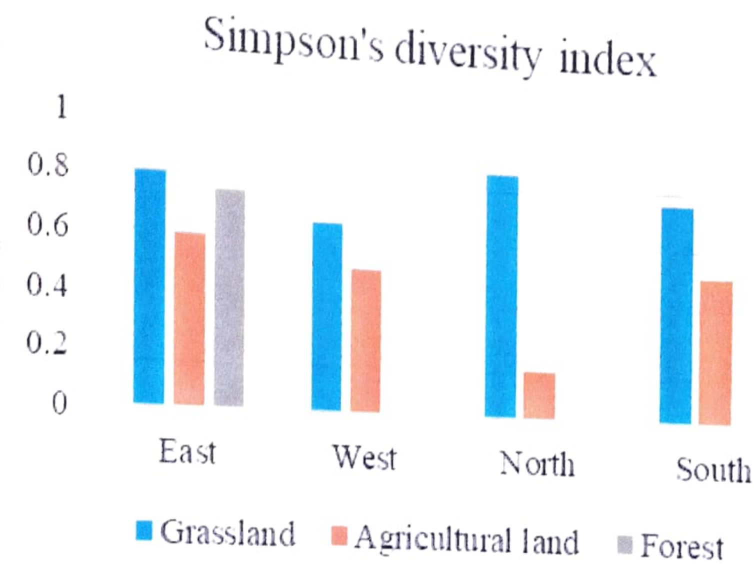


Figure 5: Shanon-Weiner diversity index and Simpson's diversity index at different land use

The biodiversity of grassland around reservoir is highest as compared to other land use followed by forest land and agricultural land is found to be less diverse.In grassland near reservoir, the west region is comparably more covered by invasive plant species followed by east, north, and south as shown in Figure 5. Later, it is discovered that the west region has the lowest biodiversity index (1.75/0.65), east (2.51/0.8), and north (2.71/0.85).In agricultural land, the plant biodiversity is seen high in the region with more coverage of invasive species.The calculated value of Shanon's index is and Simpson's index in the forest near reservoir is 1.79 and 0.75 respectively. It indicates quite fair score of biodiversity in the forest.

4.7 Impact of invasive species in biodiversity:

Table 8: Biodiversity indices in the of the plots with more than 30% coverage and less than 30% coverage of invasive species

Land use	Shanon's index		Simpson's index	
	less than 30% invasive cover	more than 30% invasive cover	less than 30% invasive cover	more than 30% invasive cover
Grassland	2.76	2.30	0.85	0.75
Agricultural land	0.93	0.87	0.45	0.35
Forest	1.76	1.58	0.74	0.74

Table 4.8 shows the value of biodiversity indices calculated according to our methodology. Generally, biodiversity of the sites with less than 30% invasive species coverage is higher than the sites with more than 30% invasive species coverage as seen in the table. Shanon's index in grassland near reservoir is 2.76 in the area with invasive species coverage less than 30%. Agricultural land with more than 30% invasive species coverage has lowest Shanon's index (0.87) and lowest Simpson's index (0.35) as well.

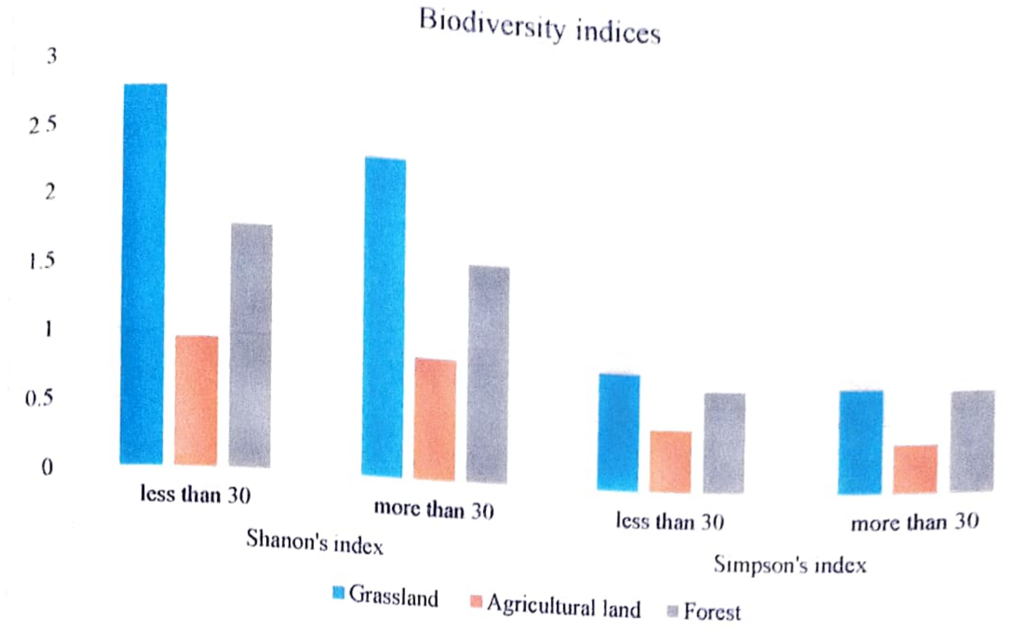


Figure 6: Shanon's index and Simpson's index of the plots with more than 30% coverage and less than 30% coverage of invasive species

Figure: 6 clearly shows less biodiversity in the area with more than 30% invasive species coverage and more biodiversity in the area with invasive species coverage is more than 30%.

