DIVERSITY OF NATURALIZED PLANT SPECIES ACROSS DIFFERENT LAND USE TYPES IN KAILALI DISTRICT, WESTERN NEPAL

A Dissertation Submitted for Partial Fulfillment of the Requirements for the Master's of Science in Botany, Central Department of Botany, Institute of Science and Technology, Tribhuvan University, Kathmandu, Nepal.

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RECOMMENDATION

This is to certify that the dissertation work entitled **"DIVERSITY OF NATURALIZED PLANT SPECIES ACROSS LAND USE TYPES IN KAILALI DISTRICT, WESTERN NEPAL"** has been completed by Mr. Ganesh Datt Joshi under our supervision. This entire work was accomplished on the basis of candidate's original research work. To the best of our knowledge, the work has not been submitted to any other academic degree. It is here by recommended for acceptance of this dissertation as a partial fulfillment of the requirement of Master's Degree in Botany at the Institute of Science and Technology, Tribhuvan University, Nepal.

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LETTER OF APPROVAL

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April, 2019 **Ganesh Datt Joshi**

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
APG	Angiosperm Phylogeny Group
CBD	Convention on Biological Diversity
CCA	Canonical Correspondance Analysis
CDB	Central Department of Botany
CFUG	Community Forest User Group
GIS	Geographic Information System
GLM	Generalized Linear Model
GPS	Global Positioning System
IAPS	Invasive Alien Plant Species
IUCN	The World Conservation Union
KATH	National Herbarium and Plant Laboratories
Max. / Min.	Maximum / Minimum
MoFE	Ministry of Forest and Environment
MoFSC	Ministry of Forest and Soil Conservation
RBGE	Royal Botanical Garden, Edinburgh
RDA	Redundancy Analysis
SOC	Soil Organic Carbon
SPSS	Statistical Package for Social Sciences
TUCH	Tribhuvan University Central Herbarium

ABSTRACT

With the increasing movement of organisms directly and indirectly by human activities across natural biogeographic barriers, the number of naturalized plant species has been increasing both in disturbed and human-modified ecosystems. Due to variation in propagule pressure of naturalized plant species, available resources, disturbance regimes and species interactions, diversity of naturalized species may vary across vegetation and land use types. Naturalized plants species richness measured in different vegetation and land use types in Kailali district by using Modified-Whittaker nested vegetation sampling method (50 m × 20 m) and five plots were sampled in each of the seven land use types so, total number of sampling plots were 35. We recorded 792 species including 22 pteridophytes, 1 gymnosperm and 769 angiosperms; among them 670 were native species, 87 naturalized species and remaining 35 species were cryptogenic. Species richness of native, naturalized and invasive species significantly ($p<0.05$) varied across land use types. Naturalized species richness was the highest in roadside grazing land (17.2±1.35), followed by agriculture land (11.4±2.11) and it was the lowest in *Shorea*-*Terminalia* forest (3.6±1.43). Among invasive species *Ageratum houstonianum* was the most frequent (41%), followed by *Senna tora* (33%). However, *Senna tora* had the highest cover (64%) followed by *Ageratum houstonianum* (30%). The naturalized species richness showed significant relation ($p\leq0.05$) with grazing, native species richness, distance from river, tree canopy cover, soil pH, distance from settlement area and distance from road. Also, invasive species richness was significantly correlated with naturalized non-invasive species richness, grazing, tree canopy cover, soil pH, native species richness. Present study revealed the naturalized species were more colonized in human-modified and disturbed land use types that provide propagules for further spread to other vegetation and land use types in the region so, land use modification and disturbance factors as major governing factors for the naturalized plant species diversity. Therefore, the more modified and disturbed landuse types should be regularly monitored for early detection and eradication as a part of management strategy for naturalized plant species.

Keywords: Alien species, species richness, vegetation sampling, modified land use, disturbance.

CHAPTER 1: INTRODUCTION

1.1 Background

The biological species introduced in an ecosystem other than its native range are non-native, exotic or alien species (Colautti and Maclsaac, 2004). Alien species are native to one region that have been introduced and established into an area outside of their natural range either by accidentally or intentionally (Vitousek *et al*., 1997; Richardson *et al*., 2000; CBD, 2002). Those alien species having wide dispersal and self-establishment are naturalized species and if these species become aggressive or spread beyond the manageable level in any ecosystems are considered Invasive Alien Species (IAS). The alien plant species with the self-sustainable population (naturalized species) becomes problematic if they spread widely and cause significant negative impact on the native ecosystem (Sharma *et al*., 2005). According to "rules of tens", almost 10% of dispersed species have chance to the establishment and out of which, 10% have chance to become naturalized and 10% of naturalized becomes invasive (Williamson, 1996). Therefore, naturalized species are probable invasive species of future and their proper inventory is of urgent need, and invasive species are of great concern because of their fast spreading capacity, high competitive power towards native species and ability to establish and colonize in new area within short period of time (McNeely *et al.* 2001; Sharma *et al*., 2005).

Biological invasions has been considered as an important component of global environmental changes and is one of the major threats to native biodiversity, ecosystem functioning and productivity (Vitousek *et al.*, 1997, Pimental *et al*., 2005) and leads to change in the structure, composition of native communities (CBD, 2000; Kohli *et al.,* 2004). Biological invasions are impacting all components of the ecosystem including biodiversity (Vila *et al*., 2011). Biological invasions have been increasing in all landscapes and ecosystems by the steady increase in human movements and global trade. The Invasive Alien Plant Species (IAPS) have strong vegetative growth rate, high seed production capacity, high seed germination rate, long seed viability, phenotypic plasticity, and adaptive capacity to cope with harsh environmental conditions (Grice, 2006). Therefore, invasive species have a negative impact on local, regional as well as global scales, threatening biodiversity, food security and accelerating global environmental change (Mack *et al*., 2000).

Land use, disturbance, and climate change are driving factors for alien plants invasions (Londsale, 1999; Lamsal *et al*., 2018). Disturbance leads to the destruction of resident biomass which results in the increase of resource availability and less competition for invaders from residents which facilitate the invasion process (Davis *et al*., 2000). Human activities like migration, roadways construction, transportation, tourism, and farming practices may favor the biological invasions (Vitousek *et al.,* 1997; Liu *et al*., 2005). Roads being disturbed sites may facilitate the spread of invasive species by disturbing native ecosystem, changing physical habitats, and providing dispersal pathways for alien species. The dispersal pathways and sustainability of invasive species depend on the availability of resources and anthropogenic activities. The frequent availability of unused resources increase the vulnerability of habitat to biological invasions (Davis *et al*., 2000) while anthropogenic activities increases the dispersal pathways and propagule pressure of invasive species (Simberloff, 2009). From the anthropogenic landscape, some of the invasive species expand to natural landscape such as grassland, shrubland and forest where they not only compete with native species for resources but also degrade the habitats thereby making the ecosystem hostile to native species and increasing the rate of human-induced biodiversity loss. Therefore, in global scale, biological invasions have been considered the second most threat to biodiversity loss after habitat fragmentation (Glowka *et al.,* 1994). The major factors responsible for the introduction of alien species are climate, land use, dispersal pathways and some species becomes invasive to overcome these barriers (Richardson *et al*., 2000). There are many recorded cases of alien species around the globe that have turned in to invasive species, and huge economic loss due to the invasion by invasive alien species has been recorded from developed countries (Pimental *et al*., 2005; Paini *et al*., 2016). There are various effects of naturalized species on the native biodiversity and it is common that their introduction, ability to become naturalized and impact upon native species is a major concern of these days. The naturalized species alters the native community composition, decrease species diversity, affect ecosystem processes and cause huge ecological imbalance and affect ecosystem processing. During each decade more species become invasive and; more ecosystems were irreversibly altered

(Rejmanek, 1999). But, not all naturalized species have a negative effect on native biota; most of the naturalized species are inhabiting in the natural habitat harmoniously with the native biota and show no detectable impact upon native species at all (Simberloff, 1981; Lane, 1993).

Human land use promotes major changes in the species composition and abundance, yet native and alien species can exhibit different responses towards land use modifications (Jesse *et al*., 2018). More modified ecosystems like agriculture fields are most affected by the impact of biological invasions (Paini *et al*., 2016). The threat and challenge of naturalized species increasing due to globalization, land use modifications, and climate change issues may cause widespread of invasive species (Walther *et al*., 2005). So, the problem of naturalized species is a crucial challenge for prevention and management due to uncertain prediction (McDougall *et al*., 2011).

The biological invasions has been serious global environmental issues (Dhitam *et al*., 2007) and it is considered second most threat to the biodiversity loss after habitat destructions (Sala *et al*., 2000). The wide range of habitats and environmental conditions makes Nepal especially vulnerable to the establishment of invasive species of foreign origin (Kunwar, 2003). Nepal is ranked as a 3rd most vulnerable country to the threat of invasive species among the 124 countries of the world (Paini *et al*., 2016). Therefore, In Nepal, biological invasions has been emerged as new environmental problem (Shrestha, 2016).

1.2 Justification

Almost every country is grappling with the problem caused by biological invasions and the Kailali district is no exception to this. Study on naturalized plant diversity across vegetation types in some locations of central Nepal has been already done (Banjade, 2017; Chataut, 2017; Dhakal, 2017 and Thapa, 2017) but not in Western, Nepal. The information about naturalized species diversity in this study area is still limited. Therefore, the present study has documented the diversity of naturalized plant species across land use and vegetation types in the study area. Also, identified and quantified the diversity of the naturalized plant species across land use modifications. Land use change and disturbance are major factors that govern biological invasions (Londsale, 1999; Jesse *et al*., 2018). Thus, such type of research is of the urgent need to fulfill the existing knowledge gap on the status of naturalized plant species and underlying factors across different land use types in the study area. Results of this study can play an important role for prioritizing management options to control biological invasions. Those land use types which have high number of naturalized species including invasive species may serves as sources of propagules for further invasion. Such land use types should be monitored earlier as compared to those which have less number of such species. Hopefully, such types of research will be useful for the local level policy-making bodies regarding the management issues.

1.3 Hypothesis

Following research hypothesis was designed for this study;

- Human-modified land use types have a higher diversity of the naturalized plant species than non-modified land use types.

1.4 Objectives

The broad objective of this study was to analyze the diversity of naturalized plant species across different land-use types in Kailali district, Western, Nepal. The specific objectives included:

1. To prepare a checklist of naturalized plant species found in Kailali district.
2. To analyze the diversity of naturalized plant species across different land-use types.
3. To identify the underlying factors that affects the naturalized plant diversity.

1.5 Limitations

Followings are limitations of present research;

1. Sample site does not represent all vegetation types of Kailali district but the major types were represented.
2. The checklist of vascular plants of the district was prepared based on previous works and plant collection in limited areas during the present study. Records of previous studies could not be cross-validated during this study.

CHAPTER 2: LITERATURE REVIEW

2.1 Biological invasions as an environmental challenge

Alien species grows fast, spread rapidly and pose threats to ecosystem services (Vitousek *et al.*, 1997; Everard *et al*., 2018). Invasion by alien species is among the most important global scale problem for natural ecosystems. Alien plant species are recognized as one of the major threat to biodiversity and cause great economic loss. Introduction and establishment of such species lead to change in structure and composition of native communities (Rice and Emery, 2003). The impacts of invasive species are immense, insidious and usually irreversible and degrade the natural ecosystem, habitats, and productivity. The trait that makes a species easily invasive are wider geographic range, higher competitive ability, presence of allelopathic chemicals, dispersal by animals, presence of alternative mode of reproduction, smaller seed size, high seed productivity, and phenotypic plasticity (Sharma *et al*., 2005). Therefore, biological invasions are a global issue for biodiversity conservation (Simberloff *et al*., 2010).

2.2 Dispersal pathways and control measures

Alien species enter into the new geographical region by different dispersal pathways like transportation, tourism, wind, water, trade, etc. The rapidly increasing trade and tourism are responsible for the introduction of alien plant species from one geographical area to next. Seeds of many notorious plants are dispersed by animals, birds, human being and they have adaptive capacity to invade in new areas (Richardson *et al.,* 2000). Road networks are one of the dispersal pathways for alien species in the disturbed areas (Formen and Alexander, 1998; Thapa, 2017). Similarly, most of the invasive weeds are dispersed by the facility of transportation (Sabbir *et al*., 2019). Invasive species can be managed by physical, biological and chemical methods in the early stage of establishment. In biological control approach, some of the herbivores or plant pathogens were applied to suppress the growth as one of the most relevant ways for invasive weeds management. The biological agents can be introduced to feed upon the particular species with proper study of their side impact and introduced biological species should be eco-friendly. Various pesticides and herbicides have been used for the control of invasive weeds as a chemical control method. Manual uprooting of invasive weeds before the flowering period is one of the convenient ways for physical management method (Sabbir *et al*., 2019).

2.3 Impact of land use modification on naturalized species diversity

Human land use changes the species diversity and fluctuate the terrestrial and aquatic ecosystems. The native species reached the highest abundance in forest areas then the modified and disturbed lands (Jesse *et al*., 2018). Some of the species shows great challenge in the wetland ecosystem, agriculture land (Siwakoti, 2012; Paini *et al*., 2016), and some are challenging to the roadside, grazing lands, fallow land, urban areas, forest areas (Tiwari *et al*., 2005). Developing countries are much vulnerable to the impact of alien plant species because they rely heavily on resource-based livelihood such as aquaculture, agriculture, and forestry (Matthews and Brandt, 2004).

Based on previous works, disturbance factors and human-modified land use carry more number of naturalized plant species in Nepal. A research work on diversity of naturalized plant species across vegetation shows human-disturbed land use and edge forest areas in mid-hill region (central Nepal) carrying good number of naturalized plant species in comparison to less disturbed core forest as disturbed fallow land in Kaski district i.e., 24% of total vascular plant species and human-disturbed *Pinus roxburghii* forest at Tanahu district i.e., 20% of total but least in *Shorea robusta* forest (least disturbed site) at Dhading district i.e., 7% of total recorded vascular plants (Chataut, 2017). One of the research on naturalized diversity in Siwalik region (Hetauda, central Nepal) shows the highest number of naturalized species recorded from *Dalbergia* forest i.e., 26 species followed by grassland i.e., 23 species while least in *Shorea* forest i.e., 11 species (Dhakal, 2017). One of the research on Marsyangdi river valley (central Nepal) shows the highest number of naturalized species in *Schima-Castenopsis* forest i.e., 10 species followed by *Bombax* forest i.e., 8 species and than Shrub land i.e., 6 species (Thapa, 2017). Modi watershed of Annapurna conservation area (central Nepal) revealed the highest number of naturalized plant species in *Bombax-Schima* forest and sub-tropical mixed forest have the highest naturalized species i.e., 10 species followed by Pine forest i.e., 7 species while least in upper sub-alpine grassland i.e., 1 species (Banjade, 2017). The research on diversity and distribution of invasive species along the road networks in western Nepal and central Nepal shows more disturbed and modified land use such as roadside, grassland, pasture land, waste land, fallow land and urban areas with high abundance (Paudel, 2015; Poudel 2016). These findings show the disturbance and land use modification are major governing factors as dispersal pathways for biological invasions and tropical low land (with higher disturbance) have higher abundance of alien plants than the higher elevations of Nepal.

2.4 Factors governing the biological invasions

There are various environmental factors that are responsible for governing the occurrence and distribution of naturalized plant species. The disturbance factors (fire, trampling, logging, grazing), elevation slope, aspect, moisture, temperature, soil properties are some of the important environmental factors that affecting naturalized plants diversity (Chataut, 2017; Dhakal, 2017). Tropical areas are more invaded by naturalized species than higher elevation (Stolgren *et al.*, 2002). The alien plants require direct light for flourishing and growth (Fagan and Peard, 2004; Bhuju *et al.*, 2013). In the forest, the tree canopy determines the amount of light available on the ground surface. High tree canopy means low availability of light on the ground which is less favorable for the naturalized species. Most of the alien plants are herbaceous and better suited on open canopy (D'Antonio *et al*., 1992). With the increasing tree canopy cover, species richness of naturalized species decreases (Bhuju *et al*., 2013). Roadside grasslands and agriculture lands are more suited for naturalized plants as more disturbance, open canopy and grazing impacts (Parendes and Jones, 2000). Grazing impact is higher in such grasslands which is one of the major drivers for dispersal by animal's movements (Pouchard and Alaback, 2004). Besides grazing impact, fire is a major disturbance which alters the species composition and expands distribution and dominance of invasive plant species (Brooks and Lusk, 2008).

2.5 Naturalized plants diversity in Nepal

Nepal is ranked third most threatened country from biological invasions to agriculture sector (Paini *et al*., 2016). The first documentation of naturalized plant species in Nepal started since 1958 (Tiwari *et al.*, 2005). There are different numbers of naturalized species reported by various researchers in a different time. There are 166 naturalized plant species in Nepal as assessed by Tiwari *et al.,* (2005). Latter, 219 species of naturalized plant species were reported by Siwakoti, (2012). Now, there are at least 179 plant species were reported by Shrestha *et al*., (2019) which contributes almost 3% of total angiosperm flora of Nepal.

A comprehensive study was conducted by IUCN Nepal in 2002-2003 and recorded 21 as problematic species based on their invasive characters (Tiwari *et al*., 2005; Siwakoti, 2012). In addition to them, four naturalized species *Ageratum conyzoides, Erigeron karvinskianus*, *Galinsoga quadriradiata* and *Spermacoce alata* are invasive plant species in Nepal (Shrestha, 2016). Later, one more additional species *Spergula arvensis* reported in agro-ecosystem from central Nepal. Therefore, total invasive species in Nepal are 26 and are found in the different ecosystem (Shrestha *et al*., 2017). The introduction and establishment of invasive species is both accidental and intentional by land connected border, through roads, weak plant quarantine monitoring and international trade (particularly from India) are the major cause for the introduction of alien plant species in Nepal (Tiwari *et al*., 2005; Shrestha, 2016). Among naturalized plant species of Nepal, *Lantana camara, Pistia stratiotes, Eichhornia crassipes, Myriophyllum aquaticum* and *Ipomoea carnea* subsp. *fistulosa* are introduced as an ornamental plant or as hedge plant for fencing and controlling landslides along roads but now problematic in the different parts of the country. Most of the alien species are introduced with human activities through horticulture, crop and seed import, aquaculture and tourism. In the context of Nepal, $3/4^{th}$ of naturalized plants are of neo-tropical origin followed by Europe, North America (Bhattarai *et al.*, 2014).

There is a high concentration of invasive species on the southern half part of the country including Tarai, Siwalik and Mid Hills having tropical to sub-tropical climate and these invasive species are recorded from different land use types such as forest, shrubland, grassland, agro-ecosystem, wetlands, and residential area. In Nepal, the number of invasive species and their ecological and economic impacts have been increasing over the time (Shrestha, 2016) and these facts are reflected by Nepal fifth report to Convention on Biological Diversity (MoFSC, 2014b) and Nepal National Biodiversity Strategy and Action Plan 2014-2020 (MoFSC, 2014a). In agro-ecosystem, farmers have experienced significant agricultural loss in terms of quantity and quality due to invasion by various alien species but the actual monetary loss is still remaining (Tiwari *et al.*, 2005). Alien species introduced in Nepal by land-linked situation and weak quarantine monitoring and some of the naturalized species becoming invasive and many more species are leading towards their wide-spread with their impact.

The study about invasive species on Parsa Wildlife Reserve, central Nepal revealed 231 flowering plants among which 51 species were naturalized (Chaudhary, 2015). A study on naturalized plants diversity in Marsyangdi River Valley, central Nepal documented 797 vascular plant species and out of which 41 naturalized species (5%) with 6 invasive species (Thapa, 2017). A similar study on the diversity of naturalized plant species across forest types in Mid-hills of central Nepal documented 312 vascular plants out of which 34 naturalized species with 10 invasive species (Chataut, 2017). A study on the diversity of naturalized plant species across vegetation types in Tarai and Siwalik regions of central Nepal documented 339 vascular plant species with 55 naturalized species and 16 invasive species (Dhakal, 2017). A study on naturalized plant species in Modi watershed of Annapurna conservation area, central Nepal documented 537 vascular plant species having 35 naturalized species (Banjade, 2017). The presence of invasive species is higher in eastern and central Nepal than Western, Nepal (Tiwari *et al*., 2005; Shrestha, 2016). Among 26 invasive species of Nepal, four species are recorded as world's 100 worst species are *Lantana camara, Eichhornia crassipes, Mikania micrantha* and *Chromolaena odorata.* Invasive plant species such as *Parthenium hysterophorus, Bidens pilosa, Ageratum houstonianum, Ageratum conyzoides, Oxalis latifolia, Xanthium strumarium* are the major invasive species found in agro-ecosystem (Siwakoti and Shrestha, 2014) while *Pistia stratiotes, Eichhornia crassipes* and *Leersia hexandra* are found on wetland ecosystem (Shrestha, 2016). Native biodiversity of Nepal has been under pressure due to growing population demand, over-dependence on natural resources, unmanaged urbanization and land use practices (Singh and Sharma, 2014). In past 2-3 decades, many alien species have been rapidly colonizing in natural habitats and create a great threat to native ecosystems and economic loss (Rai and Scarborough, 2013). The number of invasive species is found high in the southern half of the country, where the warm and tropical climate is found (Shrestha, 2016).

2.6 Legislation for naturalized species in Nepal

The legislation for control, monitoring, and management of naturalized plant species is critical for conservation issues. The effective legislative framework is of the urgent need for control and management of invasive weeds. In Nepal, alien species introduced by trade, tourism, transport but the legal framework is not sufficient to control and management of invasive weeds. Nepal is a signatory to the Convention on Biological Diversity (CBD) and article 8 (h) of the convention calls "prevent the introduction, control, and eradication of those alien species which threaten ecosystems, habitats or species". The IUCN Guidelines for preventing biodiversity loss due to IAS has been designed to increase awareness and understanding of the impact of IAS and it provides guidelines for the prevention of introduction, control, and eradication of IAS (IUCN, 2000). A National Wetland Policy, 2003 also address the need to conserve and manage wetlands and promote their wise use in the country. The biological invasions have emerged as a new environmental problem for Nepal with direct implications to biodiversity conservation, ecosystem services, and economic development. Nepal's sixth national report to the Convention on Biological Diversity mentioned that, Nepal has initiated to develop distribution maps, conduct inventories, develops the strategy and improve the awareness under detail survey of the coverage and research in invasive in different parts of the country. This target has been implemented in a few selected wetlands only (MoFE, 2018). The invasive plant species management strategy named "*Invasive Species Management Draft*" has been prepared but not endorsed till the date (personal communication with Mohan Siwakoti; one of the members of that draft committee, 2019.3.26) so, there is progress towards management strategy of invasive species is an insufficient rate. Hopefully, it will be implemented soon and will be effective for the management and control of invasive species in Nepal. Therefore, an issue of biological invasions has not been addressed adequately in most of the national level legal instruments of Nepal (Siwakoti and Shrestha, 2014). However, limited studies have been conducted in different parts of the country and show a rapid expansion of naturalized species, habitat loss and impact on native biodiversity. Therefore, based on existing studies on naturalized species of Nepal shows the urgent need of exploration and research should be done in different parts of the country and should be focus on management and control for introduction and establishment of naturalized species.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

3.1.1 Location

The present study was conducted in Kailali district, one of the Tarai districts in Far-western Province. It is roughly rectangular in shape and spreads over latitude 28˚22' N to 29˚05' N and longitude from 80˚30' E to 81˚30' E covering an area of 3235 km^2. Elevation varies from 109 m. to 1950 m. above the sea level; Based on topography 59.7% and 40.3% of the area of the district lies in Tarai and Churia hill respectively. Where, the climate varies from tropical to sub-tropical with fertile land and one of the densely populated districts of the country. Based on land use pattern, forest and shrubland area covers 66.7%, agriculture land covers 27.8% and remaining 5.43% area covered by others. The total population of the district is 775709, population density 2.29, total households 142413, literacy rate 66.3%, percentage distribution of agriculture holding 2.91, irrigated land area 90.1% (CBS, 2011). Karnali, Mohana, Kandra, Rora, Donda, Shivaganga, Manahara, Godawari etc. are major rivers of the district. Ghodaghodi Lake area system (Ramsar site), Tikapur Park, Chisapani, Godawari, Debariya Botanical Garden etc. are major tourist destinations in the district. Dhangadhi is the provincial headquarter and commercial hub of Far-western Nepal. Total forest area occupies 215916 hectares in which 70396 hectacres occupied by Sal forest, 10746 hectares occupied by *Acacia catechu* forest and 52588 hectares by mixed forest (Rajbhandari *et al*., 2016). Present study sites for vegetation sampling lies in Ghodaghodi and Lamkichuha Municipalities and vascular plants documentation was carried throughout the Kailali district.

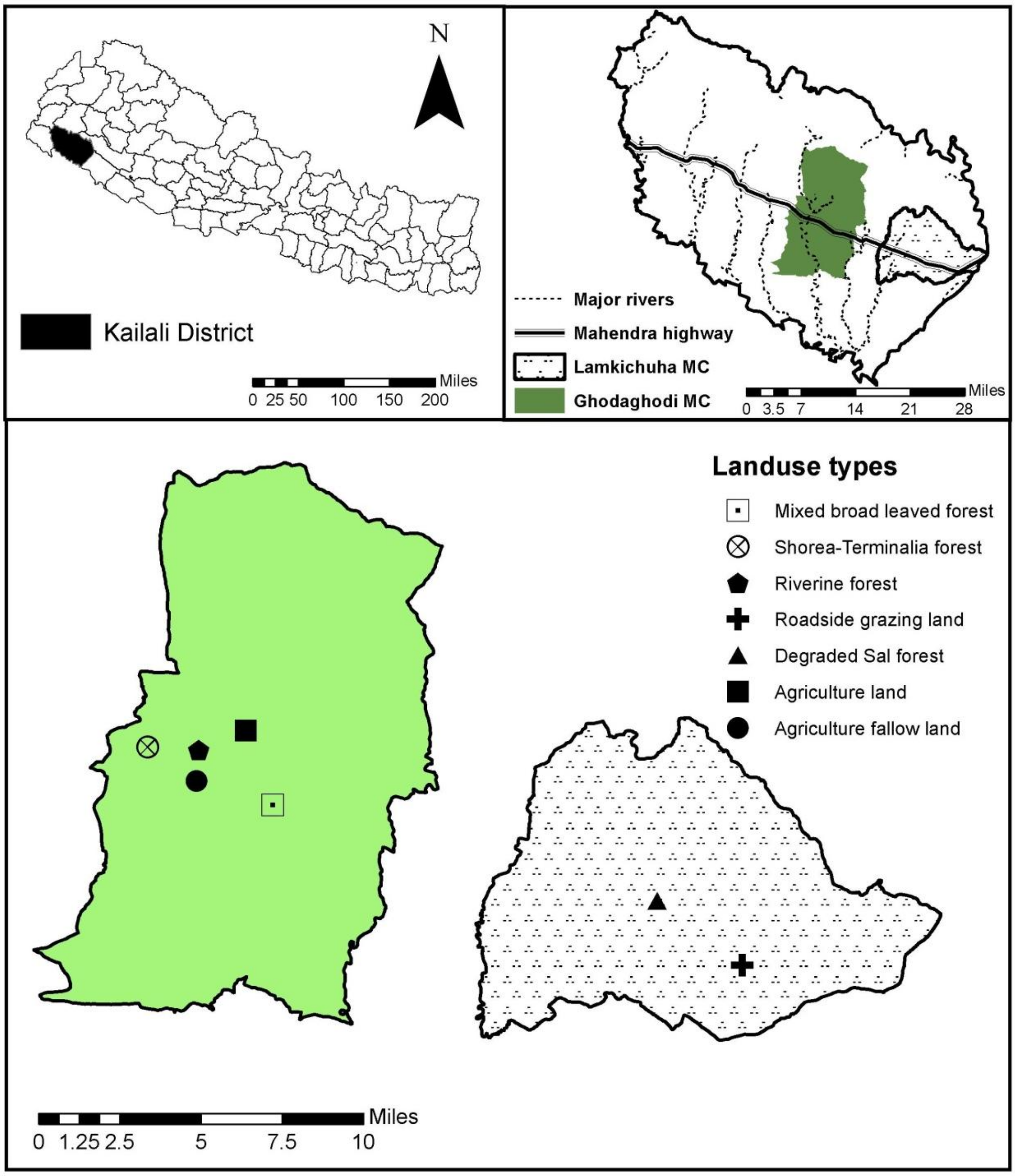

Figure 1. Study area map with sampling locations in two municipalities of Kailali district.

3.1.2 Climate

Nepal falls under Indian sub-continent with rainy summer and dry winter season. Temperature and precipitation data within ten years (2008-2018) of the nearest meteorological station i.e. Attaria station (28˚48' N and 80˚33' E) have been presented, where mean maximum temperature, mean minimum temperature and average annual precipitation were 30.71˚C, 17.80˚C and 1562 mm respectively (**Figure 2**).

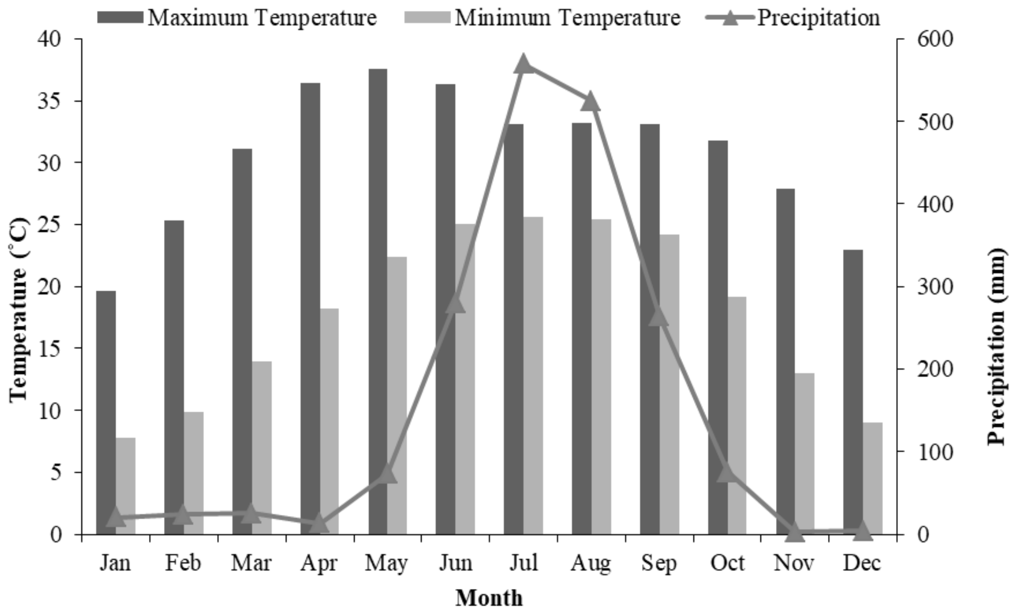

Figure 2. Temperature and precipitation records of Attaria station in Kailali district for ten years (2008-2018). (Source: Department of Hydrology and Meteorology / Government of Nepal, Kathmandu; Data provided 08.01.2019).

3.1.3 Vegetation and land use

In the present study, seven land use types were selected for vegetation sampling and vascular plants were recorded, estimated, collected and simultaneously soil collected for laboratory estimation. The selection criteria for these land use type was based on accessibility, nearby area and representation of almost vegetation types present in the district. These land use types were located in two different municipalities (Ghodaghodi Municipality and Lamkichuwa Municipality) of Kailali district.

Table 1. Over view of sampling land use and vegetation types in the study area

S.N.	Land use	Locality	Vegetation	Remarks
1.	Agriculture land	Sitalpur, Ghodaghodi MC*	Banana, Ground-nut, Sesame, Paddy field, Maize cultivation, Herbaceous plants found.	Nearby from road and settlement, modified land use.
2.	Roadside grazing land	Chisapani, Lamkichuha MC*	Dominated by herb, shrub and few tree saplings, naturalized plant species.	High coverage of invasive species, higher disturbance.

S.N.	Land use	Locality	Vegetation	Remarks
3.	Degraded Sal forest	Lamki, Lamkichuha MC*	*Shorea robusta, Adina cordifolia, Terminalia alata, Mallotus philippensis* etc.	High grazing impact, disturbed land use.
4.	Agriculture fallow land	Phanibakal – Radhakrisna, Ghodaghodi MC*	*Saccharum spontaneum, Imperata cylindrica, Digitaria ciliaris, Paspalum distichum, Axonopus compressus* etc.	Leaving barren since last 5 years, now grassland, frequent grazing.
5.	Riverine forest	Radhakrishna CF* , Ghodaghodi MC*	*Acacia catechu, Dalbergia sissoo, Bombax ceiba, M. philippensis, Albizia procera, Syzygium cumini* etc.	Flooded area, sandy river bank, almost barren underground herb.
6.	Mixed broad-leaved forest	Ghodaghodi CF*, Ghodaghodi MC*	*S. robusta, T. alata, T. chebula, T. bellerica, M. philippensis, Lagerstroemia parviflora* etc.	Adjoining to Ghodaghodi lake, harvesting impact, religious place.
7.	*Shorea-Terminalia* forest	Bhurkabhurki CF*, Ghodaghodi MC*	*S. robusta, T. alata, M. philippensis, L. parviflora, S. cumini, A. cordifolia, T. belerica, T. chebula* etc.	Frequently harvesting inside the forest area, less disturbed land use.

MC* = Municipality; CF*= Community Forest

3.2 Plant collection and vegetation sampling

This study was carried out in two different phages; first phase (preliminary field visit) included documentation of vascular plants of the district and the second phase included the estimation of naturalized plant species across different land use types and identify factors determining the diversity of naturalized plants in selected land use types. For the plant collection, areas from low land Tarai (140 m.asl.) to Churia hill (1508 m. asl.) were visited. During that visit, seven different land use types were also selected for vegetation sampling.

3.2.1 Plant specimen collection and documentation

Field visit for plant collection was done for 15 days in different locations of the district and vascular plant specimens including Pteridophytes, Gymnosperm, Monocots, and Dicots with duplicate copy were collected. Simultaneously, appropriate field notes were written including plant taxonomic information's (plant tag/collection number, botanical name, collection date, locality, local name, habit, habitat, remarks/identification characters etc.). Photographs of plant specimens, flower and fruits were captured as far as possible. Then, collected plant specimens were sun-dried within the newspaper and bloating papers. The collected plant specimens were mounted on the herbarium sheet (42 cm.×29 cm.) with the label (15 cm.×10 cm.). The vascular plant species were identified with the help of standard literatures, databases and expert consultation and placed in the respective folder. Finally, identified specimens were presented as a checklist.

3.2.2 Checklist preparation

The vascular plant species were recorded based on the collection during the present study (primary source) and previously published literatures (secondary sources). Previous works that were reviewed for the preparation of checklist were Siwakoti, (2006); Lamsal *et al*., (2014); Bhattrai and Acharya, (2015); Rajbhandari *et al.*, (2015); Rajbhandari *et al.*, (2016); MoFSC, (2017); Rajbhandari *et al.*, (2017); Rajbhandari and Rai, (2017). Then collected herbarium specimens were identified with the help of standard literatures such as the Flora of China (Wu *et al.*, 2011); Flora of Bhutan (Grierson and Long 1983, 1984, 1987, 1991, 1999, 2001); Annotated Checklist of Flowering Plants of Nepal (Press *et al.*, 2000); Flora of Plains of Eastern Nepal (Siwakoti and Varma, 1999), Flora of Kathmandu Valley (Malla *et al.*,1986), Plant Resources of Kailali district (Rajbhandari *et al*., 2016), Hand Book of Flowering Plants of Nepal (Rajbhandari and Rai, 2017), Flowering Plants of Nepal-Vol. 1 (Rajbhandari *et al*., 2017) and herbarium studied (specimen comparison) from National Herbarium and Plant Laboratories, Godawari (KATH), Tribhuvan University Central Herbarium, Kirtipur (TUCH) and Central National Herbarium, Kolkata (CAL). Doubtful specimens were identified with expert consultation. Then, plants species based on primary and secondary sources were compiled for checklist. The identified specimens were classified up to the family level by Byng *et al.*, (2016); http://www.plantsoftheworldonline.org and http://www.catalogueoflife.org (assessed in October, 2018).

The data obtained from primary collection and secondary sources were analyzed to calculate the total number of plant species within categories of native, naturalized non-invasive and invasive alien plant species. The native range of the overall vascular plant species were obtained from the open access data-bases such as http://www.plantsoftheworldonline.org; www.eol.com; https://www.gbif.org; http://griis.org; http://tropical.theferns.info (assessed in October, 2018). Identified species were further categorized as native, naturalized (which was further divided into non-invasive and invasive), and cryptogenic. The native species are 'those species, which have originated in a particular area without human involvement or that has arrived there without intentional or unintentional intervention of humans from an area in which they are native' (Pysek *et al.*, 2004). And, alien or exotic plant species are 'those species in a given area, whose presence is due to intentional or unintentional human involvement or which have arrived there without the help of people from an area' (Pysek *et al*., 2004). Those alien plants which reproduce and sustain their populations without direct intervention by humans, often producing plentiful offspring, mainly close to parent plants and do not necessarily invade natural and semi natural vegetation are termed as 'naturalized' species (Richardson *et al*., 2000). Similarly, those aliens which produce reproductive offspring in areas distant from sites of introduction and spread rapidly are termed as 'Invasive' (Richardson *et al*., 2000). And, further naturalized species were categorized in to naturalized non-invasive and invasive by following Shrestha *et al*., (2019). Those species having doubtful / unclear native range are considered as cryptogenic species (Essl *et al*., 2018).

3.2.3 Vegetation sampling

Vegetation sampling was carried out in September 2017. Five plots were sampled in each of the seven selected land use types; altogether 35 plots were sampled. A detailed analysis of vegetation was made by Modified Whittaker Nested Vegetation Sampling Plot Design (Stolgren *et al.,* 1995). In this plot design, each 20m × 50m plot was sub-divided in to ten subplots of 0.5m × 2m along the plot boundary, two plots of 2m × 5m at two opposite corners of the plots, and a single 5m × 20m plot at the center. Therefore, a plot had 13 subplots of varying size. Finally, whole plot (20m × 50m) was considered a single plot for the vegetation analysis across land use types.

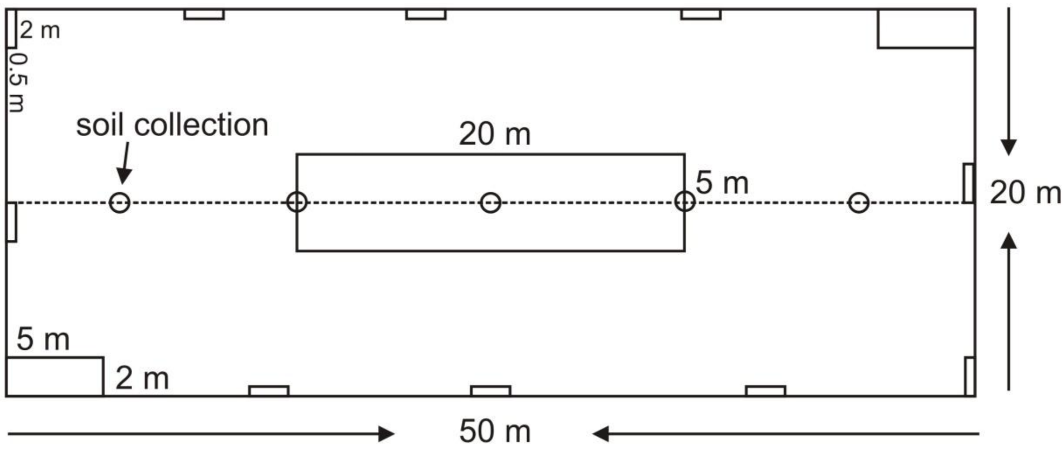

Figure 3. Outline of modified Whittaker nested vegetation sampling plot design (Stolgren *et al*., 1995).

This sampling design is applied for assessing the plant communities in multi-scale with more than 95% accuracy (Stolgren *et al.,* 1995). This sampling design considered better for vegetation sampling in multi-scale and was used by many researchers for accessing species richness (Telwala *et al*., 2013; Abella and Fornwalt, 2015) and for alien species (Stolgren *et al.,* 1995; Banjade, 2017; Chataut, 2017; Dhakal, 2017; Thapa, 2017). Trend analysis from monitoring a series of strategically-placed long term Modified Whittaker sampling plots may be an effective and valuable tool for quantifying and detecting species richness (Stolgren *et al.,* 1995). This sampling plot design is used as experimental design in the different sampling sites to estimates the total vascular plant species richness more accurately (>95%) within vegetation types but it was used previously by Banjade, (2017); Chataut, (2017); Dhakal, (2017); Thapa, (2017) in Siwalik region, mid-hill region and sub-alpine regions of central Nepal but not in west Tarai region till the day. This plot design was also used in vegetation sampling of exotic species in Colorado Rockies, USA (Stolgren *et al.*, 1999).

In the present study, site location includes latitude, longitude, elevation, and locality. The tree canopy estimation from 5 different points along middle line of sampling plots was taken by visual estimation. The disturbance factors such as fire, grazing, logging, species richness (native, naturalized and invasive) inside plots were recorded. Soil organic carbon (SOC), total soil nitrogen and soil pH were estimated by following Gupta, (2000). Distance from the nearest road (Mahendra highway and primary roads), distance from the river (Karnali River, Kandra River), distance from settlement area (Pahalmanpur, Sitalpur and Lamki) were estimated by using geographic coordinates (latitude/longitude) from point to point with the help of ruler in Google Earth (Pro. version of Google Earth 6.0; scale in meter). The cover of each species was noted according to Daubenmire cover class (Daubenmire, 1959). The cover class for canopy cover as; 1 (0-5% cover), 2 (5-25%), 3 (25-50%), 4 (50-75%), 5 (75-95%), 6 (95-100%) and then mid-value for each sub-plot were used for calculation. Disturbance regime like fire mark, grazing and tree canopy was measured by visual estimation. Fire was recognized by the presence of fire marks on the tree trunk, ground surface, or burned logs inside plots; if not seen such mark it was recorded no fire (0). The grazing marks were recognized based on dungs, grazing remains or cattle's inside sampling site. The geographical locations (Latitude/Longitude/Elevation) were measured by using Global Positioning System (model Garmin eTrex 10).

Overall native, naturalized and invasive species richness were enumerated from *Shorea-Terminalia* forest, riverine forest, agriculture land, agriculture fallow land, mixed broad leaved forest, roadside grazing land and degraded Sal forest. Among studied land-use types, agriculture land was more modified land use types (human modified ecosystem) than other selected land use types. Road side grazing land was most disturbed in terms of grazing, trampling, close distance from road, close distance from settlement area, close distance from river, transportation facility, logging, fire, tree canopy etc.

3.3 Laboratory work: Soil analysis

Soil samples were collected from five locations along the central line of each sample plot at depth of 15 cm using a soil digger. These sub samples were mixed thoroughly, homogenized and divided four equal parts and one of them was taken in a zipper polythene bag. The soil samples were dried in shade for 5-7 days and stored in air tight plastic bags until laboratory analysis. There were 5 soil samples from each land use types so altogether 35 samples were collected for laboratory estimation. Soil samples were analyzed at the ecology laboratory in the Central Department of Botany, Tribhuvan University, Nepal. Soil pH, soil organic carbon (SOC), soil nitrogen (N) was estimated by using methods described by Gupta (2000).

3.3.1 Soil pH

Soil pH was determined by using pocket-sized digital pH meter (PH009) in 1:2 ratio of soil water mixture. Before measurement, pH meter was calibrated using buffer solutions of pH 7. While measuring, 50 mL of distilled water was poured in to 25 g of soil sample. The mixture was stirred at least 20 minutes and allowed to settle down for five minutes. Then, the electrode of pH meter was dipped in to the mixture and reading was noted.

3.3.2 Soil Organic Carbon

Soil organic carbon (SOC) content was estimated by Walkley and Black's rapid titration method (1994) adopted from Gupta (2000). Soil sample (0.25) passed through a fine sieve (0.5mm) was taken in a 500 mL conical flask and added 5 mL of 1N $K_2Cr_2O_7$ and 10 mL of conc. H_2SO_4 with gentle swirling. The digestion reaction is exothermic; the flask was left for about 30 minutes for cooling in room temperature. To that mixture 100 mL of distilled water, 5 mL orthophosphoric acid and 1 mL of diphenyl indicator solution were added and shaken for a few minutes. Ferrous Ammonium Sulphate solution (0.5 N) was run from the burette, with constant stirring until the colour changed from violet to bright green through blue. The volume of Ferrous Ammonium Sulphate (FAS) solution used for titration was noted. A blank titration (without soil) was carried out at every lot of 10 samples in similar way.

Amount of FAS consumed = (Final reading - initial reading) of FAS

The standardized blank without soil was also run in the same way as control. Finally, the organic carbon (OC) in the soil was calculated by using formula:

$$\text{Soil Organic Carbon (\%)} = N\left(\frac{B-C}{weight\ of\ soil\ (g)}\right) \times 0.003 \times 100$$

Where, N = Normality of Ferrous Ammonium Sulphate

B = Blank reading

C = Titration reading

3.3.3 Total Soil Nitrogen

Total soil nitrogen estimated by micro-Kjeldahl method (Karla, 1998) that involves the conversion of organic nitrogen into ammonia by boiling with conc. H_2SO_4; the ammonia was subsequently liberated from its sulphate by distillation in presence of an alkali, which is titrated against HCl. It proceeds in three steps: Digestion, Distillation and Titration.

Digestion: One gram of dry and sieved soil, 0.4 g $CuSO_4$ and 3.5 g K_2SO_4 were taken in the digestion flask and than 6 mL Conc. H_2SO_4 was added to the soil mixture with gentle shaking. The mixture was heated on the preheated mantle at low heat until bubbles disappeared from the black mixture and heated until mixture change to grey-greenish colour for complete digestion. The digested mixture was cooled to room temperature and about 50 mL distilled water was added to the mixture with gentle shaking.

Distillation: The Kjeldahl distillation flask with digested materials was assembled on distillation chamber and warmed up for 15 minutes adjusting the heating mantle's adjuster at 30. In the Kjeldahl distillation flask, 30 mL NaOH (40%) was added through the funnel connected to the tube of distillation flask and the cork was set. In clean and dry beaker 10 mL of Boric acid was pipetted and placed below the nozzle of the condenser in such a way that the ends of nozzle dip into the indicator. The heating mantle's temperature adjuster was set at 60-70. When the distillate began to condense, the colour of boric acid indicator changed from pink to light green. Distillation was continued until the volume of distillate in the beaker reached about 50 mL.