CHAPTER 5: DISCUSSION

5.1 Plant Diversity

129 species of plants under 46 families were recorded in the study area. 75 species (28 families) were recorded from grassland, 62 from agricultural land (27 families) and 88 species (35 families) were recorded from the forest that is higher than the vegetation diversity recorded by (Dhakal et al., 2015) in Jagdishpur. 20 out of 26 (Shrestha, 2016) invasive species; 13 from grassland, 17 from agricultural land, and 14 from forest are present in Jagdishpur. The checklist of IAPs shows the risk of rapid invasion and cause loss of biodiversity.

Comparatively, highest vegetation diversity was seen in the grassland followed by forest and agricultural land was least diverse in terms of biodiversity. Lower biodiversity in the agricultural land is seen due to agriculture management intervention (Kettenring & Adams, 2011).*Ageratina adenophora*,*Ageratum conyzoides*, *Amaranthus spinosus*, *Chromolaena odorata*, *Eichhornia crassipes*, *Ipomoea carnea*, *Mikania micrantha*, *Mimosa pudica*, *Parthenium hysterophorus*, *Senna tora*, *Xanthium strumarium*, etc. are common invasive species found in the region.

Ageratina adenophora grows well in pasturelands, warm areas, overgrazed areas and poorly managed areas (Auld & Martin, 1975; CABI, 2022) and hence it also poses risk to native biodiversity in Jagdishpur. Open space is dominant in Jagdishpur reservoir and agriculture is practiced in most of the area with human settlement. Human mobility promotes multiplication and growth of *Ageratina adenophora* (Malla *et al.*, 2021). Similarly, another invasive species *Senna tora* was found to be distributed in cropped land, pastures, roadsides, woodland, waste land and natural grasslands and this could be due to their ability to survive in different types of soil (CABI, 2022).*Parthenium hysterophorus* is another most common invasive species in all three land use types (grassland, agricultural land and forest) around Jagdishpur reservoir. It is more frequent and dominant all over the land use around the reservoir. The reproductive capacity of *Parthenium hysterophorous* is better in warm and moist soil condition (Nguyen *et al.*, 2008) and causes adverse biodiversity loss in the area of its occurrence (Nigatu *et al.*, 2010) that ultimately risks the future of the agricultural land and forest land around the reservoir. *Ipomea* *carnea* is an amphibious invasive plant species (Shaltout*et al.*, 2010), reproducing both sexually and asexually throughout the year, cannot be effectively controlled by physical and chemical means (Shaltout*et al.*, 2010) and also has allelopathic effect over other vegetation. Loss of biodiversity, allelopathic effect, siltation of lake or reservoir etc. are the major effects of *Ipomea carnea* (Kumar *et al.*, 2018).

Xanthium strumarium was dominant in agricultural land. Degradation of soil and loss of soil productivity and biodiversity with *Xanthium strumarium* has been reported by Iqbal et al., (2021). Iqbal *et al.*, (2021) explored that *Xanthium strumarium* is one of the palatable invasive species found in grassland and agriculture ecosystem. Herbivores graze on them and the height of *Xanthium strumarium* is maintained but at the same time the thorny fruits are dispersed through the help of animals feeding on it.Besides this, the ability of *Xanthium strumarium* to phenological and morphological changes makes it able to invade larger areas (Ullah *et al.*, 2022).

Mikania micrantha was recorded in all the land use areas around the reservoir. It is one of the fastest multiplying species as it reproduces both sexually and asexually (Swamy & Ramakrishnan, 1987). Vigorous multiplication and growing capacity of *Mikania micrantha* has depleted habitat of *Rhinoceros unicornis* in Chitwan National Park (Ram, 2008), and in the present study sites it has raised the concern to protect the habitat of many migratory, resident and passerine birds in Jagdishpur (Thapa & Saund, 2013). However, disturbance in agricultural land and grassland might oppose its invasion (Weidlich *et al.*, 2020) but the risk in the forest land remains same.

5.2 Impact of invasive species in plant biodiversity:

This study has found out that the presence of invasive species in an area causes loss of biodiversity. Areas with invasive species coverage more than 30% have lower Shanonweiner index and Simpson's biodiversity index indicating the reduced plant diversity.Invasion by the exotic and invasive species leads to ecological disturbance (Weidlich *et al.*, 2020) and biodiversity loss. Gaudel*et al.* (2016) have also recommended that the invasive species effects on the regeneration of the existing species due to carpeting nature of such species like *Mikania micrantha, Ageratina adenophora, Chromolaena odorata* etc. According to Tiwari *et al.*, (2005), *Ipomoea carnea ssp. fistulosa, Ipomoea aquatica, Paspalum distichum, Eichhornia crassipes*, etc. have dominated the JagdishpurReservior, a Ramsar site. Marcin and Jagodzinski

(2020) have found that the invasive species have negative impact on the natural regeneration of the species in the invaded region. Invasive species has been considered as an important component of global environmental changes (Vitousek*et al*., 1997) and a leading cause of decline and/or loss of native biodiversity (Ricciardi *et al*., 1998, Kohli *et al*., 2004) and ecosystem services (Pejchar and Mooney, 2009).

Invasive species richness is more in agricultural land than other land use, however overall plant diversity is less in comparison to grassland and forest. More species richness in agricultural land is due to disturbance factor due to farming activities such as tillage, use of manure, fertilizers and pesticides (Kettenring and Adams, 2011). *Ipomea carnea* inside the reservoir has caused siltation and loss of aquatic floral diversity. 42% of native species of USA are in danger to fall into risk due to invasive species (Pimentel *et al*., 2005). The vulnerability of invasion by invasive species also depends on the biotic resistance of ecosystems which states that freshwater ecosystems are more vulnerable to invasion (Rejmánek and Richardson, 1996). The sole purpose of the Jagdishpur reservoir is irrigation. This irrigation facilities from the reservoir helps in promoting the dispersal of invasive species faster in agricultural land and finally it leads to degradation of agricultural land and reduction of crop production as well. With increase of coverage of IAPS, there was increase of species richness of IAPS. More coverage of IAPS results secretion of high amounts of allelopathic and phytotoxic chemicals. Such chemicals can affect the species richness of other vegetation in one hand while on the other hand it would be favorable for species richness and infestation of IAPs (Kettenring & Adams, 2011). High abundance of IAPS modifies the micro-habitat in such a way that it becomes hostile for seed germination and seedling growth due to which might result less density of saplings with increasing of coverage of IAPs. IAPS are also considered as biological polluters (Westbrooks, 1991) and are capable of hybridizing with native plant relatives that result in unnatural changes to aplant's genetic makeup (Richburg 2008, Kunwar and Acharya, 2013). Invasive Alien Species (IAS) as one of five major drivers of biodiversity loss in inland waters (MEA, 2005). IAPS invasion affected native species in almost every ecosystem on Earth and have caused hundreds of species extinctions (McNeely *et al*., 2001) through competition, predation, hybridization, transmission of pathogens and the disruption of local ecosystems andecosystem functions and can recover its distribution after removal of IAPS (Andreu and Vila, 2011). The IAPS has ecological and evolutionary as well as economic impacts. The ecological and evolutionary impacts include extinction of species, modification ofecosystem process (e.g., nutrient cycling, fire regime, hydrology), and evolution. Pimentel et al. (2000) suggested that, about 42% of the species on the threatened or endangered species list are at risk primarily due to alien species. Reduced plant diversity is seen in the areas covered by invasive species, this might be due to the allelochemicals produced by invasive species. All IAPs listed haven't shown invasive property in the study area but poses risk of eruption of invasive nature. Easy dispersal due to light weight seeds and short life cycle of invasive species also adds to the risk of invasive species eruption in the area. *Ipomea carnea* is distributed both in and out around the reservoir, adds up to the risk of plant biodiversity loss and siltation of the reservoir.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Jagdishpur reservoir is one of the important wetlands and IBAs of Nepal. This study on the invasive species in Jagdishpur reservoir and its impact has verified the occurrence of 20 species of IAPs. They are found to be distributed in grassland, agricultural land and forest around the reservoir. Invasive species is distributed more in grassland and have impact on biodiversity too.

Invasive species with significant coverage has found to have negative impact in plant biodiversity. *Parthenium hysterophorus, Senna tora, Ipomoea carnea, Amaranthus spinosus, Mimosa pudica, Chromolaena odorata*etc. are the commonly found invasive species in the study area. *Cynodon dactylon* and *Sachharum spontaneum* are the commonly found grasses. More biodiversity in grassland might be due to availability of favorable condition and less disturbance. Plant diversity in forest has more invasive species in peripheral region due to favorable condition of undergrowth invasive species under canopy cover. Due to continuous farming intervention activities, invasive species are less common in terms of population in agricultural land. Invasive species are abundantly distributed in different land use in and around Jagdishpur reservoir.

The impact of invasive specieson loss of plant biodiversity is evident in the areas where the coverage of invasive species is more and has been demonstrated with both Simpson diversity index and also Shanon's biodiversity index value. Significant changes in the values of these indices adds to the proof that the IAPs have negative impact in the native plant diversity and ecology.

From this study, it is clear that one of the important wetlands and Ramsar site of Nepal, Jagdishpur lake has significant number of invasive plant species.The results of this study have shown that the loss of biodiversity in and around Jagdishpur reservoir is in alarming state and need to take necessary action to conserve its biodiversity.

6.2 Recommendation

- As the invasive species are quite high around the jagdishpir reservoir, due attention need to be provided for its management by the concern authority in time.