Titration: Beaker containing about 50 mL distillate was removed and titrate it with 0.1 N HCl in burette. The volume of HCl consumed by distillate to change the green colour into pink was recorded. Finally, the following formula was used to calculate soil nitrogen;

$$\text{Soil N (\%)} = \frac{14 \times N \times (S - B) \times 100}{M}$$

Where, N = Normality of HCl

S = volume of HCl consumed with sample (mL)

B = volume of HCl consumed with blank (mL), M = mass of soil taken (mg).

3.4 Numerical analysis

3.4.1 Frequency of invasive species

Frequency of individual invasive species in sample plots was examined based on presence / absence (1/0) data from sampling plots. Overall invasive species frequency of particular invasive species in the study area was presented based on their proportion (%). The frequency of invasive species in each land use types are calculated according to Zobel *et al.* (1987) by the following formula;

$$\text{Frequency (F)} = \frac{\textit{Number of sampling plots in which species occurred}}{\textit{Total number of sampling plots examined}} \times 100\%$$

3.4.2 Canopy analysis

Tree canopy cover estimated by visual estimation as well as aerial photographs taken from the different five central locations on the ground surface. We have considered cover values 1/2/3/4/5/6 for Daubenmire cover class 0-5%, 5-25%, 25-50%, 50-75%, 75-95%, 95-100% respectively and then taking mid-values for each cover class and finally mean value was taken. Tree's were absent in Agriculture land, Agriculture fallow land, and Roadside grazing land, therefore tree canopy for these plots were considered zero. Average canopy for invasive species from different land use types were analyzed from mid-values. Cover percentage of invasive species was evaluated by visual estimation method, considering each plot is 100 percent and then put in the suitable cover class. All together canopy cover of 12 invasive species was analyzed for comparative analysis as follows;

$$\text{Canopy cover of IAPS (\%)} = \frac{\textit{Average midvalue of cover class for particular species}}{\textit{Total number of sampling plots observed}} \times 100$$

3.4.3 β-diversity across land use types

The total number of species encountered within a sampling plot (1000 m^2) was considered as total species richness. The β-diversity measurement of each land use types was calculated by adopting Whittaker (1960).

$$\beta w = \frac{S}{\alpha}$$

Where, S = total number of species recorded in the land use type and **α** = the mean of species richness of the five plots in each land use types.

3.4.4 Statistical analysis

The statistical analyses were performed using Microsoft Excel 2010, Statistical Package for Social Sciences (SPSS), RStudio and CANOCO. The normality and homogeneity of variance were tested by using SPSS version 20. The Kolmogorov-Smirnov significant value was used to test the normality of the data ($p>0.05$; significant) and presented data were normal. To compare the mean naturalized species richness among land-use types (*Shorea-Terminalia* forest, Riverine forest, Agriculture land, Agriculture fallow land, mixed broad leaved forest, Roadside grazing land and Degraded Sal forest) one-way analysis of variance was conducted followed by Tukey test. Multivariate analysis were used to understand the pattern and relationship between naturalized plant species and environmental variables and were presented by using CANOCO for windows 4.5. A preliminary analysis of presence/absence species data (0/1) and environmental variables were taken as environmental variables, combining all 35 plots in seven land use types through Detrended Correspondence Analysis (DCA, an indirect gradient analysis), revealed a gradient length 4.447 in terms of SD units. Therefore, Canonical Correspondence Analysis (CCA, direct gradient analysis) were appropriate for the analysis of naturalized species with environmental variables by CANOCO software. Therefore, the CCA ordination technique was applied to access the species-environmental relationship and analyzed the effect of different environmental variables with species richness. Monte Carlo permutation test was subsequently used within CCA to determine the significance of the relation between naturalized species distribution along the environmental gradients. Based on the DCA first axis gradient length (<2.5); invasive species richness with environmental variables relationship were presented by RDA biplot. The relation of naturalized species richness with different environmental variables like distance from road, distance from settlement, distance from river, grazing, native richness, soil organic carbon, total soil nitrogen, soil pH, tree canopy, logging, grazing were assessed by Generalized Linear Model (GLM) regression analysis which were performed separately by using RStudio version 0.99.1172 (R Core Team 2015).

CHAPTER 4: RESULTS

4.1 Enumeration of vascular plant species

Altogether 792 vascular plant species under 130 families were recorded based on primary and secondary sources from Kailali district, Western Nepal **(Appendix 1-3)**. Total 357 species were recorded from present study / primary sources and additional 435 species were obtained from different secondary sources **(Figure 4)**. Out of total vascular plant families; 11 Pteridophytes families, 1 Gymnosperm family, 21 monocot families and 97 dicot families were documented. Altogether 312 species of vascular plants were collected during the preliminary field visit and additional 45 species were collected during vegetation sampling. Total 279 species were collected from sampling plots with 234 species becomes repeated with the preliminary collection. Altogether 22 species of Pteridophytes, 1 species of Gymnosperms (*Pinus roxburghii* Sarg.), 240 species of Monocots and 529 species of Dicots were recorded and presented as a checklist **(Appendix 4-6)**.

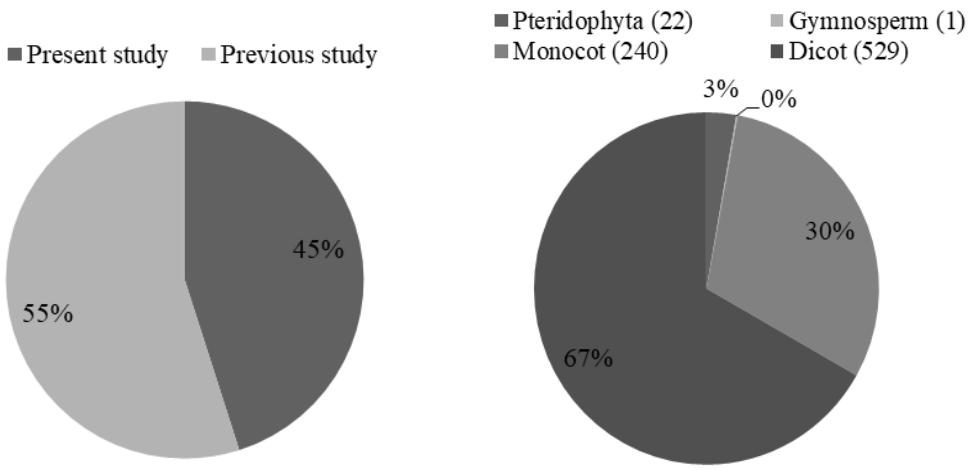

Figure 4. Contribution of vascular plant species based on primary and secondary sources

Based on total recorded vascular plant species from the district, top ten vascular plant families and species number were enumerated where Poaceae were dominant family followed by Fabaceae, Orchidaceae, Cyperaceae, Lamiaceae, Asteraceae, Malvaceae, Acanthaceae and Apocynaceae **(Figure 5)**.

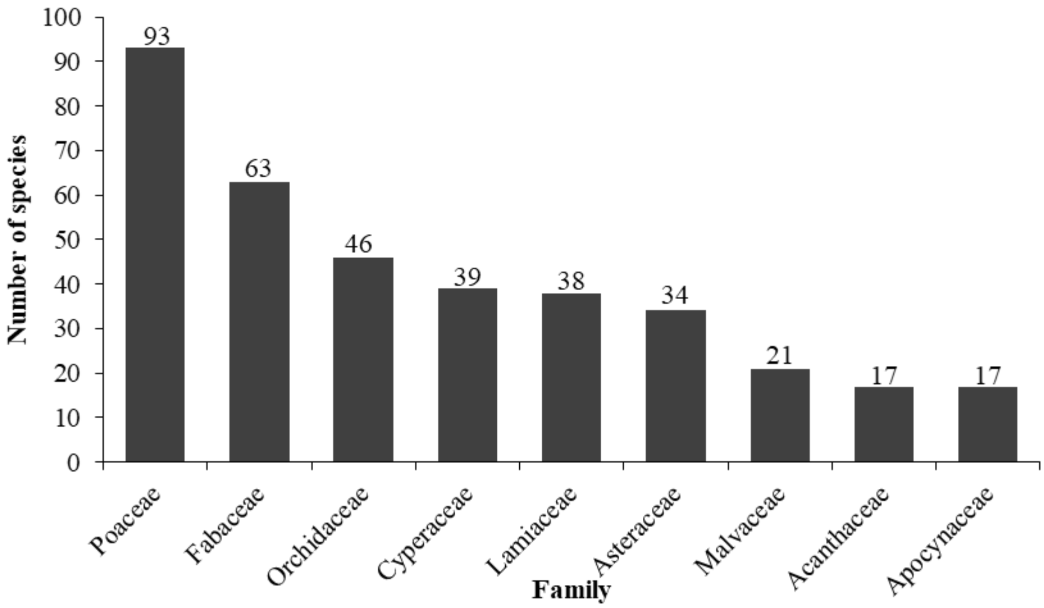

Figure 5. Top ten vascular plants families based on the number of species present.

4.2 Category of vascular plant species

Out of total vascular plant species; 670 were native species, 87 species naturalized and 35 species cryptogenic (native range not clear yet; August 2018). The naturalized species belong to 29 families, 70 genera and 87 naturalized species **(Figure 6)** and out of naturalized species, 66 species were naturalized non-invasive species and 21 species (24% of total naturalized species) were invasive which belong to 19 genera and 11families (**Figure 6b**).

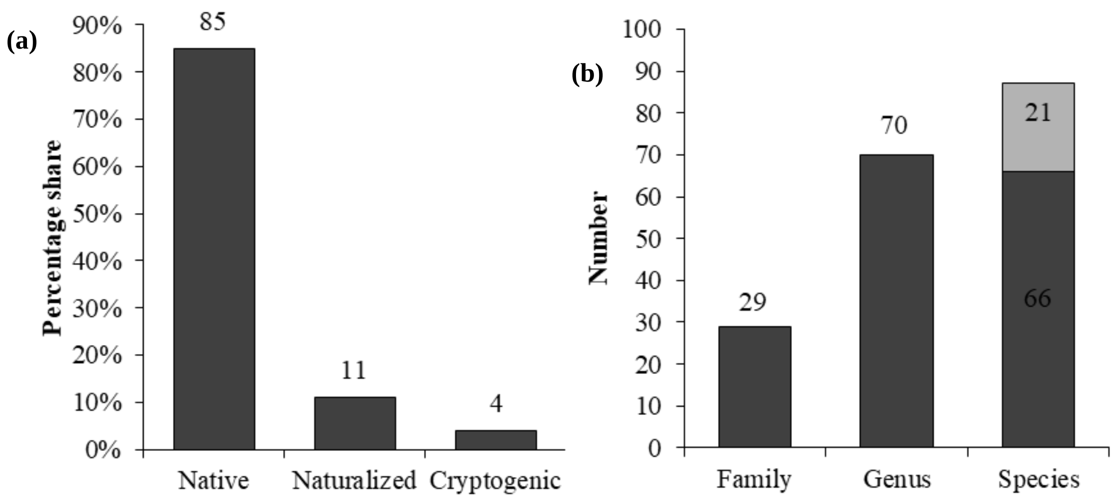

Figure 6. (a) Vascular plant categorization (b) naturalized species in different taxonomic groups.

The total number of naturalized plant species and invasive species within families were presented. Where, Asteraceae (16 species) was the biggest family of naturalized plant species followed by Amaranthaceae, Fabaceae, Poaceae, Euphorbiaceae, Solanaceae. Similarly, Asteraceae was the biggest family of invasive plant species followed by Fabaceae and Amaranthaceae **(Figure 7)**. While there were absence of invasive species in families like Poaceae, Euphorbiaceae, Solanaceae, Malvaceae, Brassicaceae, Cyperaceae, Onagraceae, Oxalidaceae, Adoxaceae, Apocynaceae, Asperagaceae, Boraginaceae, Martyniaceae, Myrtaceae, Nyctaginaceae, Piperaceae, Plantaginaceae and Sphenocleaceae but families like Papaveraceae, Pontederiaceae, Rubiaceae and Verbenaceae had invasive plant species only.

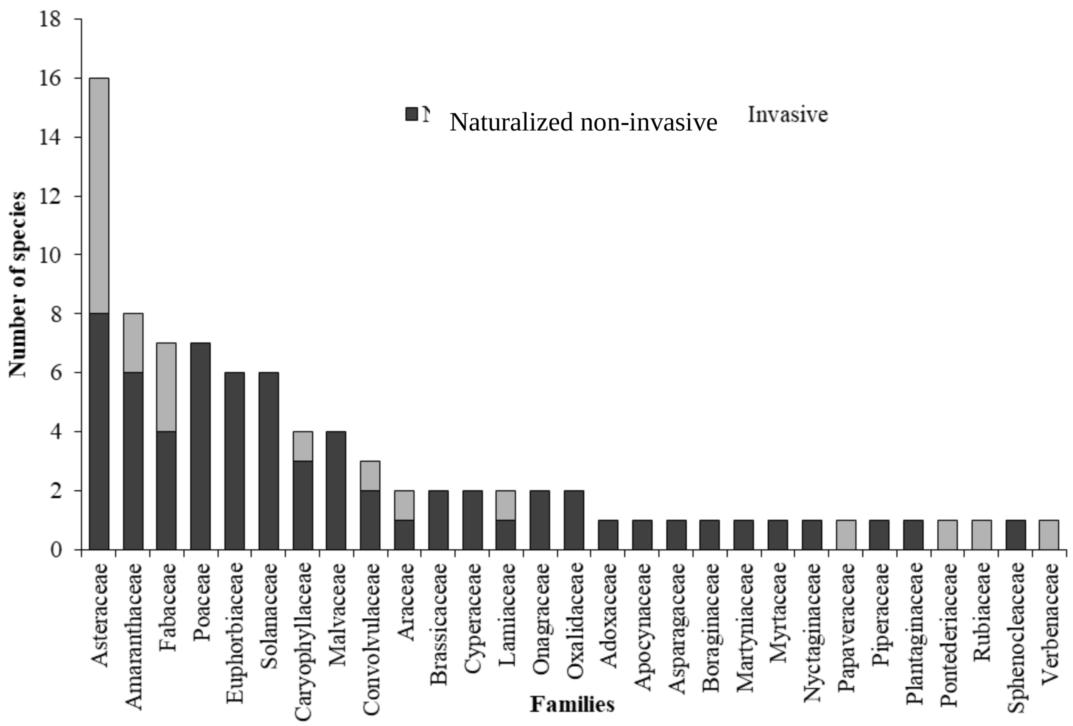

Figure 7. Number naturalized non-invasive and invasive species within each family.

4.3 Life forms and native range of naturalized plant species

The life form of all 87 naturalized plants species was categorized into herb, shrub, trees and climber species. Naturalized herbaceous species were found dominant (83%) followed by shrub, tree, and climber **(Figure 8a)**. Among total naturalized plant species, most of species (79%) were native to tropical America followed by Africa, Europe and Australia **(Figure 8b, Appendix 5)**.

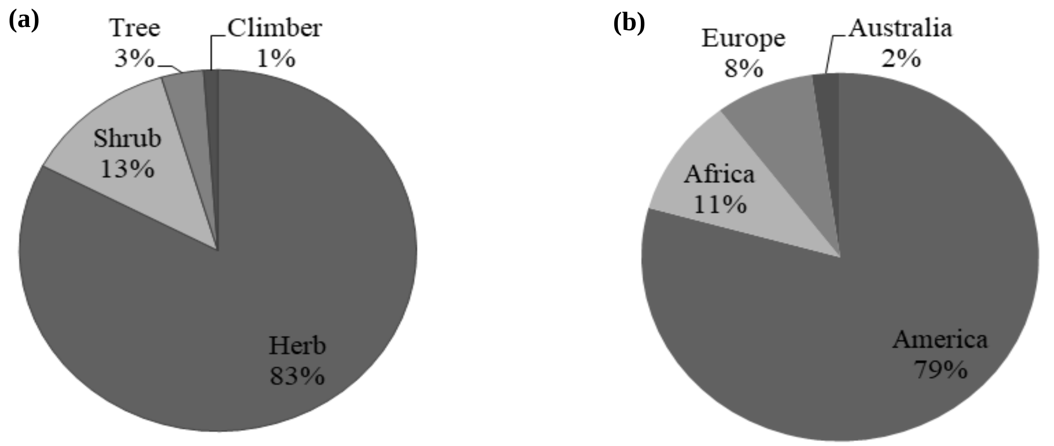

Figure 8. (a) Life forms of naturalized species (b) Native range of naturalized species.

4.4 Naturalized species diversity across land use types

Altogether 279 species of vascular plant species recorded from seven land use types having 201 native species, 43 naturalized (including 31 naturalized non-invasive and 12 invasive) species, 31 species were remains cryptogenic **(Appendix 6)**. Among studied land-use types, roadside grazing land had the highest number of naturalized species followed by agriculture land, degraded Sal forest, agriculture fallow land, mixed forest, riverine forest and least in *Shorea-Terminalia* forest (comparatively least disturbed land use). The roadside grazing land, agriculture land, degraded Sal forest had higher disturbance than other forests (mixed forest, riverine forest and *Shorea-Terminalia* forest) with least number of naturalized plant species. So, more human-modified and disturbed land use types had the higher richness of naturalized plant species as well as invasive species in comparison to the least disturbed land use types in the sample plots **(Appendix 7)**.

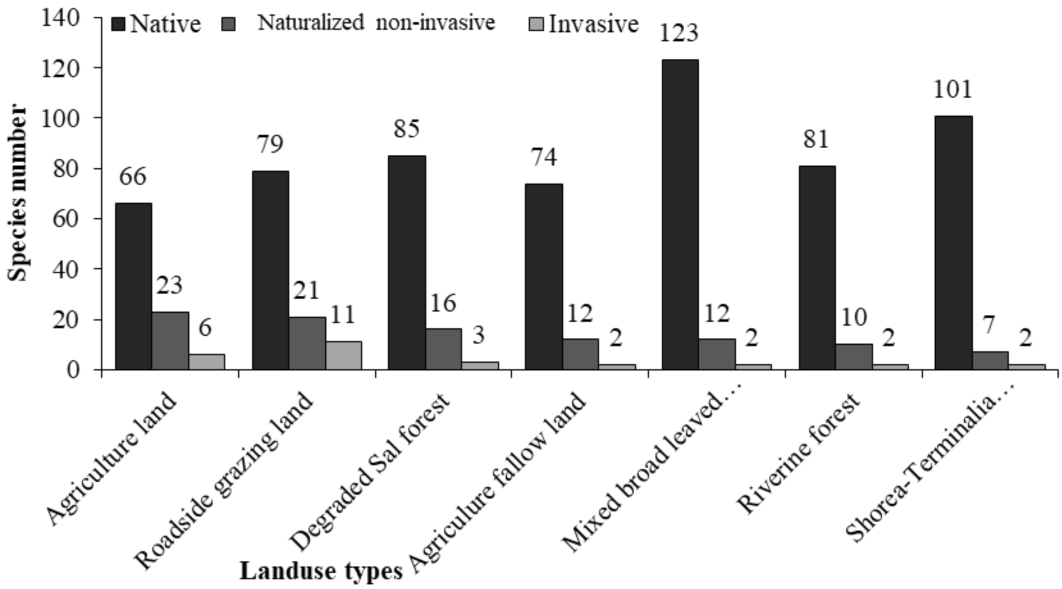

Figure 9. Number of native, naturalized non-invasive and invasive species across land use types.

The analysis of variance (ANOVA) across land use types with mean native species richness, mean naturalized species richness, mean invasive richness across sampling plots showed significance level (>0.05) for the test of normality. The descriptive statistics of land use types with mean native species richness mean naturalized species richness and mean invasive species richness with significance value and standard error were presented **(Table 2, Figure 10)**. Mean total vascular plant species richness was highest in mixed broad leaved forest followed by roadside grazing land, degraded Sal forest, *Shorea-Terminalia* forest, agriculture field, agriculture fallow land, and riverine forest. Mean native richness was found the highest in the mixed broad leaved forest followed by *Shorea-Terminalia* forest, riverine forest, degraded Sal forest, agriculture fallow land, roadside grazing land, and agriculture land. Similarly, mean naturalized species richness was the highest in roadside grazing land, agriculture land, degraded Sal forest, agriculture fallow land, mixed forest, riverine forest and *Shorea-Terminalia* forest while mean invasive richness was highest in roadside grazing land followed by agriculture land degraded Sal forest, agriculture fallow land, riverine forest, *Shorea-Terminalia* forest and least in the mixed broad leaved forest.

Table 2. Mean species richness of native, naturalized and invasive species richness values showed mean and standard error across different land use types.

Land use types	Native richness	Naturalized richness	Invasive richness
Agriculture land	25.6±3.62	11.4±2.11	2.8±0.2
Roadside grazing land	35.2±1.8	17.2±1.35	6.4±0.5
Degraded sal forest	37.6±1.93	10.4±0.67	2.6±0.24
Agriculture fallow land	35.8±1.46	6.2±1.06	1.4±0.5
Mixed broad leaved forest	51.6±1.5	5.2±0.37	0.6±0.4
Riverine forest	38±2.46	5.2±1.01	1±0.4
Shorea-Terminalia forest	42.6±1.54	3.6±1.43	0.8±0.2

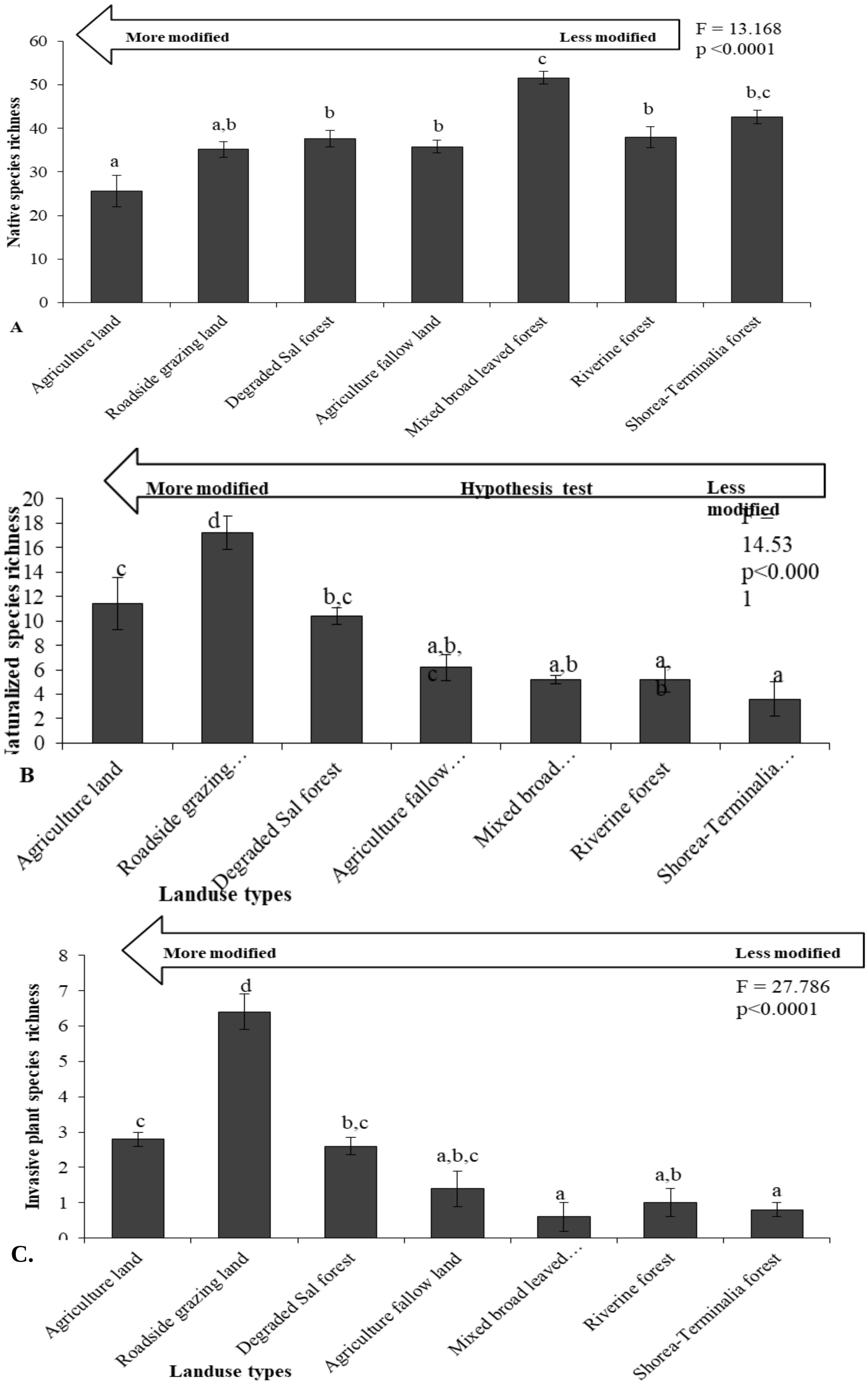

Figure 10. A. Native species richness, B. Naturalized species richness C. Invasive plant species richness (per 0.1 ha.) across land use types.