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APPENDICES

Appendix 1: List of species recorded in Jagdishpur reservoir

S. No.	Species name	Family
1.	*Acacia catechu* L.f. Willd	Fabaceae
2.	*Acacia nilotica* (L.) D	Fabaceae
3.	*Achyranthes aspera* L.	Amaranthaceae
4.	*Acmella oleracea* (L.) R.K. Jansen	Asteraceae
5.	*Aegle marmelos* Linn. corr.	Poaceae
6.	*Ageratina adenophora* (Spreng.) King & H.Rob	Asteraceae
7.	*Ageratum conyzoides* L.	Asteraceae
8.	*Ageratum haustonium* Mill.	Asteraceae
9.	*Albizia procera* (Roxb.) Benth.	Fabaceae
10.	*Alternanthera philoxeroides* (Mark.) Griseb	Amaranthaceae
11.	*Alternanthera sessilis* (L.) R. Br. ex DC.	Amaranthaceae
12.	*Amaranthus spinosus* Linn.	Amaranthaceae
13.	*Argemone Mexicana* L.	Papaveraceae
14.	*Artemisa indica* L.	Asteraceae
15.	*Artocarpus heterophyllus* Lam.	Moraceae
16.	*Artocarpus lacucha* wall.	Moraceae
17.	*Axonopus compressus* (Sw.) P. Beauv.	Poaceae
18.	*Azadirachta indica* A. iuss	Meliaceae
19.	*Bahunia purpurea* L.	Fabaceae
20.	*Bambusoideae* Luerss	Poaceae
21.	*Bidens pilosa* L.	Asteraceae
22.	*Blyxa japonica* ThouaB ex Rich	Hydrocharitaceae
23.	*Bothriochloa ischaemum* (L.) Keng	Poaceae
24.	*Brachiaria mutica* (Forssk.) Stapf	Poaceae
25.	*Brassica campestris* L. varr sarson Prain	Brassicaceae
26.	*Cajanus cajan* (L.) Millsp.	Fabaceae
27.	*Calocasia esculenta* (L.) Schott	Araceae
28.	*Calotropis gigantean* (L.) Dryand	Apocynaceae

29.	*Cannabis sativa* L.	Cannabaceae
30.	*Cascabela thevetia* (L.) Lippold	Apocynaceae
31.	*Centella asiatica* Linn. urb	Mackinlayaceae
32.	*Chromolaena odorata* (L.) R.m.King & H.Rob.	Asteraceae
33.	*Chrysopogona ciculatus* (Retz.) Trin.	Poaceae
34.	*Cissampelos pareira* L.	Menispermaceae
35.	*Clerodendrum infortunatum* L.	Lamiaceae
36.	*Coccinia grandis* (L.) voigt	Cucurbitaceae
37.	*Commelina benghalensis* L.	Commelinaceae
38.	*Croton bonplandianum* L.	Euphorbiaceae
39.	*Curcuma caesia* Roxb.	Zingiberaceae
40.	*Cynodon dactylon* (L.) pers	Poaceae
41.	*Cyperus compactus* Retz.	Cyperaceae
42.	*Cyperus compressus* L.	Cyperaceae
43.	*Cyperus difformis* L.	Cyperaceae
44.	*Cyperus iria* L.	Cyperaceae
45.	*Cyperus rotundus* L.	Cyperaceae
46.	*Dactyloctenium aegyptium* Desv.	Poaceae
47.	*Dalbergia sissoo* Roxb.	Fabaceae
48.	*Desmodium gangeticum* Desv.	Fabaceae
49.	*Desmostachya bipinnata* (L.) stapf	Poaceae
50.	*Digitaria sanguinalis* (L.) Scop.	Poaceae
51.	*Echinocholoa colona* (L.) Link.	Poaceae
52.	*Eclipta prostrata* (L.) L.	Asteraceae
53.	*Eichhornia crassipes* mark	Pontederiaceae
54.	*Eleusine indica* (L.) Gaertn	Poaceae
55.	*Emilia sonchifolia* (L.) Dc. ex. weight.	Asteraceae
56.	*Eragrostis amabilis* (L.) weight & Arn. ex nees	Poaceae
57.	*Eragrostis atrovirens* (Desf.) Trin. ex Steud.	Poaceae
58.	*Eragrostis spectabilis* (Pursh) Steud.	Poaceae
59.	*Eragrostis unioloides* (Retz.). Nees ex steud.	Poaceae
60.	*Erigeron karvinskianus* Dc.	Asteraceae

61.	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae
62.	*Euphorbea hirta* Linn.	Euphorbiaceae
63.	*Euphorbia prostrate* Aitun.	Euphorbiaceae
64.	*Evolbulus nummularius(white flower)* L.	Convolvulaceae
65.	*Ficus benghalensis* L.	Moraceae
66.	*Ficus hispida* Linn.	Moraceae
67.	*Ficus religiosa* L.	Moraceae
68.	*Matteucciastruthio pteris* L.	Onocleaceae
69.	*Fimbristylis complanata* Vahl.	Cyperaceae
70.	*Fimbristylis dichotoma* (L.) Vahl.	Cyperaceae
71.	*Fimbristylis miliaceae* (L.) Vahl.	Cyperaceae
72.	*Galinsoga quadriradiata* Ruiz & Pav.	Asteraceae
73.	*Garuga pinnata* Roxb.	Burseraceae
74.	*Haldina cardifolia* (Roxb.) Ridsdale	Rubiaceae
75.	*Hymenachne amplexicaulis* (Rudge) Nees	Poaceae
76.	*Hymenocallis littoralis* (Jacq.) Salisb.	Amaryllidaceae
77.	*Imperata cylindrical* (L.) P. Beauv.	Poaceae
78.	*Ipomoea carnea* Jacb.	Convolvulaceae
79.	*Jasminum auriculatum* Vahl.	Oleaceae
80.	*Jatropha gossypiifolia* Karl. L.	Euphorbiaceae
81.	*Kyllinga brevifolia* Rottb.	Cyperaceae
82.	*Leersia hexandra* Sw.	Poaceae
83.	*Leucaena leucocephala* (lam.) de wit	Fabaceae
84.	*Ludwigia adscendens* (L.) H. Hara	Onagraceae
85.	*Mallotus philipensis* (Lam.) Muell.Arg.	Euphorbiaceae
86.	*Mangifera indica* L.	Anacardiaceae
87.	*Melia azedarach* L.	Meliaceae
88.	*Mikania micrantha* Kunth	Asteraceae
89.	*Mimosa pudica* L.	Fabaceae
90.	*Mitragyna parvifolia* (Roxb.) Korth	Rubiaceae
91.	*Morus alba* L.	Moraceae
92.	*Murraya koenigii* (L.) Sprengel	Rutaceae

93.	*Nymphoide shydrophylla* Lour. Kuntze	Menyanthaceae
94.	*Oplismenus burmanii* (Retz.) P. Beauv	Poaceae
95.	*Oryza rufipogon* Griff.	Poaceae
96.	*Oryza sativa* L.	Poaceae
97.	*Ottelia alismoides* (L.) Pers.	Hydrocharitaceae
98.	*Oxalis latifolia* Kunth.	Oxalidaceae
99.	*Panicum repens* L.	Poaceae
100.	*Parthenium hysterophorus* L.	Asteraceae
101.	*Phyla nodiflora* (L.) Greene	Verbenaceae
102.	*Phyllanthus niruri* L.	Phyllanthaceae
103.	*Piper longum* L.	Piperaceae
104.	*Plumeria rubra* L.	Apocynaceae
105.	*Polygonum barbatum* L.	Polygonaceae
106.	*Pterocarpus marsupium* Roxb.	Fabaceae
107.	*Ricinus communis* L.	Euphorbiaceae
108.	*Rungia pectinata* Nees	Acanthaceae
109.	*Saccharum spontaneum* L.	Poaceae
110.	*Schefflera digitata* J.R. Forst. et G. Forst	Araliaceae
111.	*Schleichera oleosa* (Lour.) Oken	Sapindaceae
112.	*Schoenoplectiella mucronata* (L.) J. Jung	Cyperaceae
113.	*Senna occidentalis* L.	Fabaceae
114.	*Senna tora* (L.) Roxb.	Fabaceae
115.	*Setaria pumila* (Poir) Roem & Schult.	Poaceae
116.	*Shorea robusta* Gaerth.	Dipterocarpaceae
117.	*Sida acuta* Burm. f.	Malvaceae
118.	*Sida cordifolia* L.	Malvaceae
119.	*Solanum nigrum* L.	Solanaceae
120.	*Spermacoce alata* Aubl.	Rubiaceae
121.	*Syzygium cumini* (L.) Skeels.	Myrtaceae
122.	*Tamarandus indica* L.	Fabaceae
123.	*Tectona grandis* L.f.	Verbenaceae
124.	*Terminalia arjuna* (Roxb) Wight & Arn.	Combretaceae

125.	*Tridax procumbens* L.	Asteraceae
126.	*Typha angustifolia* L.	Typhaceae
127.	*Vigna mungo* (L.) Hepper	Fabaceae
128.	*Xanthium strumarium* L.	Asteraceae
129.	*Ziziphus nummularia* (Burm. f.) Wight & Arn.	Rhamnaceae

Appendix 2: List of names of species, family and IVI in grassland near reservoir

S. No.	Species name	Family	IVI (F)	IVI (W)	IVI (N)	IVI (S)
1.	*Acacia nilotica*	Fabaceae	0.83		1.04	
2.	*Achyranthes aspera*	Amaranthaceae	9.62	8.95	19.21	6.33
3.	*Aegle marmelos*	Poaceae		1.27	2.03	
4.	*Ageratum conyzoides*	Asteraceae	3.34	1.71	3.71	3.88
5.	*Alternanthera philoxeroides*	Amaranthaceae	3.56	1.66	4.24	4.14
6.	*Alternanthera sessilis*	Amaranthaceae			1.64	
7.	*Amaranthus spinosus*	Amaranthaceae		5.51	3.11	1.68
8.	*Artemisa indica*	Asteraceae	0.75	3.7	2.08	2.86
9.	*Axonopus compressus*	Poaceae	0.91	1.44	0.84	
10	*Bothriochloa ischaemum*	Poaceae	4.25		8.03	5.82
11	*Brachiaria mutica*	Poaceae	1.39		2.51	2.01
12	*Calocasia esculenta*	Araceae	0.75		1.62	
13	*Calotropis gigantea*	Apocynaceae	5.04	4.33	3.62	2.63
14	*Cannabis sativa*	Cannabaceae	0.83	1.27		1.22
15	*Centella asiatica*	Mackinlayaceae	0.91	1.79	2.06	
16	*Chromolaena odorata*	Asteraceae	6.72		10.91	
17	*Commelina benghalensis*	Commelinaceae	5.79	1.61	4.23	
18	*Croton bonplandianum*	Euphorbiaceae	6.31	5.94	5.48	8.38
19	*Cynodon dactylon*	Poaceae	31.16	31.59	27.17	36.55
20	*Cyperus compactus*	Cyperaceae			0.62	
21	*Cyperus compressus*	Cyperaceae		1.75		
22	*Cyperus difformis*	Cyperaceae		2.77	0.74	