4.5 Species diversity across land use types

Among the sampled land use type (**Table 3**) in Kailali district, highest beta diversity ($\beta = 2.51$) was obtained in agriculture land (i.e. highest species turn over rate) which was followed by mixed broad leaved forest, road side grazing land and *Shorea-Terminalia* forest, riverine forest, degraded Sal forest and least in the agriculture fallow land.

Table 3. A comparative account of β-diversity of overall vascular plants species.

SN	Land-use types	Species	Species richness	β-diversity
1	Agriculture land	119	47.4	**2.51**
2	Roadside grazing land	127	56.8	2.24
3	Degraded Sal forest	114	53.2	2.14
4	Agriculture fallow land	97	46.6	2.08
5	Mixed broad leaved forest	150	60.4	2.48
6	Riverine forest	100	45.8	2.18
7	*Shorea-Terminalia* forest	111	49.6	2.24

4.6 Contribution of naturalized plant species across land use types

The percentage sharing of naturalized plant species were found higher in more disturbed and more modified land use types such as Roadside grazing land and agriculture land than in less disturbed and less modified land use types such as mixed broad leaved forest and *Shorea-Terminalia* forest **(Table 4)**.

Table 4. The percentage share of naturalized species across land use types.

SN	Land use types	Total number of species	No. of naturalized species	Naturalized sp. share (%)
1	Roadside grazing land	127	32	**25.2**
2	Agriculture land	119	29	24.4
3	Degraded Sal forest	114	19	16.7
4	Agriculture fallow land	97	14	14.4
5	Mixed broad leaved forest	150	14	9.3
6	Riverine forest	100	12	12
7	*Shorea-Terminalia* forest	111	9	8.1

4.7 Cover of invasive plant species

Overall canopy cover for invasive species from sampling plots was analyzed. Among 12 invasive species recorded from all sampling land use types, *Senna tora* had the highest canopy cover (63.87%) followed by *Ageratum houstonianum, Hyptis suaveolens, Parthenium hysterophorus* (Figure 11). Among all sampling land use types, *S. tora* was found the most dominant species in terms of cover **(Figure 11)** and had the highest cover in the roadside grazing land **(Appendix 9).**

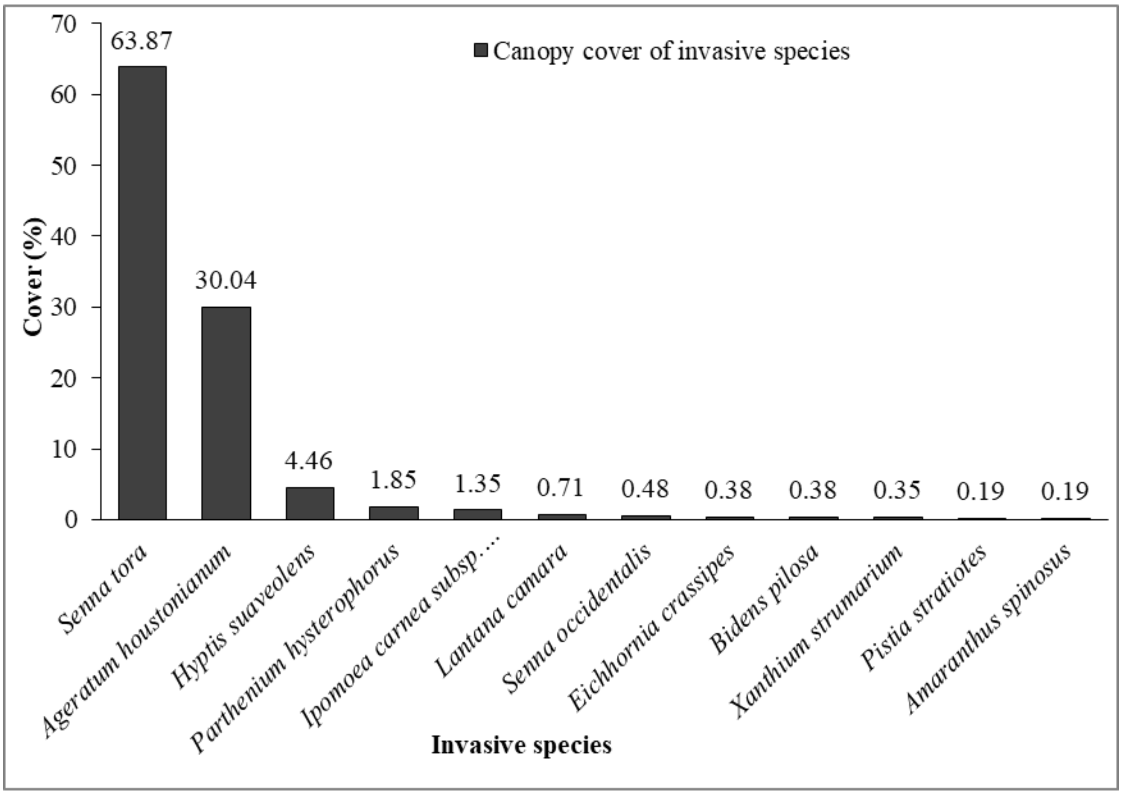

Figure 11. Average canopy cover of invasive species in selected land-use types.

4.8 Frequency of invasive species

Among total recorded invasive species, *Ageratum houstonianum* had the highest frequency (41.34%) followed by *Senna tora*, *Parthenium hysterophorus* **(Figure 12)**. Among all sampling land use types, *S. tora* was most frequent (95.5%) in roadside grazing land and followed by *A. houstonianum* in the degraded Sal forest (70.8%) and Agriculture land (69.2%) **(Appendix 10).**

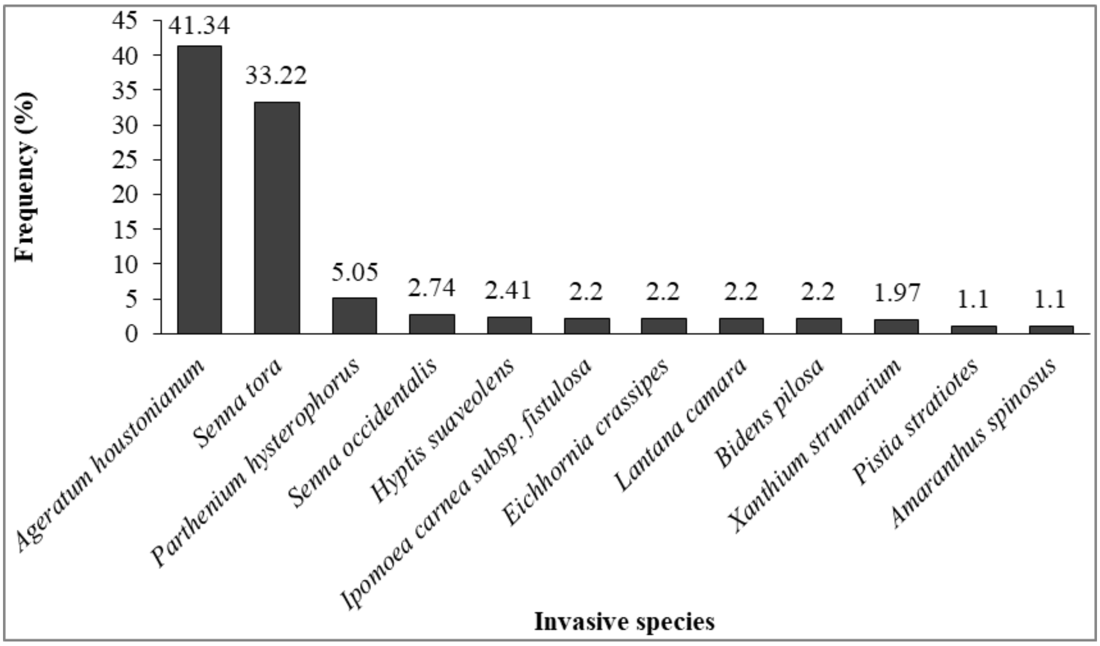

Figure 12. Frequency of invasive species in selected land use types.

4.9 Influence of environmental factors on naturalized plant species

Multivariate analysis for species richness of naturalized species and invasive species relationship with environmental variable such as disturbance factors (logging, fire, grazing), average tree canopy, distance from primary road, distance from river, distance from settlement, native richness, soil pH, SOC, total soil nitrogen were presented by ordination analysis. Detrended Correspondence Analysis (DCA) ordination showed the relationship between species richness, sampling plots and environmental variables with the Eigen values 0.385 and 0.333 on axes I and II respectively **(Table 5)**. Similarly, lengths of the gradient were found 4.447 on axes I and 3.349 on axes II. Therefore, length of gradient in DCA axes-I was found >2.5 (SD units). Therefore, Canonical Correspondence Analysis (CCA) was performed for naturalized species richness **(Table 6)**.

The CCA ordination explained the relationship of naturalized plant species with sample plots and environmental variables (**Figure 13A and 13B**). Relative importance of environmental variables and their impact on naturalized species composition was derived from the Monte Carlo Permutation test and it was observed that naturalized species was governed ($p \leq 0.05$) by grazing, native species richness, distance from river, total soil nitrogen, average tree canopy, Soil pH, distance from settlement, distance from road **(Table 7)**, These were the significant variables that affect the diversity of naturalized species in different land use and vegetation types. However, other environmental variables such as fire, elevation, logging, and SOC had less significance over the distribution of naturalized species in the present study.

Table 5. Detrended Correspondence Analysis (DCA) ordination summary for naturalized plant species and different environmental variables.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigen values	0.38	0.33	0.22	0.15	3.593
Length of gradient	**4.44**	3.34	2.74	2.07	
Species-environment correlations	0.75	0.75	0.612	0.903	
Cumulative %tage varience of species data	10.7	20.0	26.1	30.5	
Cumulative %tage varience of sp.-env. relations	12.8	22.4	0	0	
Sum of all eigen values					3.593
Sum of all canonical values					1.544

Table 6. Canonical Correspondance Analysis (CCA) ordination summary for naturalized species and different environmental variables.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigen values	0.27	0.23	0.19	0.18	3.593
Species-environment correlation	0.91	0.94	0.90	0.86	
Cumulative percentage varience of species	7.6	14.0	19.4	24.6	
Cumulative %tage varience of sp.-env. relations	17.7	32.6	45.2	57.2	
Sum of all eigen values					3.593
Sum of al canonical eigen values					1.544

Table 7. Relative importance of environmental variable and their impact on naturalized species composition as derived by Monte Carlo permutation test (with 9999 replicates) of Canonical Correspondance Analysis ordination.

SN	Environmental variable	Abbreviation	F-value	p-value
1	Grazing	Graz	1.803	**0.0005**
2	Native species richness	Nat.rich	1.783	**0.0026**
3	Distance from river	Dist.riv	1.723	**0.0045**
4	Average tree canopy	Av.canp	1.69	**0.0014**
5	Total soil nitrogen	N2	1.658	**0.0086**
6	Soil pH	PH	1.523	**0.0212**
7	Distance from settlement	Dist.set	1.457	**0.040**
8	Distance from road	Dist.roa	1.45	**0.046**
9	Elevation	Elev	1.395	0.089
10	Soil organic carbon	SOC	1.23	0.19
11	Logging	Logi	1.076	0.328
12	Fire	Fire	1.057	0.37

***Bold letter represents statistically significant values.**

The multivariate analysis showed the environmental variables like grazing, native species richness, distance from river, tree canopy, total soil nitrogen, soil pH, distance from settlement area, distance from road were showed significant relation ($p \leq 0.05$) with naturalized species richness than elevation, soil organic carbon, logging, and fire impact in the study area (**Table 7**). The naturalized plant species were associated with disturbance as, *Parthenium hysterophorus, Amaranthus spinosus, Lantana camara* were associated with grazing. Similarly, naturalized species such as *Ageratum houstonianum, Senna tora, Gomphrena celosoides* were associated with road side and settlement areas (**Figure 13B**).

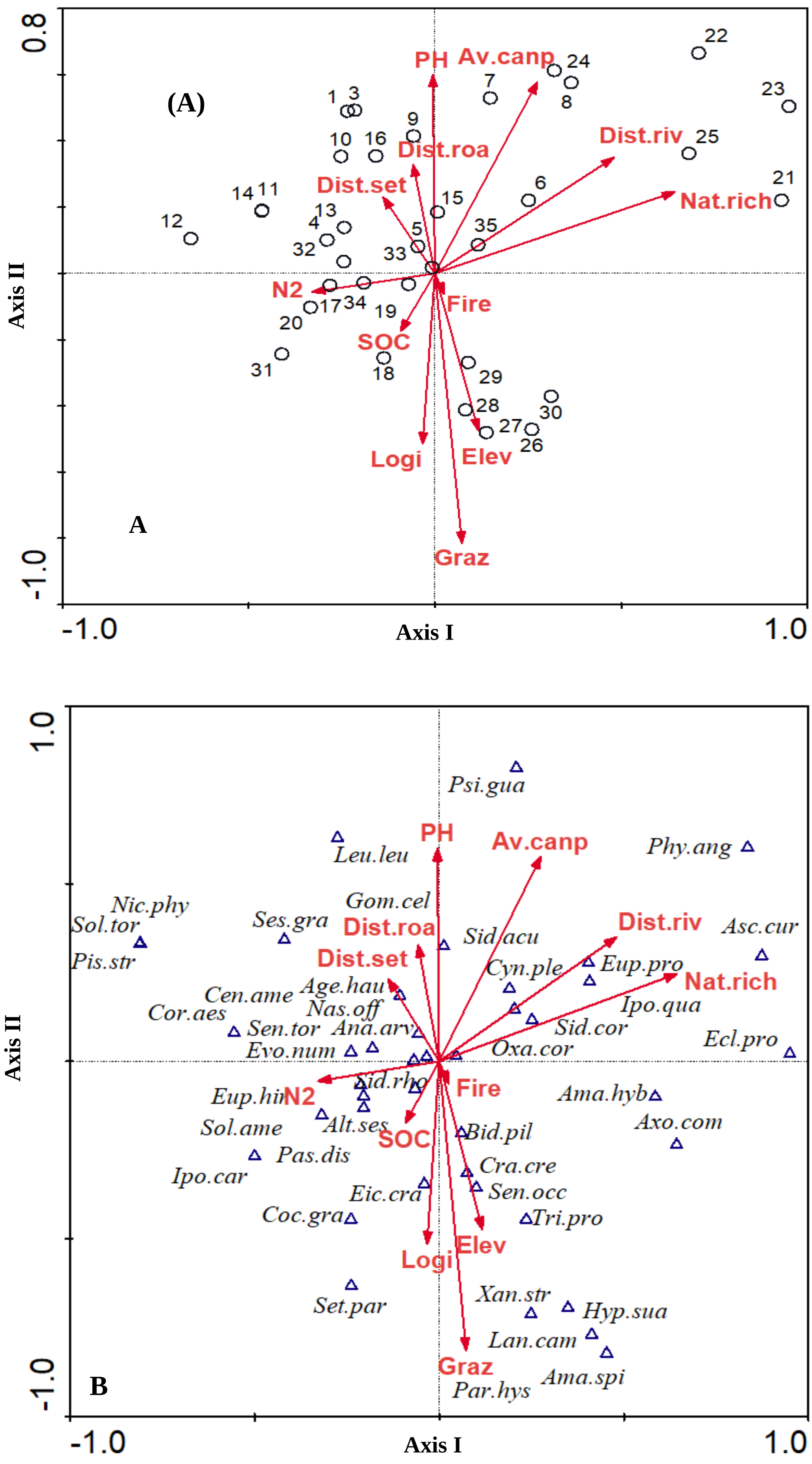

Figure 13. CCA biplot for (A) sample plots and environmental vaiables (B) environmental variables and naturalized species. Environmental variables abbreviation given in the table 7, while in species naming first three letters indicates generic name and last three with species epithet (**Appendix 5**).

From the above diagram **(Figure 13A)**, there was no distinct clustering of sampling plots because of almost similar kind of species composition in almost sampling sites, it might be due to sample plots were located in the low land (Tarai) and sampling sites were close to each other. Similarly, no distinct groupings of vascular plant species were recorded. Based on CCA ordination, disturbance factors were highly correlated with the naturalized species distribution. Depending upon the length of gradient of first axis value for DCA ordination (**Table 8**), the different environmental variables, and invasive plant species relationship were presented by RDA ordination). Relative importance of environmental variables and their impact on invasive species composition was derived from the Monte Carlo Permutation test (with 9999 replicates) and it was observed that invasive species was governed ($p \leq 0.05$) by naturalized non-invasive richness, grazing, average tree canopy, soil pH, native species richness, and elevation **(Table 10)**.

Table 8. DCA ordination summary for invasive plant species and environmental variables.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigen values	0.471	0.252	0.094	0.027	1.897
Length of gradient	**2.113**	1.587	1.507	1.233	
Species - environment correlations	0.964	0.757	0.593	0.760	
Cummulative %tage variance of sp. data	24.8	38.1	43.1	44.5	
Cummulative %tage variance of sp.- env relation	37.3	48.8	0	0	
Sum of all eigen values					1.897
Sum of all canonical eigen values					1.075

Table 9. RDA ordination summary for invasive species and environmental variables.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigen values	0.293	0.104	0.059	0.044	1.00
Sp. - env. correlations	0.895	0.737	0.698	0.718	
Cummulative percentage variance of sp. data	29.3	39.8	45.8	50.1	
Cum. %tage variance of sp.-env. relation	55.2	74.9	86.0	94.3	
Sum of all eigen values					1.00
Sum of all canonical eigen values					0.531

Table 10. Relative importance of environmental variable and their impact on invasive species composition as derived by Monte Carlo permutation test of RDA ordination.

SN	Environmental variable	Abbreviation	F-value	p-value
1	Naturalized non-invasive richness	Non-inv	6.376	**0.002**
2	Grazing	Graz	5.6	**0.002**
3	Soil pH	PH	4.673	**0.002**
4	Average tree canopy	Av.canp	4.711	**0.004**
5	Native species richness	Nat.rich	3.074	**0.014**
6	Elevation	Elev	2.665	**0.036**
7	Distance from settlement	Dist.set	2.138	0.072
8	Distance from road	Dist.roa	1.811	0.106
9	Soil organic carbon	SOC	1.735	0.108
10	Distance from river	Dist.riv	1.569	0.15
11	Logging	Logi	1.444	0.168
12	Total soil nitrogen	N2	0.66	0.704
13	Fire	Fire	0.233	1.00

***Bold letter represents statistically significant values.**

The relationship between different invasive plant species and environmental variables were analyzed by RDA ordination (**Table 9**, **Figure 14**). Therefore, invasive species diversity and distribution was significantly governed by different environmental variables like naturalized non-invasive richness, grazing, soil pH, average tree canopy, native species richness, elevation while other environmental variables like distance from settlement area, distance from road, soil organic carbon, distance from river, logging, total soil nitrogen and fire impact were less significant in the study area.

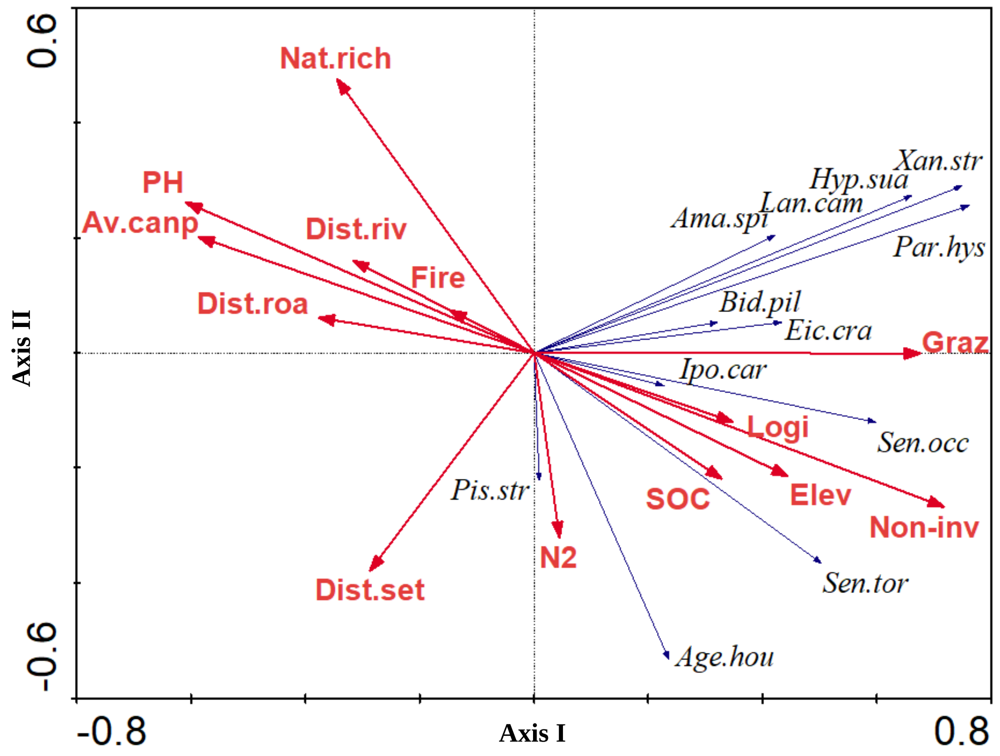

Figure 14. RDA biplot for the environmental variables and invasive species richness.