23	*Cyperus iria*	Cyperaceae	2.14	6.06	2.93	1.68
24	*Cyperus rotundus*	Cyperaceae	1.03	2.06	4.38	6.69
25	*Dactyloctenium aegyptium*	Poaceae	0.75	1.48	1.54	2.45
26	*Dalbergia sissoo*	Fabaceae	9.56	3.33	9.71	5.31
27	*Desmodium gangeticum*	Fabaceae	9.74		5.44	11.45
28	*Desmostachya bipinnata*	Poaceae	2.43	3.07	5.01	3.47
29	*Digitaria sanguinalis*	Poaceae		1.83	2.71	
30	*Echinocholoa colona*	Poaceae	1.11	1.27	2.38	4.08
31	*Eclipta prostrata*	Asteraceae		2.45	0.69	
32	*Eichhornia crassipes*	Pontederiaceae	2.43			
33	*Eleusine indica*	Poaceae	0.79	1.31		
34	*Eragrostis atrovirens*	Poaceae	2.59	1.66	1.49	
35	*Eragrostis spectabilis*	Poaceae	1.03	2.92	1.24	4.57
36	*Euphorbea hirta*	Euphorbiaceae	2.37		3.32	1.73
37	*Evolbulus nummularius(white flower)*	Convolvulaceae	1.03	2.81	3.56	3.11
38	*Fimbristylis complanata*	Cyperaceae	5.46		1.11	
39	*Fimbristylisdichotoma*	Cyperaceae	0.75		0.79	
40	*Fimbristylis miliaceae*	Cyperaceae		1.41	0.64	
41	*Hymenachne amplexicaulis*	Poaceae	0.79			
42	*Hymenocallis littoralis*	Amaryllidaceae	1.66	1.6	0.59	1.63
43	*Imperata cylindrica*	Poaceae	1.43		0.64	1.71
44	*Ipomoea carnea*	Convolvulaceae	3.56	5.41	4.72	1.68
45	*Jatropha gossypiifolia*	Euphorbiaceae	0.75			1.53
46	*Kyllinga brevifolia*	Cyperaceae	3.24	1.39	1.72	5.23

47	*Leersia hexandra*	Poaceae		1.48		1.48
48	*Ludwigia adscendens*	Onagraceae	0.79			
49	*Mallotus philipensis*	Euphorbiaceae	1.62	1.45	0.62	
50	*Mikania micrantha*	Asteraceae	1.23	2.06	0.62	
51	*Mimosa pudica*	Fabaceae	7.25	6.01	3.69	
52	*Nymphoides hydrophylla*	Menyanthaceae	2.02	2.83		
53	*Oplismenus burmanii*	Poaceae	0.79	1.89	1.59	1.96
54	*Oryza rufipogon*	Poaceae	2.63	1.31	0.89	1.73
55	*Ottelia alismoides*	Hydrocharitaceae	0.87			
56	*Oxalis latifolia*	Oxalidaceae	5.63	3.46	1.71	3.98
57	*Panicum repens*	Poaceae	0.79		1.75	3.34
58	*Parthenium hysterophorus*	Asteraceae	84.52	109.81	69.69	83.54
59	*Phyla nodiflora*	Verbenaceae		2.73		4.68
60	*Phyllanthus niruri*	Phyllanthaceae	1.82	3.91	3.01	3.83
61	*Polygonum barbatum*	Polygonaceae	3.567	1.83		1.40
62	*Ricinus communis*	Euphorbiaceae	3.24	1.27		8.79
63	*Rungia pectinata*	Acanthaceae	2.81	1.51	4.17	5.21
64	*Saccharum spontaneum*	Poaceae	6.89	22.53	10.99	2.71
65	*Schoenoplectiella mucronata*	Cyperaceae	1.15		0.89	2.51
66	*Senna tora*	Fabaceae	1.74	1.5	5.28	1.27
67	*Setaria pumila*	Poaceae	3.81	1.44	0.72	2.78
68	*Sida acuta*	Malvaceae	2.53	1.62	1.99	4.77
69	*Sida cordifolia*	Malvaceae	8.06	5.21	5.11	11.55
70	*Solanum nigrum*	Solanaceae			1.95	

71	*Tridax procumbens*	Asteraceae	9.94	7.91	10.61	8.22
72	*Typha angustifolia*	Typhaceae	1.15			
73	*Xanthium strumarium*	Asteraceae	3.52	1.45	8.58	2.93
74	*Ziziphus nummularia*	Rhamnaceae	4.61	1.22	4.17	8.94

Appendix 3: List of names of species, family and IVI in agricultural land near reservoir

S. No.	Species name	Family	IVI (E)	IVI (W)	IVI (N)	IVI (S)
1.	*Acacia nilotica*	Fabaceae	2.12			1.86
2.	*Achyranthes aspera*	Amaranthaceae	11.61	1.92	8.44	6.44
3.	*Acmella oleracea*	Asteraceae			3.24	2.08
4.	*Ageratina adenophora*	Asteraceae			4.35	8.68
5.	*Ageratum conyzoides*	Asteraceae	7.15		1.76	6.19
6.	*Ageratum haustonium*	Asteraceae	3.93	2.17		15.32
7.	*Amaranthus spinosus*	Amaranthaceae		3.84	1.51	0.92
8.	*Artocarpus heterophyllus*	Moraceae			1.73	
9.	*Axonopus compressus*	Poaceae	2.85			
10.	*Azadirachta indica*	Meliaceae	1.73			
11.	*Bahunia purpurea*	Fabaceae			1.72	
12.	*Bambusoideae*	Poaceae			2.17	6.91
13.	*Bidens pilosa*	Asteraceae				0.93
14.	*Bothriochloa ischaemum*	Poaceae	1.89	2.19		
15.	*Brassica campestris*	Brassicaceae		2.18		0.92
16.	*Cajanus cajan*	Fabaceae		1.92		0.92
17.	*Calocasia esculenta*	Araceae	5.21		11.14	5.41
18.	*Centella asiatica*	Mackinlayaceae	3.71			0.93
19.	*Chromolaena odorata*	Asteraceae	9.81	2.23	3.81	4.24
20.	*Chrysopogon aciculatus*	Poaceae	6.84		2.01	2.01
21.	*Clerodendrum infortunatum*	Lamiaceae			2.46	4.41

22.	*Coccinia grandis*	Cucurbitaceae				0.92
23.	*Commelina benghalensis*	Commelinaceae	10.09		7.43	2.65
24.	*Croton bonplandianum*	Euphorbiaceae			1.51	2.05
25.	*Curcuma caesia*	Zingiberaceae			6.32	
26.	*Cynodon dactylon*	Poaceae	98.19	117.23	146.43	94.02
27.	*Cyperus compressus*	Cyperaceae			4.18	
28.	*Cyperus iria*	Cyperaceae		3.01		2.79
29.	*Cyperus rotundus*	Cyperaceae	4.05	7.11	5.09	1.12
30.	*Dalbergia sissoo*	Fabaceae			4.74	4.36
31.	*Desmostachya bipinnata*	Poaceae	5.25			1.29
32.	*Eichhornia crassipes*	Pontederiaceae			1.51	
33.	*Emilia sonchifolia*	Asteraceae	3.72	2.45	3.12	2.52
34.	*Eragrostis amabilis*	Poaceae				1.11
35.	*Erigeron karvinskianus*	Asteraceae	2.25	4.41		3.31
36.	*Evolbulus nummularius(white flower)*	Convolvulaceae				1.14
37.	*Galinsoga quadriradiata*	Asteraceae				1.09
38.	*Imperata cylindrica*	Poaceae	45.92	74.32	9.42	39.98
39.	*Ipomoea carnea*	Convolvulaceae	3.67		1.75	1.84
40.	*Jasminum auriculatum*	Oleaceae			1.51	
41.	*Leucaena leucocephala*	Fabaceae				2.95
42.	*Mangifera indica*	Anacardiaceae			1.51	
43.	*Matteuccia struthiopteris*	Onocleaceae			1.51	
44.	*Melia azedarach*	Meliaceae			1.74	2.05

45.	*Mikania micrantha*	Asteraceae				5.16
46.	*Mimosa pudica*	Fabaceae	1.97	5.39	4.84	
47.	*Morus alba*	Moraceae				0.92
48.	*Oryza sativa*	Poaceae	1.765	4.41	1.75	1.27
49.	*Parthenium hysterophorus*	Asteraceae	22.67	9.84	19.86	9.21
50.	*Phyllanthus niruri*	Phyllanthaceae		1.92		2.03
51.	*Piper longum*	Piperaceae			5.51	
52.	*Saccharum spontaneum*	Poaceae	7.03	6.71	5.63	9.69
53.	*Senna occidentalis*	Fabaceae	3.09			2.41
54.	*Senna tora*	Fabaceae	24.49	12.21	4.77	15.49
55.	*Setaria pumila*	Poaceae		6.62	1.74	
56.	*Sida cordifolia*	Malvaceae	1.73	3.84	1.51	5.32
57.	*Solanum nigrum*	Solanaceae		2.19	5.47	2.45
58.	*Spermacocealata*	Rubiaceae	5.48	9.13		4.68
59.	*Typha angustifolia*	Typhaceae				0.92
60.	*Vigna mungo*	Fabaceae		6.86	1.75	
61.	*Xanthium strumarium*	Asteraceae		1.92	4.96	5.78
62.	*Ziziphus nummularia*	Rhamnaceae	1.74	3.84		2.02

Appendix 4: List of names of species, family and IVI in forest near reservoir

S. No.	Species name	Family	IVI
1.	*Acacia catechu*	Fabaceae	3.18
2.	*Acacia nilotica*	Fabaceae	0.33
3.	*Achyranthes aspera*	Amaranthaceae	3.59
4.	*Acmella oleracea*	Asteraceae	2.27
5.	*Aegle marmelos*	Poaceae	0.33
6.	*Ageratum conyzoides*	Asteraceae	0.41
7.	*Ageratum haustonium*	Asteraceae	1.14
8.	*Albizia procera*	Fabaceae	0.66
9.	*Amaranthus spinosus*	Amaranthaceae	2.03
10.	*Argemone mexicana*	Papaveraceae	0.78
11.	*Artemisa indica*	Asteraceae	0.39
12.	*Artocarpus lacucha*	Moraceae	1.05
13.	*Axonopus compressus*	Poaceae	0.45
14.	*Bahunia purpurea*	Fabaceae	0.33
15.	*Bambusoideae*	Poaceae	0.33
16.	*Bidens pilosa*	Asteraceae	0.45
17.	*Blyxa japonica*	Hydrocharitaceae	1.26
18.	*Bothriochloa ischaemum*	Poaceae	0.34
19.	*Calocasia esculenta*	Araceae	0.58
20.	*Cascabela thevetia*	Apocynaceae	1.11
21.	*Centella asiatica*	Mackinlayaceae	4.36