4.10 Relation of naturalized species richness with environmental factors

The naturalized plant species diversity was governed by different observed environmental variables **(Figure 15)**. Naturalized species richness and its relationship with closer distance from highway/primary road, distance from settlement area, distance from river, average tree canopy, soil pH, SOC, total soil nitrogen, native species richness, grazing, elevation, logging were analyzed by Generalized Linear Model (GLM) regression and naturalized species richness showed significant (<0.05) relationship with distance from road, river distance, average tree canopy, soil pH, SOC, native species richness and grazing effect. The regression statistics between different variables were analyzed up to 2nd order unimodal analysis **(Appendix 11).**

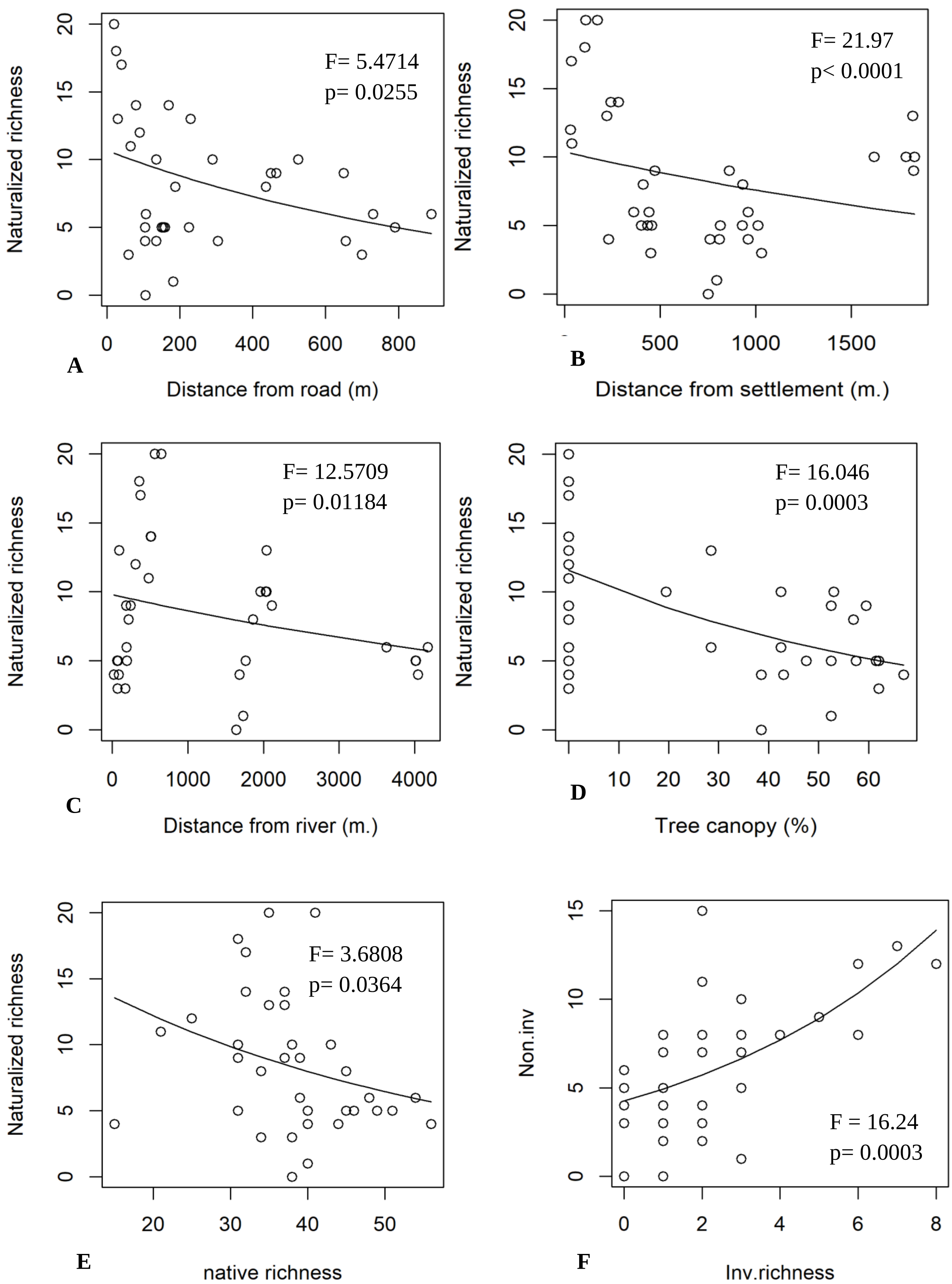

Figure 15. Relationship between naturalized species and with different variables (A) naturalized species richness with distance from road (B) naturalized species richness with distance from settlement (C) naturalized species richness with distance from river (D) naturalized species richness with average tree canopy (E) naturalized species richness with native species richness (F) naturalized non-invasive species richness with invasive species richness.

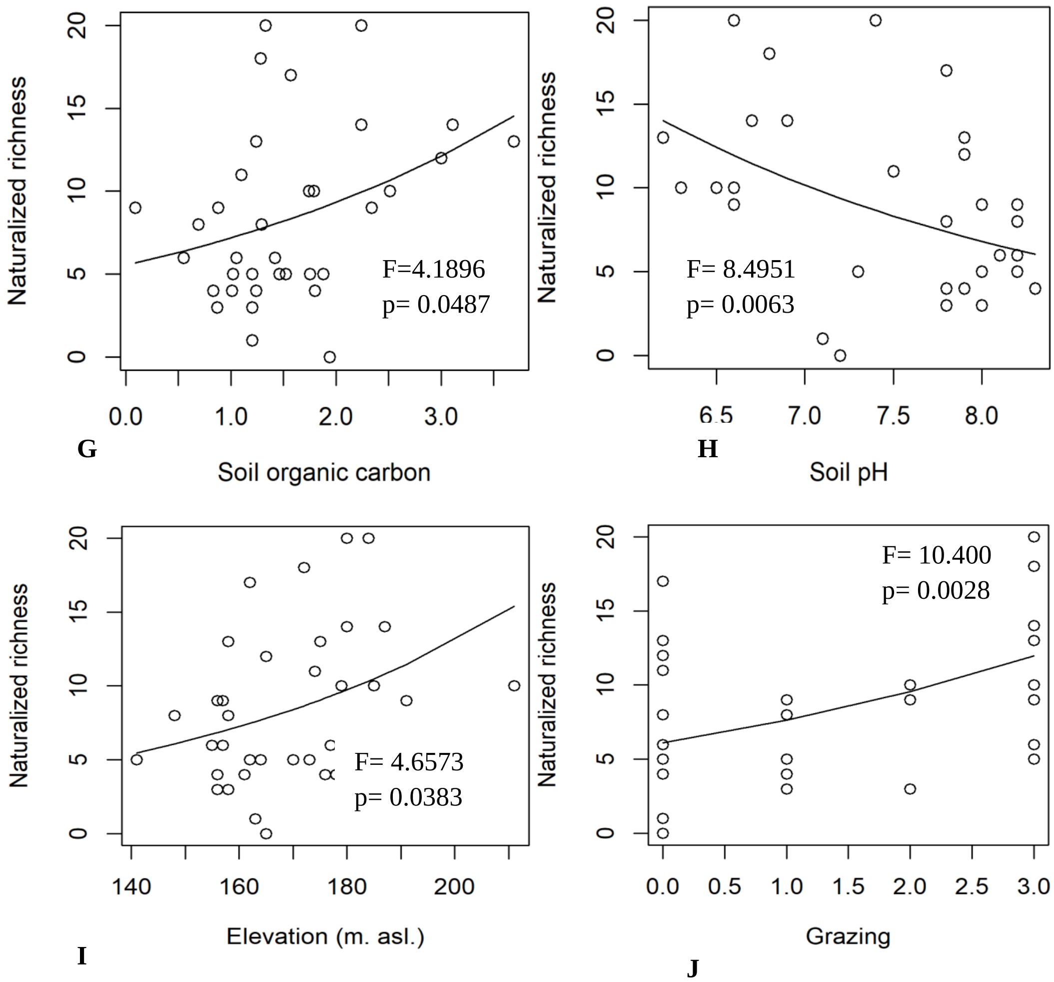

Figure 15. Relationship between naturalized species and with different variables (G) naturalized species richness with soil organic carbon (H) naturalized species richness with soil pH (I) naturalized species richness with elevation (J) naturalized species richness with grazing.

GLM regression analysis showed that naturalized species richness decreased with increasing distance from road networks, settlement area, and river distance. Similarly naturalized species richness increased with the declining tree canopy. High grazing impact and logging also affect the naturalized species richness significantly. The naturalized species richness also increased with increasing elevation. Naturalized species richness was dicreased with increasing native species richness in overall.

CHAPTER 5: DISCUSSION

5.1 Floristic composition of vascular plant species

The present study area is bestowed with the wide range of floral diversity in Kailali district, Western, Nepal. There are limited researches carried for the documentation of vascular plant species focusing on higher plants and ethno-medicinal plants used by tribal peoples but naturalized plants have not been explored. The documentation of vascular plant species based on primary source (present study) and secondary sources (Lamsal *et al.,* 2014; Bhattarai and Acharya, 2015; Rajbhandari *et al*., 2015; Rajbhandari *et al.,* 2016; Rajbhandari *et al*., 2017; Rajbhandari and Rai, 2017) revealed the documentation of vascular plant species. Poaceae is the dominant family, followed by Fabaceae and Orchidaceae as top three dominant families **(Figure 5)** and also, according to Rajbhandari *et al*., (2016) these three families are dominant families.

5.2 Naturalized species diversity in the district

Out of 792 species reported in the present study, 87 species were aliens that were naturalized. Among these naturalized species, 24 % (21 species) were invasive. According to the "rule of tens", 10% of introduced species have chance to turn into naturalized and 10% among naturalized have chance to turn into invasive and the range to turn in to invasive is 5-20 % (Williamson 1996; Jaric and Cvijanovic, 2012). In this study 24% of naturalized were turn in to invasive, this was slightly more than the predicted range of tens rule. While in case of national data of Nepal 26 species were turn in to invasive out of 179 naturalized species (Shrestha *et al*. 2017; Shrestha *et al.* 2019). That means 15 % of naturalized species were turn in to invasive, which is consistent with the range predicted by tens rule. In Kailali district, the largest number of naturalized plant species belongs to family Asteraceae. This family has been also reported as the largest for naturalized plant species in the different parts of Nepal by Tiwari *et al.*, (2005); Siwakoti, (2012); Chataut, (2017); Dhakal, (2017); Thapa, (2017); Bhattrai, (2018). The dominance of family Asteraceae may be attributed to its massive seed production and efficient seed dispersal mechanism (Arianoutsou *et al*., 2013). The comparative research on Mediterranean biomes also revealed the Asteraceae is the dominant family among 1627 naturalized plant species (Arianoutsou *et al*., 2013). Out of 26 invasive plant species of the country, 21 species were recorded from Kailali district during the present study. Therefore, based on the present study we can say that, only five invasive plant species of Nepal were absent in the Kailali district. Although, *Chromolaena odorata*, *Oxalis latifolia* were reported from adjoining districts of Kailali such as Bardia district (Poudel, 2016). Therefore, there is a probability of introduction of these species to Kailali district in the future. Hence, this district is much vulnerable with the challenge of these species, as these species are common in Tarai area of Nepal (Siwakoti, 2012).

5.3 Native range and life forms of naturalized species

In Nepal, there are 179 naturalized plant species (Shrestha *et al*., 2019) and 26 invasive plant species (Shrestha *et al*., 2017) and the majority are native to tropical America (Bhattarai *et al*., 2014). Our result also indicates that 79% naturalized species are native to tropical America. Therefore, present finding resembles 3/4th of naturalized plant species are neo-tropical origin by Bhattarai *et al*., 2014. Based on life forms, the annual herbs were dominant life forms (83%) of naturalized species followed by shrubs (13%), Tree (3%) and climber (1%) which is similar to the findings of Pettit *et al*., (1995) and Thapa, (2017). The alien species are considered as ruderal species which is found in highly disturbed land use and they are best to exploit the gap created by perennial species (Pittit *et al*., 1995).

5.4 Cover and frequency of invasive plant species

In terms of coverage and frequency, *Senna tora* was the most dominant species along the roadside grazing land followed by *Ageratum houstonianum* in the degraded Sal forest and agriculture land. Therefore, *A. houstonianum* is most dominant weed and recorded from almost all sampled land use types and this species recorded as one of the top-ranked worst invasive species in agro-ecosystem of Chitwan-Annapurna Landscape, central Nepal (Shrestha *et al*., 2019). *A. houstonianum* was also recorded as the second most frequent invasive species in the Tarai and Siwalik regions of central Nepal (Dhakal, 2017). The *S. tora* has been spreading in roadside agro-ecosystems of Nepal and *Parthenium hysterophorus* is one of the harmful weed of agro-ecosystem and third most dominant invasive species along roadside in central Nepal (Paudel, 2015; Poudel, 2016). A similar pattern has been also observed in the present study area. *P. hysterophorus* is initially invaded in the roadside grazing land and then spread towards agro-ecosystem and forest areas by mean of vehicle movement and transportation of agricultural products are the main mean to spread seeds to another land area (Shrestha *et al*., 2015).

Out of total recorded invasive species, *Lantana camara* and *Eichhornia crassipes* were among the 100 of the world's worst invasive species (Lowe *et al.*, 2000). But, *Lantana camara* and *Eichhornia crassipes* are already common in the different locations of the district. *Eichhornia crassipes* is reported from almost all Ramsar sites in Nepal (Siwakoti, 2012, Lamsal *et al.*, 2014) but it was absent in Ghodaghodi lake area system (personal observation, 2018). However, the areas that surround Ghodaghodi Lake, *E. crassipes* could be found. *E. crassipes* is the most troublesome invasive species in the aquatic ecosystem of Tarai, Siwalik, and Mid Hills and threatening the Ramsar sites and negatively affect the wetland biodiversity of Nepal (Siwakoti, 2006; MoFSC, 2017). Therefore, regular monitoring of this invasive weed in such aquatic ecosystem is of urgent need. The impact of invasive species includes economic losses due to the loss of agricultural productivity, increased labor cost to remove these weeds from agriculture field as well as from aquatic ecosystem and cause health hazards to human and livestock (Shrestha *et al*. 2015).

5.5 Species diversity across land-use types

Total species richness was found highest in the mixed broad leaved forest followed by roadside grazing land, agriculture land, degraded Sal forest, *Shorea-Terminalia* forest, riverine forest, and agriculture fallow land. Mixed broad leaved forest was moderately disturbed interms of loging, grazing, local level tourist destination (adjoining to Ghodaghodi lake system) and close distance from Mahendra highway; it supports the theory of intermediate disturbance as moderate disturbance supports more heterogeneous communities (Dial and Roughgarden, 1998). We obtain statistically significant ($P<0.05$) difference in native richness, naturalized richness and invasive richness across different land use types. The present study found significant ($p<0.0001$) relation with mean native species richness, naturalized richness and invasive richness across different land use. The α-diversity and β-diversity were found to be different at vegetation types across land use types. The β-diversity was found the highest in agriculture land (2.51) because of the highly modified ecosystem, high disturbance, species heterogeneity and followed by mixed broad leaved forest (2.48) while least in agriculture fallow land (2.08). Since, species turnover or beta diversity is the number of species eliminated and replaced per unit time, local richness gradient has major impact on estimation of beta diversity and greater turnover is obtained in localities with low species richness (Magurran, 2004) but, present result differs with this, while it partly resembled with the findings of Chataut (2017) and Dhakal (2017).

5.6 Land use and naturalized plants diversity

The species composition depends upon the degree of invasion, disturbance like grazing intensity, environmental gradients and soil nutrients (carbon, nitrogen). Livestock grazing could have a profound effect on the structure of vegetation (Illius and O'Conner, 1999). Land use the determining factors for the distribution of alien (naturalized, invasive) plant species and considered as one the factors for plant invasion; similarly, vegetation types are one of the determining factors for the plant invasion (Lonsdale, 1999). Our results showed a significant relation ($p \leq 0.05$) of the naturalized plant species across different land use types in the study area **(Table 2)**. Invasive species such as *Ageratum houstonianum, Parthenium hysterophorus, Hyptis suaveolens, Amaranthus spinosus, Xanthium strumarium, Bidens pilosa, Lantana camara, Eichhornia crassipes, Senna occidentalis, Ipomoea carnea subsp. fistulosa, Senna tora* are found in roadside grazing land which is similar to the result of Paudel (2015) and Poudel (2016). Invasive species like *A. houstonianum, S. tora, P. stratiotes, E.crassipes, B. pilosa, I. carnea subsp. fistulosa* found in agriculture field, *A. houstonianum, S. tora, S. occidentalis* found in degraded Sal forest, *A. houstonianum* and *S. tora* recorded from agriculture fallow land while *A. houstonianum* and *S. tora* are common in mixed broad leaved forest, riverine forest and *Shorea-Terminalia* forest such type of land use for invasive species is partly supported by Tiwari *et al*., (2005); Siwakoti, (2012); Shrestha, (2016). Highest number of naturalized species found in more modified and more disturbed land use types such as roadside grazing land with 32 species (25.2% to total floristic composition of that vegetation), this study site is very close to Mahendra highway and more disturbed land in terms of grazing, open canopy (deforestration effect), logging, vehicle movements, transportation facility, anthropogenic activities etc. And, then naturalized species richness followed by agriculture land (29 species; 24.4%), degraded Sal forest (19 species; 17.7%), agriculture fallow land (14 species; 14.4%), mixed broad leaved forest (14 species; 9.3%), riverine forest (12 species; 12%) and least in *Shorea-Terminalia* forest (9 species; 8.1%). Again, degraded forests and roadside may have the higher number of alien species (Pauchard and Alaback, 2004) which may be due to frequent grazing and also, transportation facilities which act as a carrier of propagule up to higher elevation where road networks already connected. But, now invasion is directed towards the less disturbed environment due to increasing propagule pressure, natural and anthropogenic disturbance and resistance of the established communities (Pauchard *et al*., 2009). This increasing impact of alien plant species in more disturbed and more modified land use types support the present research hypothesis. Therefore, present results are consistent with the fact that human activities have an important influence on the dispersal and establishment of alien plants (Sax and Brown 2000; Liu *et al*., 2005).

5.7 Naturalized plant species richness and governing factors

Our results demonstrate the distribution of naturalized species across seven land use types and analyze the factors affecting naturalized plants diversity. Land use modification is one of the major determining factors for the plant invasion (Lansdale, 1999) and therefore, more modified land use supports more number of naturalized species. Invasive species also show the same pattern as more modified and more disturbed land use types having higher invasive richness. Therefore, increased light exposure, water runoff, road networks facilitate that the seed dispersal mechanism (Forman and Alexander, 1998). Agriculture land and roadside grazing land suffered from anthropogenic activities and disturbances such as near area from road, settlement, local pathways, grazing, logging, trampling, open canopy, high rate of litter decomposition (soil nitrogen, SOC, soil pH), which is suitable for the colonization of naturalized species (Deutschewitz *et al*., 2004) while, in *Shorea-Terminalia* forest, mixed broad leaved forest and riverine forest having less number of naturalized species due to low disturbance. Major disturbance such as fire, grazing, high tree canopy and far distance from road, trail, pathways (anthropogenic activities) and community settlement area determine the populations of naturalized plant species and it is supported by Seipel *et al*., (2012) which mentioned the distance from trail, and community settlement determine the population of naturalized plant species.

The increasing volume of global trade and land use changes enhance the opportunity for global spreading of alien species and are likely to become challenging in future. The problem of invasive species is the global issue; it continues to grow in socio-economy, health, gross agricultural productivity and ecology around the globe. Alien species exacerbates poverty and threaten the development through their impact in agriculture, forestry and peoples livelihoods in the developing countries (Mattews and Brandt, 2004). The land use types which are more modified that have greater chances of invasion by exotic species than the pristine lands similarly islands are more easily invaded than the mainlands (Simberloff and Holle, 1999).

In the present study, naturalized plant species richness show a significant relation ($p<0.05$) with road distance from sample plots. Therefore, naturalized plant species richness significantly increases with decrease in distance from road (**Figure 15A**). Roadside grazing land, agriculture land and degraded Sal forest which is affected ($p<0.05$) by grazing that favoring the naturalized species richness and invasive species richness; it is similar to findings of Anderson *et al*., (2015); Paneru, (2018). This may be due to the availability of enough resources like light, nutrients with open canopy, which is similar to Thapa (2017).

The naturalized species richness increases with decreasing distance from settlement area **(Figure 15B)** i.e., closer the settlement area higher the abundance of naturalized and invasive species (Seipel *et al*., 2012). It depends on the intensity of disturbance on land use so; settlement area is more disturbed and more suited for the establishment and spread of species in surrounding areas. This view was supported by Kirpluk and Bomanowska (2015). The major anthropogenic activities human movement, farming, transportation, business, cattle grazing, logging, garbage waste that help in arrival and distribution of invasive species propagules in different areas where they can colonize and affect the native community (Colautti *et al*., 2006). Similarly, distance from the river shows a significant relationship with naturalized species richness. Therefore, naturalized species richness increase with decrease in distance from the river **(Figure 15C)**. River or running water bodies serves as dispersal pathways for the translocations of diospores from one location to the adjacent, so nearby sampling area from river having the higher number of naturalized species.

Naturalized plant species richness shows significant relation with tree canopy cover **(Figure 15D)**. The naturalized plant species richness increases with decrease in tree canopy cover i.e., open tree canopy more favors the naturalized plant species (Fagan and Peart, 2004; Bhuju *et al*., 2013). The highest number of naturalized plants richness observed in the open tree canopy (i.e., roadside grazing lands, agriculture land, degraded Sal forest, agriculture fallow land) and naturalized species absent in more than 70% tree canopy cover. The relationship between the tree canopy cover and naturalized species richness shows negative relationship i.e., with increasing tree canopy there is a decrease in naturalized plants richness (Chaudhary, 2015; Chataut, 2017). Most of the invasive plants are herbaceous and better suited on open canopy (D'Antonio *et al.,* 1992). Those vegetation types having the higher tree canopy cover, that less supports naturalized species richness. It might be due to naturalized species are the light demanding, so in roadside grass land, agriculture land, degraded Sal forest with sparse tree canopy that supports the more naturalized plant species. Naturalized plant species richness also significantly governed by native species richness. With the increase in naturalized plants richness, there is significant decrease in the native flora of that sample plot **(Figure 15E).** It has been proposed that biotic resistant hypothesis offered by the native enemy, competitors and disease organisms play a significant role to resist invasion (Hunt and Yamada, 2003). In the present study, there is a significant relationship with native species richness and naturalized species richness, as with increasing native species richness there is a significant decrease in naturalized species richness, therefore, biotic resistance hypothesis is accepted (Peng *et al*., 2019). At 0.1 hector scales, with increasing the native species richness there is decrease in naturalized species richness so; GLM regression strongly supported this theory of biotic resistance hypothesis across 0.1hectors scales sample.

Fire impact is not clearly illustrated here **(Figure 13B)** because, it is frequently present (i.e., low fire evidence) but, fire is considered one of the major factors for biological invasions (Brooks and Lusk, 2008; Abella and Fornwalt, 2015). Fire evidence was found only in two sampling plots so, fire impact is not significant in the present study. According to Thapa (2017), it was the most governing factor for the distribution of naturalized plant species in the high elevation of central Nepal. It was also observed that fire may facilitate the invasion mechanism in grass prairie in USA (Stolgren *et al*., 1995). It may be due to the high intensity fire consume plant biomass, reduces the consumption of soil nutrients that increases the potentiality of invasive species.

Naturalized diversity becomes decreases along the elevation range (Thapa, 2017) but, present study shows that with increasing elevation, overall naturalized species richness also increasing. It is because of the small range of elevation in sampling study area (i.e., 130 – 220 m. asl.) but most of the studies on elevation distribution of any species shows unimodal patterns (Bhattarai and Vetaas, 2003; Baniya, *et al*, 2009). The unimodal relation has been also reported for naturalized plant species along an elevation gradient in Nepal shows the maximum richness of naturalized plant species was found at 1100 m. elevation (Bhattarai *et al*., 2014). Also, different vegetation types are invaded by naturalized species and areas with more precipitation at lower elevation have greater number of naturalized species (Larson *et al*., 2001).

Grazing is another responsible factor that governed the diversity of naturalized plant species **(Figure 13B and Figure 15J)**. High intensity of grazing impact may facilitate the naturalized species (Banjade, 2017; Chataut, 2017; Dhakal, 2017; Thapa, 2017; Bhattrai, 2018), which is similar to present findings. Grazing impact is higher in grasslands which is one of the major drivers for dispersal by animal's movements (Pouchard and Alaback, 2004). Therefore, animal grazing serves as dispersal pathways for naturalized species. Also, grazing affects the soil physio-chemical properties i.e., increasing soil pH and decreasing soil organic carbon (Paneru, 2018). Soil organic carbon and nitrogen play vital role in the growth and development of plants and continuous use of organic and inorganic fertilizers influences soil physical and chemical properties (Dhillon *et al*., 2018). Therefore, soil nutrition plays a vital role for the naturalized species establishment.

More disturbed land use and open canopy areas like grassland, roadside, fallow land are best reservoirs for the alien plant's propagules dispersal. The present study also indicated that, the modified and disturbed land-use types (roadside grazing land and agriculture land, fallow land, degraded forest) are much abundant with naturalized species; this finding is similar with Tyser and Worley, (1992). Therefore, there is a high chance of having naturalized plant species in such land use and this may be due to the availability of enough resources like nutrients (soil organic carbon, soil nitrogen) for plant invasions. Species composition depends upon the degree of invasion, disturbance, water sources, climatic conditions, environmental gradient and soil nutrients (Davis *et al*., 2000). The impact of invasive species includes economic losses due to the loss of agricultural productivity, increased labor cost to remove these weeds in the agriculture field, health hazards to human and livestock (Shrestha *et al*., 2015; Paini *et al*., 2016).

The distributions of invasive species are spreading rapidly and somewhere just started their invasion in Kailali district. According to Poudel (2016), *Mikania micrantha* was absent in Western, Nepal and in the present study also. *Lantana camara*, *Ipomoea carnea* subsp. *fistulosa* was planted as a hedge plant but, now spreading rapidly in the roadside and agro-ecosystems. Similarly, *Ageratum houstonianum* emerged out problematic weed of the district and present all most all land use and vegetation (Poudel, 2016; Shrestha *et al*., 2019.) Despite many other factors like human activities, propagule pressure, biological trait and habitat properties of invading species might be responsible for variation in species richness pattern along with land use types. Habitat disturbance, an inevitable consequence of modern land use change makes the ecosystem more vulnerable to invasive species that are transported either intentionally or accidentally by anthropogenic activities. Land use changes may facilitate plant invasion by causing fluctuations in levels of resources i.e., soil nutrients, water availability, light, etc. (Davis *et al*., 2000). The invasive species richness showed statistically significance ($P<0.0001$) difference across different land use types **(Figure 10C)**. Such land use wise variation might be due to the difference in availability of unexploited resources by resident species, allelopathic interactions and effect of enemies, disturbance regimes and competitive ability of invasive species (Grime, 1973; Davis *et al*., 2000). Disturbance through land use modification causes changes in the availability of resources. The reason for the higher invasive species richness in roadside grazing land followed by agriculture land may be due to disturbance and opportunistic behavior of invasive species. They can utilize the available resources efficiently when they get the chance to colonize in disturbed or exposed habitats through rapid growth and dispersal. Most of the roadside grazing lands in western Tarai region with solid waste dumping site, high impact of grazing, vehicle moments, vehicle parking, play grounds, highly populated areas and high human movements with higher abundance of invasive species (Poudel, 2016). Based on present results, such habitats exhibit the higher number of naturalized and invasive plant species in comparison to other less disturbed land use types. Similarly, most of the lands adjoining to road networks left barren for purpose of housing, infrastructure development and business purpose such factors contributed for the spread and establishment of many invasive species across the land use and vegetation. Climate change also impacts the dynamics of plant invasions (Lamsal *et al*., 2018).

More modified land and more disturbed land use having higher chances of occurrence of invasive species (Rastogi *et al*., 2015). Therefore, roadside grazing land and agriculture land (highly modified ecosystem) act as a reservoir of invasive plant species and may be spread rapidly to adjoining land use types in upcoming days in the Kailali district. Naturalized species are commonly present in more disturbed sites, grassland, fallow land all over the country and spreading in other adjacent disturbed land use types (Tiwari *et al.,* 2005), as roadside grazing land and agriculture land have higher amount of resource available (light, water, nutrients, etc.) compared to other land use types and such situation may facilitates to invasion process (Davis *et al*., 2000). Those land use having the higher number of naturalized species that less supports the native species as, agriculture land having 29 naturalized species (66 native species), road side grazing land 32 species (79 native species), degraded Sal forest 19 naturalized species (85 native species), agriculture fallow land 14 naturalized species (74 native species), mixed broad leaved forest 14 naturalized species (123 native species), riverine forest 12 naturalized species (81 native species) and *Shorea-Terminalia* forest 9 naturalized species (101 native species). It supports for the "Biotic resistant hypothesis" that species-rich communities are more successful at resisting the biological invasions by alien species then the poor species communities. It has been argued that the native-alien species relationship is negative at small spatial scales but positive at larger scales, but the fact for the role of spatial scales on native-alien species relationship has been contradictory (Peng *et al.,* 2019).

Invasive species are one of the major causes of crop loss and adversely affect the food security (Cook *et al*., 2011). Invasive alien species in the USA cause major environmental damages and losses up to almost US$120 billion per year similarly, crop and forest products losses have been estimated almost US$40 billion per year (Pimental *et al.*, 2005). Therefore, the present study also shows the higher number of invasive species from agriculture land and agro-ecosystems. The biggest agricultural producers China, USA, India, and Brazil experienced the greatest cost loss from invasive species invasions. Therefore, invasive species cause significant threats to the global agriculture production (Paini *et al*., 2016). In Nepal, alien plant species may increase in upcoming days because of the open border, weak quarantine monitoring and increasing trade from India and China (two neighboring countries) as already facing the great challenge from biological invasions.

Therefore, different environmental variables are responsible for governing the occurrence and distribution of alien plants across vegetation. Disturbance factors are some of the important environmental variables responsible for biological invasions. Roadside grassland and agriculture lands are more suited for alien plants as a more modified ecosystem (Parendes and Jones, 2000). Therefore, Nepal National Biodiversity Strategy and Action Plan (2014-2020) also suggesting the disturbance factors like uncontrolled fire, overgrazing, logging, developmental activities, expansion of agricultural cultivation, land use modifications and habitat degradation are major threat to biodiversity loss and promoting the introduction of alien species in some extent (MoFSC, 2014a) and it is quite relevant in the present study.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Out of total documented vascular plants species, naturalized plant species contributes $1/10^{th}$ of total vascular plant species and invasive species contributes $1/4^{th}$ of recorded naturalized species; which contributes nearly $4/5^{th}$ invasive flora of Nepal. Therefore, naturalized species contributes the greater proportion of total naturalized plants of Nepal and almost from tropical American origin. The present study documented the *Ageratum houstonianum* as the most frequent and *Senna tora* with the highest coverage indicating the most problematic weed across land use types in the study area. Human land use modifications cause major changes in the naturalized species abundance and their composition in different land use types. Present study reflects the linear increase of naturalized plant species along the more modified and more disturbed land use types and the decreasing order of naturalized species richness in different sampling land use types presented as; roadside grazing land > agriculture land > degraded Sal forest > agriculture fallow land > mixed broad leaved forest = riverine forest > *Shorea-Terminalia* forest and invasive species richness also correlated with disturbance and land use modifications as roadside grazing land > agriculture land > degraded Sal forest > agriculture fallow land > riverine forest > Shorea-Terminalia forest > mixed broad leaved forest. Thus, roadside grazing lands and agriculture land were highly invaded by naturalized plant species which supports the hypothesis that the more modified land use had the higher naturalized species richness. Therefore, this study concluded that more modified and disturbed land use type should be kept in priority for management of naturalized species including invasive species.

6.2 Recommendations

Although floral composition from low land to Churia hill of the district is limited studied and the naturalized species diversity is also least concerned. The preventive measures should be taken by local people and concerned authorities against alien plants to protect native species and ecosystem on time. If essential steps or management practices not adopted against invasive species, the native species and local ecosystem might be in risk in the near future. Science-based assessment and public awareness should be carried out for proper documentation, management, and control of naturalized species and important to know their exact status. Local level and national level policy makers and stakeholders are suggested to make plan and policies that focus on conservation of native species and periodical monitoring of naturalized species for controlling the spreade of invasive species in different land use types of the lowland. So, more specified recommendations of this study as follows;

- More modified land-use types are more prone to the establishment of naturalized species that's why regular monitoring should be focused on modified and disturbed land use such as roadside grazing lands and agricultural land which are highly vulnerable to biological invasions. These land uses types can serve as a propagule source for the invasion in new habitats by naturalized species as well as invasive species.

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APPENDIX

Appendix 1. List of Pteridophytes families and belonging species from Kailali

SN	Family	Species	SN	Family	Species
1	Thylypteridaceae	5	2	Pteridaceae	4
3	Lygodiaceae	2	4	Ophioglossaceae	2
5	Polypodiaceae	2	6	Selaginellaceae	2
7	Athyriaceae	1	8	Dryopteridaceae	1
9	Hypodematiaceae	1	10	Marsileaceae	1
11	Salviniaceae	1		**Total**	**22**

Appendix 2. List of monocot families and belonging species from Kailali

SN	Family	Species	SN	Family	Species
1	Poaceae	93	2	Orchidaceae	46
3	Cyperaceae	39	4	Araceae	14
5	Commelinaceae	8	6	Asparagaceae	6
7	Dioscoraceae	5	8	Zingiberaceae	5
9	Arecaceae	4	10	Hydrocharitaceae	3
11	Pontederiaceae	3	12	Smilacaceae	3
13	Colchicaceae	2	14	Hypoxidaceae	2
15	Acoraceae	1	16	Alismataceae	1
17	Aponogetonaceae	1	18	Costaceae	1
19	Eriocaulaceae	1	20	Potamogetonaceae	1
21	Typhaceae	1		**Total**	**240**

Appendix 3. Dicot families with recorded species number

SN	Family	Species	SN	Family	Species	SN	Family	Species	SN	Family	Species
1	Fabaceae	63	2	Lamiaceae	38	3	Asteraceae	34	4	Malvaceae	21
5	Acanthaceae	17	6	Apocynaceae	17	7	Rubiaceae	16	8	Moraceae	15
9	Euphorbiaceae	14	10	Polygonaceae	13	11	Amaranthaceae	12	12	Convolvulaceae	10
13	Phyllanthaceae	10	14	Urticaceae	9	15	Vitaceae	9	16	Lythraceae	8
17	Plantaginaceae	8	18	Rosaceae	8	19	Gesneriaceae	7	20	Rutaceae	7
21	Solanaceae	7	22	Araliaceae	6	23	Boraginaceae	6	24	Gentianaceae	6
25	Oleaceae	6	26	Onagraceae	6	27	Ranunculaceae	6	28	Anacardiaceae	5
29	Campanulaceae	5	30	Combretaceae	5	31	Cucurbitaceae	5	32	Fagaceae	5
33	Lauraceae	5	34	Linderniaceae	5	35	Myrtaceae	5	36	Caryophyllaceae	4
37	Celastraceae	4	38	Cornaceae	4	39	Polygalaceae	4	40	Apiaceae	3
41	Brassicaceae	3	42	Menispermaceae	3	43	Meliaceae	3	44	Orobanchaceae	3
45	Oxalidaceae	3	46	Papaveraceae	3	47	Piperaceae	3	48	Primulaceae	3
49	Salicaceae	3	50	Adoxaceae	2	51	Dilleniaceae	2	52	Ericaceae	2
53	Lentibulariaceae	2	54	Malpighiaceae	2	55	Melastomataceae	2	56	Menyanthaceae	2
57	Nyctaginaceae	2	58	Pentaphyllaceae	2	59	Phrymaceae	2	60	Rhamnaceae	2
61	Sabiaceae	2	62	Sapotaceae	2	63	Saxifragaceae	2	64	Scrophulariaceae	2
65	Verbenaceae	2	66	Violaceae	2	67	Actinidiaceae	1	68	Balsaminaceae	1
69	Berberidaceae	1	70	Betulaceae	1	71	Bignoniaceae	1	72	Bigoniaceae	1
73	Bixaceae	1	74	Burseraceae	1	75	Cannabaceae	1	76	Capparaceae	1
77	Caprifoliaceae	1	78	Cleomaceae	1	79	Coriariaceae	1	80	Dipterocarpaceae	1
81	Ebenaceae	1	82	Geraniaceae	1	83	Hydroleaceae	1	84	Hypericaceae	1
85	Juglandaceae	1	86	Lecythidaceae	1	87	Linaceae	1	88	Loranthaceae	1
89	Martyniaceae	1	90	Myricaceae	1	91	Nelumbonaceae	1	92	Nymphaeaceae	1
93	Sapindaceae	1	94	Sphenocleaceae	1	95	Symplocaceae	1	96	Thymelaeaceae	1

Appendix 4. List of native species recorded based on present study and secondary sources.

SN	Name of species	Family	Remarks	SN	Name of species	Family	Remarks
1	*Barleria cristata* L.	Acanthaceae	D23	2	*Dicliptera bupleuroides* Nees	Acanthaceae	Raj.2016
3	*Eranthemum pulchellum* Andrews	Acanthaceae	Raj.2016	4	*Eranthemum purpurascens* Wight ex Nees.	Acanthaceae	Raj.2016
5	*Hemigraphis hirta* (Vahl) T. Anderson	Acanthaceae	D517	6	*Justicia adhatoda* L.	Acanthaceae	Raj.2016
7	*Justicia diffusa* Willd.	Acanthaceae	D568	8	*Rostellularia procumbens* (L.)Nees.	Acanthaceae	Raj.2016
9	*Nelsonia canescens* (Lam) Spreng.	Acanthaceae	Raj.2016	10	*Ruellia beddomei* C. B. Clarke.	Acanthaceae	D239
11	*Rungia pectinata* (L.) Nees	Acanthaceae	Raj.2016	12	*Strobilanthes pentstemonoides* (Nees.) T. Anderson.	Acanthaceae	D174
13	*Strobilanthes urticifolia* Wall.ex Kuntze.	Acanthaceae	D127	14	*Thunbergia coccinea* Wall. ex. D. Don.	Acanthaceae	D284
15	*Thunbergia grandiflora* (Roxb. ex Rottl.) Roxb.	Acanthaceae	Raj.2016	16	*Andrographis paniculata* (Burm.f.) Nees.	Acanthaceae	D242
17	*Strobilanthes angustifrons* C. B. Clarke	Acanthaceae	Raj.2016	18	*Saurauia napaulensis* DC.	Actinidiaceae	Raj.2016
19	*Viburnum cylindricum* Buch. - Ham. ex D. Don	Adoxaceae	Raj.2016	20	*Caldesia parnassifolia* (Bassi.) Parl.	Alismataceae	Raj.2016
21	*Achyranthes aspera* L.	Amaranthaceae	D11	22	*Achyranthes bidentata* Blume	Amaranthaceae	Raj.2016
23	*Aerva lanata* (L.) Juss.	Amaranthaceae	D236	24	*Cyathula prostrata* (L) Blume	Amaranthaceae	Raj.2016
25	*Toxicodendron wallichii* (Hook.f.) Kuntze.	Anacardaceae	Raj.2016	26	*Buchanania cochinchinensis* (Lour.) M.R. Almeida	Anacardiaceae	Raj.2016
27	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	Lam.2014	28	*Semecarpus anacardium* L.f.	Anacardiaceae	Raj.2016
29	*Spondias pinnata* (L.) Kurz.	Anacardiaceae	D424	30	*Centella asiatica* (L.) Urb.	Apiaceae	D477
31	*Oenanthe javanica* (Blume) DC	Apiaceae	Raj.2016	32	*Torilis japonica* (Houtt.) DC	Apiaceae	Raj.2016
33	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	D256	34	*Beaumontia grandiflora* Wall.	Apocynaceae	Raj.2016
35	*Calotropis gigantea* (L.) W.T.Aiton	Apocynaceae	Raj.2016	36	*Calotropis procera* (Aiton) W.T.Aiton.	Apocynaceae	Raj.2016

SN	Name of species	Family	Remarks	SN	Name of species	Family	Remarks
37	*Carissa carandas* L.	Apocynaceae	Bha.2015	38	*Cryptolepis dubia* (Burm.f.) M.R. Almeida	Apocynaceae	Raj.2016
39	*Holarrhena pubescens* Wall.ex G.Don.	Apocynaceae	D781	40	*Ichnocarpus frutescens* (L.) W.T. Aiton.	Apocynaceae	Raj.2016
41	*Oxystelma esculentum* (L.f) Sm.	Apocynaceae	D830	42	*Pentasacme pulcherrima* A.J.C. Grierson & D.G. Long.	Apocynaceae	D493
43	*Pentasachme wallichii* Wight.	Apocynaceae	Raj.2016	44	*Pergularia daemia* (Forssk.) Chiov.	Apocynaceae	Raj.2016
45	*Rauvolfia serpentina* (L.) Benth.ex Kurz.	Apocynaceae	D241	46	*Trachelospermum lucidum* (D. Don) K. Schum.	Apocynaceae	Raj.2016
47	*Vallaris solanacea* (Roth) Kuntze	Apocynaceae	Raj.2016	48	*Vincetoxicum belostemma* (Benth.) Kuntze.	Apocynaceae	Raj.2016
49	*Aponogeton undulatus* Roxb.	Aponogetonaceae	D302	50	*Amorphophallus napalensis* (Wall.) Bogner. & Mayo.	Araceae	Raj.2016
51	*Arisaema concinnum* Schott	Araceae	Raj.2016	52	*Arisaema griffithii* Schott.	Araceae	D249
53	*Arisaema tortuosum* (Wall.) Schott	Araceae	Raj.2016	54	*Colocasia esculenta* (L.) Schott.	Araceae	D822
55	*Colocasia fallax* Schott.	Araceae	D413	56	*Pothos chinensis* (Raf.) Merr.	Araceae	Raj.2016
57	*Rhaphidophora glauca* (Wall.) Schott.	Araceae	D196	58	*Scindapsus officinalis* (Roxb.) Schott.	Araceae	D419
59	*Typhonium trilobatum* (L.) Schott.	Araceae	Raj.2016	60	*Wolffia globosa* (Roxb.) Hartog & Plas	Araceae	Lam.2014
61	*Brassaiopsis glomerulata* (Blume) Regel	Araliaceae	Raj.2016	62	*Brassaiopsis hainla* (Buch.-Ham.) Seem.	Araliaceae	Raj.2016
63	*Heteropanax fragrans* (Roxb.) Seem	Araliaceae	Raj.2016	64	*Hydrocotyle himalaica* P.K. Mukh.	Araliaceae	Raj.2016
65	*Hydrocotyle javanica* Thunb.	Araliaceae	Raj.2016	66	*Hydrocotyle sibthorpioides* am.	Araliaceae	Raj.2016
67	*Calamus tenuis Roxb.*	*Arecaceae*	*Raj.2016*	*68*	*Phoenix loureiroi Kunth.*	*Arecaceae*	*D458*
69	*Phoenix sylvestris* (L.) Roxb.	Arecaceae	D458	70	*Wallichia oblongifolia* Griff.	Arecaceae	Raj.2016
71	*Asparagus filicinus* Buch.-Ham. ex D. Don	Asparagaceae	Raj.2016	72	*Asparagus racemosus* Willd.	Asparagaceae	D751
73	*Chlorophytum arundinaceum* Baker.	Asparagaceae	D496	74	*Chlorophytum nepalense* (Lindl.) Baker	Asparagaceae	Raj.2016

SN	Name of species	Family	Remarks	SN	Name of species	Family	Remarks
75	*Chlorophytum tuberosum* (Roxb.) Baker.	Asparagaceae	D796	76	*Acmella calva* (DC.) R.K. Jansen	Asteraceae	Raj.2016
77	*Anaphalis contorta* (D. Don) Hook.f.	Asteraceae	Raj.2016	78	*Anaphalis royleana* DC.	Asteraceae	D130
79	*Artemisia indica* Willd.	Asteraceae	Raj.2016	80	*Caesulia axillaris* Roxb.	Asteraceae	D34
81	*Carpesium abrotanoides* L.	Asteraceae	Raj.2016	82	*Centipeda minima* (L.) A. Braun & Asch.	Asteraceae	Raj.2016
83	*Elephantopus scaber* L.	Asteraceae	D25	84	*Eschenbachia japonica* (Thunb.) J.Kost.	Asteraceae	Raj.2016
85	*Melanoseris macrorhiza* (Royle.) N. Killian	Asteraceae	Raj.2016	86	*Sigesbeckia orientalis* L.	Asteraceae	Raj.2016
87	*Aster peduncularis* Wall.ex Nees.	Asteraceae	D166	88	*Duhaldea cappa* (Buch.-Ham. ex D.Don) Pruski & Anderb.	Asteraceae	D118
89	*Sonchus wightianus* DC.	Asteraceae	Raj.2016	90	*Taraxacum parvulum* DC.	Asteraceae	Raj.2016
91	*Diplazium esculentum* (Retz.) Sw.	Athyriaceae	Raj.2016	92	*Impatiens scabrida* DC.	Balsaminaceae	Raj.2016
93	*Berberis asiatica* Roxb.ex DC.	Berberidaceae	Raj.2016	94	*Alnus nepalensis* D. Don.	Betulaceae	Raj.2016
95	*Oroxylum indicum* (L.) Kurz.	Bignoniaceae	Raj.2016	96	*Begonia picta* Sm.	Bigoniaceae	D288
97	*Cochlospermum religiosum* (L.) Alston	Bixaceae	D725	98	*Bothriospermum zeylanicum* (J.Jacquin) Druce.	Boraginaceae	Raj.2016
99	*Cynoglossum zeylanicum* (Vahl.) Brand.	Boraginaceae	D303	100	*Ehretia laevis* Roxb.	Boraginaceae	Raj.2016
101	*Euploca strigosa* (Willd.) Diance & Hilger.	Boraginaceae	Raj.2016	102	*Trichodesma indicum* (L.) Sm.	Boraginaceae	Raj.2016
103	*Rorippa indica* (L.) Hiern	Brassicaceae	Raj.2016	104	*Garuga pinnata* Roxb.	Burseraceae	Raj.2016
105	*Campanula dimorphantha* Schweinf.	Campanulaceae	Raj.2016	106	*Campanula pallida* Wall.	Campanulaceae	Raj.2016
107	*Campanula sylvatica* Wall.	Campanulaceae	Raj.2016	108	*Codonopsis viridis* Wall.	Campanulaceae	Raj.2016
109	*Lobelia heyneana* Schult.	Campanulaceae	Raj.2016	110	*Celtis timorensis* Span.	Cannabaceae	D570
111	*Capparis spinosa* L.	Capparaceae	Raj.2016	112	*Dipsacus inermis* Wall.	Caprifoliaceae	D151
113	*Celastrus paniculatus* Willd.	Celastraceae	Raj.2016	114	*Euonymus hamiltonianus* Wall.	Celastraceae	Raj.2016