22.	*Chromolaena odorata*	Asteraceae	2.47
23.	*Chrysopogon aciculatus*	Poaceae	0.97
24.	*Clerodendrum infortunatum*	Lamiaceae	2.06
25.	*Commelina benghalensis*	Commelinaceae	29.29
26.	*Croton bonplandianum*	Euphorbiaceae	3.06
27.	*Cynodon dactylon*	Poaceae	70.21
28.	*Cyperus compactus*	Cyperaceae	0.63
29.	*Cyperus compressus*	Cyperaceae	0.43
30.	*Cyperus iria*	Cyperaceae	1.69
31.	*Cyperus rotundus*	Cyperaceae	1.44
32.	*Dactyloctenium aegyptium*	Poaceae	0.33
33.	*Dalbergia sissoo*	Fabaceae	13.28
34.	*Desmostachya bipinnata*	Poaceae	31.56
35.	*Digitaria sanguinalis*	Poaceae	0.41
36.	*Echinocholoa colona*	Poaceae	0.33
37.	*Emilia sonchifolia*	Asteraceae	1.27
38.	*Eragrostis spectabilis*	Poaceae	0.41
39.	*Eragrostis unioloides*	Poaceae	1.66
40.	*Eucalyptus camaldulensis*	Myrtaceae	0.33
41.	*Euphorbea hirta*	Euphorbiaceae	1.52
42.	*Euphorbia prostrata*	Euphorbiaceae	0.54
43.	*Evolbulus nummularius(white flower)*	Convolvulaceae	3.073
44.	*Ficus benghalensis*	Moraceae	0.66

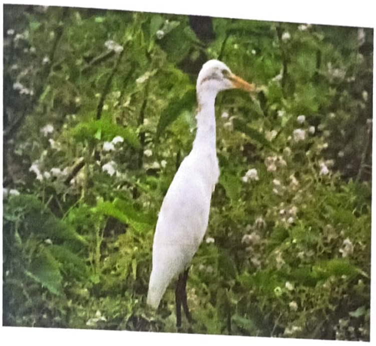
45.	*Ficus hispida*	Moraceae	0.33
46.	*Ficus religiosa*	Moraceae	1.01
47.	*Garuga pinnata*	Burseraceae	0.33
48.	*Haldina cardifolia*	Rubiaceae	0.33
49.	*Imperata cylindrica*	Poaceae	17.98
50.	*Ipomoea carnea*	Convolvulaceae	1.61
51.	*Kyllinga brevifolia*	Cyperaceae	0.52
52.	*Leucaena leucocephala*	Fabaceae	0.72
53.	*Mallotus philipensis*	Euphorbiaceae	0.33
54.	*Mangifera indica*	Anacardiaceae	0.66
55.	*Matteuccia struthiopteris*	Onocleaceae	0.68
56.	*Melia azedarach*	Meliaceae	3.21
57.	*Mikania micrantha*	Asteraceae	2.11
58.	*Mimosa pudica*	Fabaceae	2.71
59.	*Mitragyna parvifolia*	Rubiaceae	0.66
60.	*Murraya koenigii*	Rutaceae	0.52
61.	*Oplismenus burmanii*	Poaceae	0.52
62.	*Oxalis latifolia*	Oxalidaceae	5.98
63.	*Parthenium hysterophorus*	Asteraceae	15.32
64.	*Phyllanthus niruri*	Phyllanthaceae	1.39
65.	*Plumeria rubra*	Apocynaceae	0.33
66.	*Pterocarpus marsupium*	Fabaceae	0.56
67.	*Rungia pectinata*	Acanthaceae	0.53

68.	*Saccharum spontaneum*	Poaceae	20.31
69.	*Schefflera digitata*	Araliaceae	0.33
70.	*Schleichera oleosa*	Sapindaceae	0.67
71.	*Senna occidentalis*	Fabaceae	1.42
72.	*Senna tora*	Fabaceae	11.27
73.	*Setaria pumila*	Poaceae	0.85
74.	*Shorea robusta*	Dipterocarpaceae	1.78
75.	*Sida acuta*	Malvaceae	1.13
76.	*Sida cordifolia*	Malvaceae	0.67
77.	*Solanum nigrum*	Solanaceae	1.01
78.	*Spermacoce alata*	Rubiaceae	1.71
79.	*Syzygium cumini*	Myrtaceae	0.79
80.	*Tamarandus indica*	Fabaceae	0.38
81.	*Tectona grandis*	Verbenaceae	1.18
82.	*Terminalia arjuna*	Combretaceae	0.39
83.	*Tridax procumbens*	Asteraceae	1.12
84.	*Typha angustifolia*	Typhaceae	0.39
85.	*Xanthium strumarium*	Asteraceae	1.91
86.	*Ziziphus nummularia*	Rhamnaceae	1.02

Photo Plates:

Counting species in a quadrat

Photo of *Ipomea carnea*



Intermediate egret in Jagdishpur Reservoir

Mr. Nabin Pandey recording data

Photo of *Eichhornia crassipes*