SN	Name of species	Family	Remarks	SN	Name of species	Family	Remarks
115	*Gymnosporia rufa* (Wall.) Hook.f.	Celastraceae	Raj.2016	116	*Reissantia arborea* (Roxb.) H.Hara	Celastraceae	Raj.2016
117	*Cleome viscosa* L.	Cleomaceae	D789	118	*Gloriosa superba* L.	Colchicaceae	D2102
119	*Iphigenia indica* (L.) A Gray ex Kunth	Colchicaceae	Raj.2016	120	*Combretum roxburghii* Spreng.	Combretaceae	D433
121	*Terminalia anogeissiana* Gere & Boatur.	Combretaceae	Raj.2016	122	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	D483
123	*Terminalia chebula* Retz.	Combretaceae	D550	124	*Commelina benghalensis* L.	Commelinaceae	D404
125	*Commelina diffusa* Burm.f.	Commelinaceae	Raj.2016	126	*Commelina paludosa* Blume.	Commelinaceae	Raj.2016
127	*Cyanotis axillaris* (L.) D.Don. ex Sweet.	Commelinaceae	Raj.2016	128	*Cyanotis cristata* (L.) D.Don	Commelinaceae	Raj.2016
129	*Cyanotis vaga* (Lour.) Schult. & Schult. f.	Commelinaceae	Raj.2016	130	*Murdannia edulis* (Stoke) Faden.	Commelinaceae	D103
131	*Murdannia nudiflora* (L.) Brenan.	Commelinaceae	Raj.2016	132	*Argyreia hookeri* C.B. Clarke.	Convolvulaceae	D723
133	*Cuscuta reflexa* Roxb.	Convolvulaceae	Raj.2016	134	*Dinetus racemosus* (Roxb.) Sweet.	Convolvulaceae	Raj.2016
135	*Evolvulus alsinoides* (L.) L.	Convolvulaceae	Raj.2016	136	*Ipomoea aquatica* Forssk.	Convolvulaceae	Raj.2016
137	*Merremia hederacea* (Burm.) Halliera.	Convolvulaceae	D90	138	*Poranopsis paniculata* (Roxb.) Roberty	Convolvulaceae	D206
139	*Coriaria nepalensis* Wall.	Coriariaceae	Raj.2016	140	*Alangium chinense* (Lour.) Harms.	Cornaceae	D748
141	*Alangium salviifolium* (L.f.) Wangerin	Cornaceae	Raj.2016	142	*Cornus macrophylla* Wall.	Cornaceae	Raj.2016
143	*Cornus oblonga* Wall.	Cornaceae	Raj.2016	144	*Hellenia speciosa* (J.Koenig.) S.R. Dutta	Costaceae	Raj.2016
145	*Diplocyclos palmatus* (L.) C. Jeffrey	Cucurbitaceae	Raj.2016	146	*Momordica dioica* Roxb.ex Willd.	Cucurbitaceae	Raj.2016
147	*Solena heterophylla* Lour.	Cucurbitaceae	Raj.2016	148	*Trichosanthes cordata* Roxb.	Cucurbitaceae	D473
149	*Trichosanthes cucumerina* L.	Cucurbitaceae	D240	150	*Bolbostylis barbata* (Rottb.) C.B.Clarke.	Cyperaceae	D140
151	*Bulbostylis densa* (Wall.) Hand.-Mazz.	Cyperaceae	Raj.2016	152	*Carex cruciata* Wahlenb.	Cyperaceae	D290

SN	Name of species	Family	Remarks	SN	Name of species	Family	Remarks
153	*Cyperus compactus* Retz.	Cyperaceae	Raj.2016	154	*Cyperus difformis* L.	Cyperaceae	D414
155	*Cyperus flavidus* Retz.	Cyperaceae	Raj.2016	156	*Cyperus iria* L.	Cyperaceae	D599
157	*Cyperus niveus* Retz.	Cyperaceae	Raj.2016	158	*Cyperus pangorei* Rottb.	Cyperaceae	D590
159	*Cyperus rotundus* L.	Cyperaceae	D18	160	*Cyperus sanguinolentus* Vahl.	Cyperaceae	Raj.2016
161	*Cyperus tenuiculmis* Boeckeler	Cyperaceae	Raj.2016	162	*Eleocharis congesta* D. Don	Cyperaceae	Raj.2016
163	*Eleocharis dulcis* (Burm.f.) Trin.ex Hensch	Cyperaceae	Raj.2016	164	*Erioscirpus comosus* (Wall.) Palla.	Cyperaceae	D123
165	*Fimbristylis aestivalis* (Retz.)Vahl.	Cyperaceae	Raj.2016	166	*Fimbristylis bisumbellata* (Forssk.) Bubani	Cyperaceae	Raj.2016
167	*Fimbristylis littoralis* Gaudich.	Cyperaceae	D21	168	*Fimbristylis schoenoides* (Retz.) Vahl	Cyperaceae	Raj.2016
169	*Fimbristylis squarrosa* Vahl	Cyperaceae	Raj.2016	170	*Isolepis setacea* (L.) R. Br.	Cyperaceae	Raj.2016
171	*Schoenoplectiella juncoides* (Roxb.) Lye.	Cyperaceae	Raj.2016	172	*Schoenoplectiella mucronata* (L.) J. Jung. & H.K. Choi	Cyperaceae	Raj.2016
173	*Scleria biflora* Roxb.	Cyperaceae	Raj.2016	174	*Scleria levis* Retz.	Cyperaceae	D516
175	*Cyperus mindorensis* (Steud.) Huygh	Cyperaceae	Raj.2016	176	*Dillenia indica* L.	Dilleniaceae	Raj.2016
177	*Dillenia pentagyna* Roxb.	Dilleniaceae	Raj.2016	178	*Dioscorea belophylla* (Prain) Voigt ex Haines	Dioscoreaceae	Raj.2016
179	*Dioscorea bulbifera* L.	Dioscoreaceae	D408	180	*Dioscorea deltoidea* Wall.ex Grieseb.	Dioscoreaceae	D813
181	*Dioscorea pentaphylla* L.	Dioscoreaceae	D773	182	*Dioscorea pubera* Blume.	Dioscoreaceae	D745
183	*Shorea robusta* Roxb. ex. Gaertn.f.	Dipterocarpaceae	Lam.2014	184	*Dryopteris cochleata* (Buch.-Ham.ex D.Don.) C.Chr.	Dryopteridaceae	Raj.2016
185	*Diospyros montana* Roxb.	Ebenaceae	Raj.2016	186	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	Raj.2016
187	*Rhododendron arboreum* Sm.	Ericaceae	D167	188	*Eriocaulon exsertum* Satake.	Eriocaulaceae	D802
189	*Acalypha indica* L.	Euphorbiaceae	Raj.2016	190	*Balakata baccata* (Roxb.) Esser	Euphorbiaceae	Raj.2016
191	*Falconeria insignis* Royle	Euphorbiaceae	Raj.2016	192	*Macaranga denticulata* (Blume) Muel. Arg	Euphorbiaceae	Raj.2016
193	*Mallotus nudiflorus* (L.) Kulju & Welzen.	Euphorbiaceae	Raj.2016	194	*Mallotus philippensis* (Lam.) Mull. Arg.	Euphorbiaceae	D88

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195	*Mallotus repandus* (Rottler) Mull. Arg.	Euphorbiaceae	Raj.2016	196	*Aeschynomene aspera* L.	Fabaceae	Raj.2016
197	*Albizia lebbeck* (L.) Benth.	Fabaceae	D486	198	*Albizia odoratissima* (L. f.) Benth.	Fabaceae	Raj.2016
199	*Alysicarpus glumaceus* (Vahl.) DC.	Fabaceae	Raj.2016	200	*Alysicarpus rugosus* (Willd.) DC.	Fabaceae	D59
201	*Alysicarpus vaginalis* (L.) DC	Fabaceae	Raj.2016	202	*Bauhinia purpurea* L.	Fabaceae	D300
203	*Bauhinia vahlii* Wight & Arn.	Fabaceae	Raj.2016	204	*Bauhinia variegata* L.	Fabaceae	Raj.2016
205	*Butea buteiformis* (Voigt.) Gierson.	Fabaceae	Raj.2016	206	*Butea monosperma* (Lam.) Taub.	Fabaceae	Raj.2016
207	*Cassia fistula* L.	Fabaceae	Bha.2015	208	*Chamaecrista mimosoides* (L.) Greene	Fabaceae	Raj.2016
209	*Crotalaria alata* Buch.-Ham. ex D.Don	Fabaceae	Raj.2016	210	*Crotalaria juncea* L.	Fabaceae	Raj.2016
211	*Crotalaria sessiliflora* L.	Fabaceae	D257	212	*Crotalaria spectabilis* Roth.	Fabaceae	Raj.2016
213	*Dalbergia latifolia* Roxb.	Fabaceae	D30	214	*Dalbergia sericea* G. Don	Fabaceae	Raj.2016
215	*Dalbergia sissoo* Roxb.ex DC.	Fabaceae	D476	216	*Desmodium concinnum* DC.	Fabaceae	Raj.2016
217	*Desmodium elegans* DC.	Fabaceae	D763	218	*Desmodium gangeticum* (L.) DC.	Fabaceae	D31
219	*Desmodium laxiflorum* DC.	Fabaceae	D111	220	*Desmodium microphyllum* (Thunb.) DC.	Fabaceae	D56
221	*Desmodium oojeinense* (Roxb.) H. Ohashi.	Fabaceae	D191	222	*Desmodium triflorum* (L.) DC.	Fabaceae	Raj.2016
223	*Dumasia villosa* DC.	Fabaceae	D671	224	*Flemingia chappar* Benth.	Fabaceae	Raj.2016
225	*Flemingia macrophylla* (Willd.) Merr.	Fabaceae	Raj.2016	226	*Flemingia strobilifera* (L.) W.T. Aiton.	Fabaceae	D750
227	*Hylodesmum podocarpum* (DC) H. Ohasi & R.R. Mill.	Fabaceae	Raj.2016	228	*Indigofera heterantha* Wall.ex Brandis.	Fabaceae	D267
229	*Indigofera linifolia* (L.f.) Retz.	Fabaceae	D666	230	*Lathyrus sphaericus* Retz.	Fabaceae	Raj.2016
231	*Butea buteiformis* (Voigt.) Grierson.	Fabaceae	Raj.2016	232	*Millettia extensa* (Benth.) Baker.	Fabaceae	Raj.2016
233	*Millettia pachycarpa* Benth.	Fabaceae	Raj.2016	234	*Mimosa himalayana* Gamble	Fabaceae	Raj.2016

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235	*Mimosa rubicaulis* Lam.	Fabaceae	Raj.2016	236	*Parochetus communis* Buch.-Ham.ex D.Don.	Fabaceae	Raj.2016
237	*Phyllodium pulchellum* (L.) Desv.	Fabaceae	Raj.2016	238	*Pterocarpus marsupium* Roxb.	Fabaceae	Raj.2016
239	*Senegalia catechu* (L.f.) P.T.H. Hurter & Mabb.	Fabaceae	D213	240	*Senegalia rugata* (Lam.) Britton & Rose	Fabaceae	Raj.2016
241	*Smithia sensitiva* Aiton	Fabaceae	Raj.2016	242	*Spatholobus parviflorus* (Roxb.ex G.Don) Kuntze.	Fabaceae	Lam.2014
243	*Tephrosia candida* (Roxb.) DC.	Fabaceae	Raj.2016	244	*Tephrosia purpurea* (L.) Pers.	Fabaceae	Raj.2016
245	*Trigonella emodi* Benth.	Fabaceae	Raj.2016	246	*Uraria lagopodoides* (L.) DC.	Fabaceae	Raj.2016
247	*Uraria picta* (Jacq.) Desv.ex DC.	Fabaceae	Raj.2016	248	*Vicia tetrasperma* (L.) Schreb.	Fabaceae	Raj.2016
249	*Zornia gibbosa* Span.	Fabaceae	Raj.2016	250	*Lathyrus aphaca* L.	Fabaceae	Raj.2016
251	*Castanopsis indica* (Roxb.ex Lindl.) A. DC.	Fagaceae	D190	252	*Castanopsis tribuloides* (Sm.) A. DC.	Fagaceae	D156
253	*Quercus glauca* Thunb.	Fagaceae	D197	254	*Quercus lanata* Sm.	Fagaceae	Raj.2016
255	*Quercus oblongata* D. Don.	Fagaceae	Raj.2016	256	*Canscora alata* (Roth.) Wall.	Gentianaceae	Raj.2016
257	*Canscora diffusa* (Vahl) R. Br. ex Roem. & Schult	Gentianaceae	Raj.2016	258	*Exacum tetragonum* Roxb.	Gentianaceae	Raj.2016
259	*Swertia angustifolia* Buch.-Ham. ex. D.Don.	Gentianaceae	Raj.2016	260	*Swertia chirayita* (Roxb.) Buch.-Ham. ex C.B.Clarke	Gentianaceae	Raj.2016
261	*Centaurium pulchellum* (Sw.) Druce.	Gentianaceae	D119	262	*Geranium nepalense* Sweet.	Geraniaceae	Raj.2016
263	*Aeschynanthus hookeri* C.B. Clarke.	Gesneriaceae	D252	264	*Aeschynanthus parviflorus* D.Don. Spreng.	Gesneriaceae	Raj.2016
265	*Corallodiscus lanuginosus* (Wall.ex R. Br.) B. L. Burtt	Gesneriaceae	Raj.2016	266	*Didymocarpus aromatica* D.Don.	Gesneriaceae	Raj.2016
267	*Didymocarpus pedicellatus* .Br.	Gesneriaceae	D188	268	*Henckelia bifolia* (D.Don) A. Dietr.	Gesneriaceae	Raj.2016
269	*Rhynchoglossum obliquum* Blume	Gesneriaceae	Raj.2016	270	*Hydrilla verticillata* (L. f.) Royle.	Hydrocharitaceae	Raj.2016
271	*Najas graminea* Delile	Hydrocharitaceae	Raj.2016	272	*Ottelia alismoides* (L.) Pers.	Hydrocharitaceae	Raj.2016

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273	*Hydrolea zeylanica* (L.) Vahl.	Hydroleaceae	D64	274	*Hypericum japonicum* Thunb.	Hypericaceae	Raj.2016
275	*Leucostegia truncata* (D.Don.) Fraser-Jenk.	Hypodematiaceae	D308	276	*Curculigo orchioides* Gaertn.	Hypoxidaceae	Raj.2016
277	*Hypoxis aurea* Lour.	Hypoxidaceae	Raj.2016	278	*Engelhardtia spicata* Lesch ex Blume	Juglandaceae	D759
279	*Ajuga macrosperma* Wall.ex Benth.	Lamiaceae	D809	280	*Anisomeles indica* (L.) Kuntze.	Lamiaceae	D24
281	*Callicarpa arborea* Roxb.	Lamiaceae	D209	282	*Callicarpa macrophylla* Vahl.	Lamiaceae	D73
283	*Clerodendrum indicum* (L.) Kuntze	Lamiaceae	Raj.2016	284	*Clerodendrum infortunatum* L.	Lamiaceae	Raj.2016
285	*Clinopodium umbrosum* (M.Bieb.) K.Koch.	Lamiaceae	Raj.2016	286	*Colebrookea oppositifolia* Sm.	Lamiaceae	D92
287	*Colquhounia coccinea* Wall	Lamiaceae	Raj.2016	288	*Craniotome furcata* (Link) Kuntze	Lamiaceae	Raj.2016
289	*Elsholtzia blanda* Benth.	Lamiaceae	D792	290	*Holmskioldia sanguinea* Retz.	Lamiaceae	Raj.2016
291	*Isodon coetsa* (Buch.-Ham.ex D.Don) Kudo.	Lamiaceae	D131	292	*Isodon lophanthoides* (Buch.-Ham. ex D. Don) H.Hara	Lamiaceae	Raj.2016
293	*Leonurus japonicus* Houtt.	Lamiaceae	Raj.2016	294	*Leucas cephalotes* (Roth.) Spreng.	Lamiaceae	Raj.2016
295	*Leucas lanata* Benth.	Lamiaceae	D158	296	*Leucas lavandulifolia* Sm.	Lamiaceae	Raj.2016
297	*Micromeria biflora* (Buch.-Ham.ex D.Don.) Benth.	Lamiaceae	Raj.2016	298	*Nepeta hindostana* (B.Heyne ex Roth.) Haines.	Lamiaceae	Raj.2016
299	*Ocimum basilicum* L.	Lamiaceae	D791	300	*Ocimum gratissimum* L.	Lamiaceae	Raj.2016
301	*Ocimum tenuiflorum* L.	Lamiaceae	Raj.2016	302	*Perilla frutescens* (L.) Britton.	Lamiaceae	Raj.2016
303	*Pogostemon benghalensis* (Burm.f.) Kuntze.	Lamiaceae	Raj.2016	304	*Pogostemon stellatus* (Lour.) Kuntze	Lamiaceae	Raj.2016
305	*Premna barbata* Wall. ex Schauer	Lamiaceae	Raj.2016	306	*Premna bengalensis* C. B. Clarke	Lamiaceae	Raj.2016
307	*Pseudocaryopteris bicolor* (Roxb. ex Hardw.) P.D. Cantino	Lamiaceae	Raj.2016	308	*Pseudocaryopteris foetida* (D. Don) P. D. Cantino	Lamiaceae	Raj.2016

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309	*Rotheca serrata* (L.) Steane & Mabb.	Lamiaceae	Raj.2016	310	*Salvia plebeia* R. Br.	Lamiaceae	Raj.2016
311	*Scutellaria discolor* Colebr.	Lamiaceae	Raj.2016	312	*Teucrium quadrifarium* Buch. - Ham.ex D. Don.	Lamiaceae	D159
313	*Thymus linearis* Benth.	Lamiaceae	Raj.2016	314	*Vitex negundo* L.	Lamiaceae	Raj.2016
315	*Cinnamomum tamala* (Buch.-Ham.) Th.G.G.Nees.	Lauraceae	Raj.2016	316	*Lindera nacusua* (D. Don) Merr.	Lauraceae	Raj.2016
317	*Litsea salicifolia* (Roxb.ex. Nees.) Hook.f.	Lauraceae	D731	318	*Phoebe attenuata* (Nees) Nees	Lauraceae	Raj.2016
319	*Careya arborea* Roxb.	Lecythidaceae	D494	320	*Utricularia aurea* Lour.	Lentibulariaceae	Raj.2016
321	*Utricularia striatula* Sm.	Lentibulariaceae	Raj.2016	322	*Reinwardtia indica* Dumort.	Linaceae	Raj.2016
323	*Bonnaya ruellioides* (Colsm.) Spreng.	Linderniaceae	Raj.2016	324	*Bonnaya antipoda* (L.) Druce.	Linderniaceae	Raj.2016
327	*Vandellia anagallis* (Burm.f.) T.Yamaz.	Linderniaceae	Raj.2016	328	*Dendrophthoe falcata* (L. f.) Ettingsh.	Loranthaceae	Raj.2016
329	*Lygodium flexuosum* (L.) Sw.	Lygodiaceae	D110	330	*Lygodium japonicum* (Thunb.) Sw.	Lygodiaceae	Raj.2016
331	*Ammannia baccifera* L.	Lythraceae	Raj.2016	332	*Ammannia multiflora* Roxb.	Lythraceae	Raj.2016
333	*Lagerstroemia parviflora* Roxb.	Lythraceae	D431	334	*Lawsonia inermis* L.	Lythraceae	D642
335	*Rotala rotundifolia* (Buch.-Ham. ex Roxb.) Koehne	Lythraceae	Raj.2016	336	*Woodfordia fruticosa* (L.) Kurz.	Lythraceae	Raj.2016
337	*Aspidopterys wallichii* Hook.f.	Malpighiaceae	Raj.2016	338	*Hiptage benghalensis* (L.) Kurtz.	Malpighiaceae	Raj.2016
339	*Bombax ceiba* L.	Malvaceae	Raj.2016	340	*Corchorus capsularis* L.	Malvaceae	Raj.2016
341	*Corchorus olitorius* L.	Malvaceae	D86	342	*Corchorus tridens* L.	Malvaceae	D35
343	*Firmiana colorata* (Roxb.) R. Br.	Malvaceae	Raj.2016	344	*Firmiana fulgens* (Wall.ex Mast) K .Schum.	Malvaceae	Raj.2016
345	*Grewia asiatica* L.	Malvaceae	Raj.2016	346	*Grewia helicterifolia* Wall. ex G. Don	Malvaceae	Raj.2016
347	*Grewia serrulata* DC.	Malvaceae	Raj.2016	348	*Malva neglecta* Wallr.	Malvaceae	Raj.2016

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349	*Malva parviflora* L.	Malvaceae	Raj.2016	350	*Sida cordata* (Burm.f.) Borss. Waalk.	Malvaceae	Bha.2015
351	*Sida orientalis* Cav.	Malvaceae	Raj.2016	352	*Triumfetta annua* L.	Malvaceae	Raj.2016
353	*Triumfetta pilosa* Roth	Malvaceae	Raj.2016	354	*Triumfetta rhomboidea* Jacq.	Malvaceae	D75
355	*Urena lobata* L.	Malvaceae	D12	356	*Marsilea minuta* L.	Marsileaceae	Raj.2016
357	*Osbeckia chinensis* L.	Melastomataceae	D53	358	*Osbeckia nepalensis* Hook.	Melastomataceae	D153
359	*Cipadessa baccifera* (Roth) Miq.	Meliaceae	Raj.2016	360	*Melia azedarach* L.	Meliaceae	D999
361	*Heynea trijuga* Roxb.	Meliaceae	Raj.2016	362	*Stephania japonica* (Thunb.) Miers.	Menispermaceae	D459
363	*Tinospora sinensis* (Lour.) Merr.	Menispermaceae	Bha.2015	364	*Cocculus hirsutus* (L.) Diels	Menispermaceae	Raj.2016
365	*Nymphoides hydrophylla* (Lour.) Kuntze.	Menyanthaceae	Raj.2016	366	*Nymphoides indica* (L.) Kuntze	Menyanthaceae	Raj.2016
367	*Artocarpus lacucha* Buch.-Ham.ex D.Don.	Moraceae	Raj.2016	368	*Ficus auriculata* Lour.	Moraceae	Raj.2016
369	*Ficus hederacea* Roxb.	Moraceae	D615	370	*Ficus heterophylla* L.f.	Moraceae	D234
371	*Ficus hirta* Vahl.	Moraceae	D482	372	*Ficus hispida* L.f.	Moraceae	Raj.2016
373	*Ficus lacor* Buch.-Ham.	Moraceae	D456	374	*Ficus racemosa* L.	Moraceae	Raj.2016
375	*Ficus rumphii* Blume.	Moraceae	Raj.2016	376	*Ficus sarmentosa* Buch.-Ham. ex Sm.	Moraceae	D116
377	*Ficus semicordata* Buch. - Ham. ex. Sm.	Moraceae	D720	378	*Ficus subincisa* Buch.-Ham.ex Sm	Moraceae	Raj.2016
379	*Morus alba* L.	Moraceae	D565	380	*Morus serrata* Roxb.	Moraceae	Bha.2015
381	*Streblus asper* Lour.	Moraceae	Raj.2016	382	*Myrica esculenta* Buch.-Ham.ex D.Don.	Myricaceae	D271
383	*Syzygium cumini* (L.) Skeels	Myrtaceae	D451	384	*Syzygium formosum* (Wall.) Mason.	Myrtaceae	Raj.2016
385	*Syzygium jambos* (L.) Alston	Myrtaceae	Raj.2016	386	*Syzygium nervosum* A. Cunn.ex DC.	Myrtaceae	Raj.2016
387	*Nelumbo nucifera* Gaertn.	Nelumbonaceae	Raj.2016	388	*Nymphaea nouchali* Burm.f.	Nymphaeaceae	Raj.2016

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389	*Fraxinus floribunda* Wall.	Oleaceae	Raj.2016	390	*Jasminum multiflorum* (Burm. f.) Andrews	Oleaceae	D777
391	*Jasminum officinale* L.	Oleaceae	Raj.2016	392	Ligustrum confusum Decne.	Oleaceae	Raj.2016
393	Ligustrum nepalense Wall.	Oleaceae	Raj.2016	394	*Nyctanthes arbor-tristis* L.	Oleaceae	D788
395	*Epilobium hirsutum* L.	Onagraceae	Raj.2016	396	*Ludwigia perennis* L.	Onagraceae	D808
397	*Ludwigia prostrata* Roxb.	Onagraceae	Raj.2016	398	*Helminthostachys zeylanica* (L.) Hook.	Ophioglossaceae	D474
399	*Brachycorythis obcordata* (Lindl.ex Wall.) Summerh.	Orchidaceae	D163	400	*Bulbophyllum careyanum* (Hook.) Spreng.	Orchidaceae	Raj.2016
401	*Calanthe tricarinata* Lindl.	Orchidaceae	Raj.2016	402	*Cephalanthera longifolia* (L.) Fritsch	Orchidaceae	Raj.2016
403	*Coelogyne fimbriata* Lindl.	Orchidaceae	Raj.2016	404	*Coelogyne nitida* (Wall. ex D. Don) Lindl.	Orchidaceae	Raj.2016
405	*Coelogyne ovalis* Lindl.	Orchidaceae	Raj.2016	406	*Crepidium acuminatum* (D.Don.) Szlach.	Orchidaceae	Raj.2016
407	*Cryptochilus luteus* Lindl.	Orchidaceae	Raj.2016	408	*Cymbidium aloifolium* (L.) Sw.	Orchidaceae	Raj.2016
409	*Dendrobium denudans* D. Don	Orchidaceae	Raj.2016	410	*Dendrobium eriiflorum* Griff.	Orchidaceae	Raj.2016
411	*Dendrobium heterocarpum* Wall.ex. Lindl.	Orchidaceae	Raj.2016	412	*Epipactis helleborine* (L.) Crantz	Orchidaceae	Raj.2016
413	*Epipactis royleana* Lindl.	Orchidaceae	Raj.2016	414	*Epipactis veratrifolia* Boiss. & Hohen.	Orchidaceae	Raj.2016
415	*Eulophia dabia* (D. Don) Hochr.	Orchidaceae	Raj.2016	416	*Eulophia herbacea* Lindl.	Orchidaceae	Raj.2016
417	*Geodorum densiflorum* (Lam.) Schltr.	Orchidaceae	D452	418	*Goodyera procera* (Ker- Gawl.) Hook.	Orchidaceae	Raj.2016
419	*Goodyera repens* (L.) R. Br.	Orchidaceae	Raj.2016	420	*Habenaria arietina* Hook.f.	Orchidaceae	Raj.2016
421	*Habenaria commelinifolia* (Roxb.) Wall ex Lindl.	Orchidaceae	D670	422	*Habenaria intermedia* D. Don	Orchidaceae	Raj.2016
423	*Luisia zeylanica* Lindl.	Orchidaceae	D285	424	*Nervilia concolor* (Blume) Schltr.	Orchidaceae	Raj.2016
425	*Oberonia ensiformis* (Sm.) Lindl.	Orchidaceae	Raj.2016	426	*Oberonia falconeri* Hook.f.	Orchidaceae	Raj.2016

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427	*Oberonia pachyrachis* Rchb.f. ex Hook.f.	Orchidaceae	Raj.2016	428	*Papilionanthe teres* (Roxb.) Schltr.	Orchidaceae	Raj.2016
429	*Pecteilis triflora* (D. Don) Tang. & Wang.	Orchidaceae	Raj.2016	430	Pelatantheria insectifera (Rchb. f.) Ridl.	Orchidaceae	Raj.2016
431	*Peristylus constrictus* (Lindl.) Lindl	Orchidaceae	Raj.2016	432	*Peristylus densus* (Lindl.) Santapau & Kalipada	Orchidaceae	Raj.2016
433	*Peristylus goodyeroides* (D. Don) Lindl.	Orchidaceae	Raj.2016	434	*Phalaenopsis taenialis* (Lindl.) Christenson & Pradhan	Orchidaceae	Raj.2016
435	*Pholidota articulata* Lindl.	Orchidaceae	Raj.2016	436	*Pinalia spicata* (D.Don.) S.C. Chen. & J.J. Wood.	Orchidaceae	Raj.2016
437	*Rhynchostylis retusa* (L.) Blume.	Orchidaceae	Raj.2016	438	*Satyrium nepalense* D. Don.	Orchidaceae	Raj.2016
439	*Smitinandia micrantha* (Lindl.) Holttum	Orchidaceae	Raj.2016	440	*Spiranthes sinensis* (Pers) Ames	Orchidaceae	Raj.2016
441	*Vanda cristata* Wall.ex Lindl.	Orchidaceae	Raj.2016	442	*Vanda tessellata* (Roxb.) Hook. ex G. Don	Orchidaceae	Raj.2016
443	*Vandopsis undulata* (Lindl.) J. J. Sm	Orchidaceae	Raj.2016	444	*Zeuxine strateumatica* (L.) Schltr.	Orchidaceae	Raj.2016
445	*Aeginetia indica* L.	Orobanchaceae	Raj.2016	446	*Orobanche aegyptiaca* Pers.	Orobanchaceae	Raj.2016
447	*Sopubia trifida* Buch.-Ham. ex D. Don	Orobanchaceae	Raj.2016	448	*Biophytum reinwardtii* (Zucc.) Klotzsh	Oxalidaceae	Raj.2016
449	*Fumaria indica* (Hausskn.) Pugsley	Papaveraceae	Raj.2016	450	*Fumaria vaillantii* Loisel.	Papaveraceae	Raj.2016
451	*Eurya acuminata* DC.	Pentaphyllaceae	D279	452	*Eurya cerasifolia* (D.Don.) Kobuski.	Pentaphyllaceae	D724
453	*Erythranthe tenella* (Bunge) G.L. Nesom.	Phrymaceae	Raj.2016	454	*Mimulus strictus* Benth.	Phrymaceae	D631
455	*Antidesma acidum* Retz.	Phyllanthaceae	D427	456	*Aporosa octandra* (Buch.-Ham. ex D.Don.) Vickery	Phyllanthaceae	Raj.2016
457	*Baccaurea ramiflora* Lour.	Phyllanthaceae	Raj.2016	458	*Bridelia retusa* (L.) A. Juss.	Phyllanthaceae	Raj.2016
459	*Phyllanthus emblica* L.	Phyllanthaceae	D277	460	*Phyllanthus nubigenus* (Hook.f.) Chakrab. & N.P. Balakr.	Phyllanthaceae	Raj.2016

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461	*Phyllanthus reticulatus* Poir.	Phyllanthaceae	Raj.2016	462	*Phyllanthus urinaria* L.	Phyllanthaceae	D229
463	*Phyllanthus velutinus* (Wight.) Mull.Arg.	Phyllanthaceae	Raj.2016	464	*Phyllanthus virgatus* G. Frost.	Phyllanthaceae	D221
465	*Pinus roxburghii* Sarg.	Pinaceae	D170	466	*Piper longum* L.	Piperaceae	D469
467	*Hemiphragma heterophyllum* Wall.	Plantaginaceae	Raj.2016	468	*Limnophila indica* (L.) Druce	Plantaginaceae	Raj.2016
469	*Limnophila sessiliflora* (Vahl.) Blume.	Plantaginaceae	Lam.2014	470	*Lindenbergia grandiflora* (Buch.-Ham.ex D.Don.) Benth.	Plantaginaceae	D149
471	*Lindenbergia muraria* (Roxb.ex D. Don) Bruhl	Plantaginaceae	Raj.2016	472	*Veronica undulata* Wall.	Plantaginaceae	D15
473	*Apluda mutica* L.	Poaceae	D93	474	*Arthraxon hispidus* (Thunb.) Makino.	Poaceae	Raj.2016
475	*Arthraxon lancifolius* (Trin.) Hochst.	Poaceae	Raj.2016	476	*Arundinella bengalensis* (Spreng.) Druce	Poaceae	Raj.2016
477	*Arundinella nepalensis* Trin.	Poaceae	D169	478	*Arundo donax* L.	Poaceae	D557
479	*Bothriochloa bladhii* (Retz.) S.T. Blake.	Poaceae	Raj.2016	480	*Bothriochloa ischaemum* (L.) Keng.	Poaceae	D664
481	*Bothriochloa pertusa* (L.) A. Camus.	Poaceae	D287	482	*Urochloa ramosa* (L.) T.Q.Nguyen	Poaceae	Raj.2016
483	*Brachiaria villosa* (Lam.) A.Camus.	Poaceae	D406	484	*Capillipedium assimile* (Steudel) A. Camus.	Poaceae	Raj.2016
485	*Cenchrus flaccidus* (Griseb.) Marrone.	Poaceae	Raj.2016	486	*Chrysopogon aciculatus* (Retz.) Trin.	Poaceae	D585
487	*Chrysopogon fulvus* (Spreng.) Chiov.	Poaceae	D148	488	*Chrysopogon gryllus* (L.) Trin.	Poaceae	Raj.2016
489	*Chrysopogon serrulatus* Trin.	Poaceae	D05	490	*Coix lacryma-jobi* L.	Poaceae	Raj.2016
491	*Cymbopogon pendulus* (Nees ex Steud.) W. Watson	Poaceae	Raj.2016	492	*Cymbopogon pospischilii* (K. Schum.) C.E. Hubb.	Poaceae	Raj.2016
493	*Cynodon dactylon* (L.) Pers.	Poaceae	Raj.2016	494	*Cyrtococcum patens* (L.) A. Camus	Poaceae	Raj.2016
495	*Desmostachya bipinnata* (L.) Stapf.	Poaceae	Raj.2016	496	*Dichanthium annulatum* (Forssk.) Stapf	Poaceae	Raj.2016

SN	Name of species	Family	Remarks	SN	Name of species	Family	Remarks
497	*Digitaria abludens* (Roem. & Schult.) Veldkamp	Poaceae	Raj.2016	498	*Digitaria ciliaris* (Retz.) Koeler	Poaceae	D06
499	*Digitaria cruciata* (Nees.) A. Camus.	Poaceae	Raj.2016	500	*Digitaria longiflora* (Retz.) Pers	Poaceae	Raj.2016
501	*Digitaria radicosa* (J. Presl) Miq.	Poaceae	Raj.2016	502	*Digitaria setigera* Roth.	Poaceae	Raj.2016
503	*Digitaria stricta* Roth.	Poaceae	Raj.2016	504	*Digitaria violascens* Link	Poaceae	Raj.2016
505	*Drepanostachyum falcatum* (Nees.) Keng. f.	Poaceae	Raj.2016	506	*Echinochloa crus-galli* (L.) Beauv.	Poaceae	D734
507	*Eleusine indica* (L.) Gaertn.	Poaceae	D613	508	*Eragrostiella nardoides* (Trin.) Bor.	Poaceae	D160
509	*Eragrostis amabilis* (L.) Weight & Arn.	Poaceae	Raj.2016	510	*Eragrostis atrovirens* (Desf.) Trin.ex Steud.	Poaceae	D663
511	*Eragrostis japonica* (Thunb.) Trin.	Poaceae	Raj.2016	512	*Eragrostis minor* Host.	Poaceae	D660
513	*Eragrostis nigra* Nees ex Steud.	Poaceae	D979	514	*Eragrostis pilosa* (L.) P.Beauv.	Poaceae	D662
515	*Eragrostis tremula* Hoschst.ex Steud.	Poaceae	Raj.2016	516	*Eragrostis unioloides* (Retz.) Nees ex Steud.	Poaceae	D309
517	*Eragrostis viscosa* (Retz.) Trin.	Poaceae	Raj.2016	518	*Eulalia fastigiata* (Nees ex Steud.) Haines.	Poaceae	Raj.2016
519	*Eulalia leschenaultiana* (Decne.) Ohwi	Poaceae	Raj.2016	520	*Eulalia mollis* (Griseb.) Kuntze	Poaceae	Raj.2016
521	*Eulaliopsis binata* (Retz.) C. E. Hubb.	Poaceae	Raj.2016	522	*Hackelochloa granularis* (L.) Kunthze.	Poaceae	D58
523	*Hemarthria compressa* (L.f.) R. Br.	Poaceae	Raj.2016	524	*Heteropogon contortus* (L.) P. Beauv.ex Roem & Schult.	Poaceae	D68
525	*Hygroryza aristata* (Retz.) Nees.ex Weight & Arn.	Poaceae	Raj.2016	526	*Imperata cylindrica* (L.) P.Beauv.	Poaceae	D57
527	*Isachne albens* Trin.	Poaceae	Raj.2016	528	*Isachne globosa* (Thumb.) Kuntze	Poaceae	Raj.2016
529	*Ischaemum rugosum* Salisb.	Poaceae	Raj.2016	530	*Microstegium fasciculatum* (L.) Henrard.	Poaceae	Raj.2016

SN	Name of species	Family	Remarks	SN	Name of species	Family	Remarks
531	*Neyraudia reynaudiana* (Kunh.) Keng.ex A.S. Hitsc.	Poaceae	Raj.2016	532	*Oplismenus burmanni* (Retz.) P. Beauv.	Poaceae	Raj.2016
533	*Oryza officinalis* Wall. ex Watt	Poaceae	Raj.2016	534	*Oryza rufipogon* Griff.	Poaceae	D507
535	*Panicum curviflorum* Hornem.	Poaceae	D65	536	*Panicum dichotomum* L.	Poaceae	Raj.2016
537	*Panicum humile* Steud.	Poaceae	D826	538	*Panicum notatum* Retz.	Poaceae	D66
539	*Panicum repens* L.	Poaceae	Raj.2016	540	*Paspalum scrobiculatum* L.	Poaceae	Raj.2016
541	*Perotis hordeiformis* Nees ex Hook. & Arn.	Poaceae	Raj.2016	542	*Eragrostis nigra* Nees.ex Steud.	Poaceae	Raj.2016
543	*Phragmites karka* (Retz.) Trin.ex Steud.	Poaceae	Lam.2014	544	*Polypogon fugax* Nees.ex Steud.	Poaceae	Raj.2016
545	*Polypogon monspeliensis* (L.) Desf.	Poaceae	Raj.2016	546	*Saccharum bengalense* Retz.	Poaceae	Raj.2016
547	*Setaria helvola* (L.f.) Roem. & Schult.	Poaceae	Raj.2016	548	*Setaria palmifolia* (J. Koenig) Stapf	Poaceae	Raj.2016
549	*Setaria verticillata* (L.) P. Beauv.	Poaceae	Raj.2016	550	*Sporobolus diandrus* (Retz.) P. Beauv.	Poaceae	Raj.2016
551	*Sporobolus fertilis* (Steud.) Clayton	Poaceae	Raj.2016	552	*Sporobolus piliferus* (Trin.) Kunth.	Poaceae	D139
553	*Themeda anathera* (Nees ex Steud.) Hack.	Poaceae	Raj.2016	554	*Themeda arundinacea* (Roxb.) A. Camus	Poaceae	Raj.2016
555	*Tripogon filiformis* Nees ex Steud.	Poaceae	Raj.2016	556	*Urochloa panicoides* P. Beauv.	Poaceae	D614
557	*Polygala abyssinica* R. Br. ex Fresen.	Polygalaceae	Raj.2016	558	*Polygala crotalarioides* Buch.-Ham.ex DC.	Polygalaceae	Raj.2016
559	*Polygala longifolia* Poir.	Polygalaceae	D218	560	*Polygala persicariifolia* DC.	Polygalaceae	Raj.2016
561	*Persicaria barbata* (L.) H. Hara	Polygonaceae	D45	562	*Persicaria capitata* (Buch.-Ham. ex D. Don) H. Gross	Polygonaceae	Raj.2016
563	*Persicaria chinensis* (L.) H. Gross	Polygonaceae	Raj.2016	564	*Persicaria limbata* (Meisn.) H. Hara	Polygonaceae	Raj.2016
565	*Persicaria nepalensis* (Meisn.) Miyabe.	Polygonaceae	D168	566	*Persicaria praetermissa* (Hook.f.) H.Hara	Polygonaceae	Raj.2016

SN	Name of species	Family	Remarks	SN	Name of species	Family	Remarks
567	*Persicaria tenella* (Blume.) H. Hara	Polygonaceae	Raj.2016	568	*Persicaria viscosum* (Buch. - Ham.ex. D.Don.) H.Gross ex.T.Mori.	Polygonaceae	Raj.2016
569	*Rumex dentatus* L.	Polygonaceae	Lam.2014	570	*Rumex hastatus* D. Don	Polygonaceae	Raj.2016
571	*Rumex nepalensis* Spreng.	Polygonaceae	Raj.2016	572	*Persicaria lapathifolia* (L.) Delarbre.	Polygonaceae	Raj.2016
573	*Lepisorus nudus* Ching.	Polypodiaceae	D186	574	*Microsorum membranaceum* (D. Don) Ching.	Polypodiaceae	Raj.2016
575	*Monochoria hastata* (L.) Solms.	Pontederiaceae	D650	576	*Monochoria vaginalis* (Burm.f.) C. Presl ex Kunth	Pontederiaceae	Raj.2016
577	*Potamogeton crispus* L.	Potamogetonaceae	Raj.2016	578	*Ardisia solanacea* Roxb.	Primulaceae	Raj.2016
579	*Maesa chisia* Buch.-Ham.ex D.Don.	Primulaceae	Raj.2016	580	*Myrsine semiserrata* Wall.	Primulaceae	Raj.2016
581	*Pteris vittata* L.	Pteridaceae	Raj.2016	582	*Aleuritopteris bicolor* (Roxb.) Fraser.-Jenk.	Pteridaceae	Raj.2016
583	*Pteris biaurita* L.	Pteridaceae	D128	584	*Clematis acuminata* DC	Ranunculaceae	Raj.2016
585	*Clematis smilacifolia* Wall.	Ranunculaceae	D730	586	*Eriocapitella vitifolia* (Buch.-Ham.ex DC.) Nakai.	Ranunculaceae	Raj.2016
587	*Ranunculus diffusus* DC.	Ranunculaceae	Raj.2016	588	*Thalictrum foliolosum* DC.	Ranunculaceae	Raj.2016
589	*Ziziphus incurva* Roxb.	Rhamnaceae	Raj.2016	590	*Ziziphus jujuba* Mill.	Rhamnaceae	Raj.2016
591	*Agrimonia pilosa* Ledeb.	Rosaceae	Raj.2016	592	*Argentina lineata* (Trevir) Sojak.	Rosaceae	Raj.2016
593	*Photinia integrifolia* Lindl.	Rosaceae	Raj.2016	594	*Prunus cerasoides Buch.-Ham.ex D.Don.)*	Rosaceae	Raj.2016
595	*Pyracantha crenulata* (D. Don) M. Roem.	Rosaceae	Raj.2016	596	*Pyrus pashia* Buch.-Ham.ex D.Don.	Rosaceae	Raj.2016
597	*Rosa moschata* Hiern.	Rosaceae	Raj.2016	598	*Rubus ellipticus* Sm.	Rosaceae	Raj.2016
599	*Adina cordifolia* (Roxb.) Brandis	Rubiaceae	D907	600	*Argostemma sarmentosum* Wall.	Rubiaceae	Raj.2016
601	*Catunaregam longispina* (Thunb.) Tirveng.	Rubiaceae	D738	602	*Galium elegans* Wall.ex. Roxb.	Rubiaceae	Raj.2016

SN	Name of species	Family	Remarks	SN	Name of species	Family	Remarks
603	*Galium hirtiflorum* Req. ex DC.	Rubiaceae	D145	604	*Hymenodictyon orixense* (Roxb.) Mabb.	Rubiaceae	Raj.2016
605	*Leptodermis kumaonensis* R. Parker	Rubiaceae	Raj.2016	606	*Oldenlandia corymbosa* L.	Rubiaceae	Raj.2016
607	*Ophiorrhiza rugosa* Wall.	Rubiaceae	Raj.2016	608	*Scleromitrion diffusum* (Willd.) R.J. Wang.	Rubiaceae	Raj.2016
609	*Spermacoce articularis* L.	Rubiaceae	Raj.2016	610	*Spermacoce pusilla* Wall.	Rubiaceae	Raj.2016
611	*Spermadictyon suaveolens* Roxb.	Rubiaceae	Raj.2016	612	*Catunaregam spinosa (Thunb.) Tirveng.*	Rubiaceae	Raj.2016
613	*Hedyotis pruinosa* Wight & Arn.	Rubiaceae	Raj.2016	614	*Aegle marmelos* (L.) Corrêa	Rutaceae	D491
615	*Boenninghausenia albiflora* (Hook.) Rchb. ex Meisn.	Rutaceae	Raj.2016	616	*Clausena kanpurensis* J.F.Molino	Rutaceae	Raj.2016
617	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae	D742	618	*Murraya koenigii* (L.) Spreng.	Rutaceae	D425
619	*Toddalia asiatica* (L.) Lam.	Rutaceae	Raj.2016	620	*Zanthoxylum armatum* DC.	Rutaceae	D276
621	*Meliosma dilleniifolia* (Wall.ex Wight & Arn.) Walp.	Sabiaceae	Raj.2016	622	*Sabia paniculata* Edgew.ex Hook.f. & Thomsom.	Sabiaceae	Raj.2016
623	*Casearia graveolens* Dalzell.	Salicaceae	Raj.2016	624	*Flacourtia indica* (Burm.f.) Merr.	Salicaceae	D460
625	*Flacourtia jangomas* (Lour.) Raeusch.	Salicaceae	Raj.2016	626	*Azolla pinnata* R. Br.	Salviniaceae	Raj.2016
627	*Schleichera oleosa* (Lour.) Merr.	Sapindaceae	D418	628	*Diploknema butyracea* (Roxb.) H.J. Lam.	Sapotaceae	Raj.2016
629	*Madhuca longifolia* (J.Koenig ex L.)J.F. Macbr.	Sapotaceae	Raj.2016	630	*Astilbe rivularis* Buch.-Ham.ex D. Don.	Saxifragaceae	Raj.2016
631	*Bergenia pacumbis* (Buch.-Ham. ex D.Don) C.Y.Wu & J.T. Pan.	Saxifragaceae	Raj.2016	632	*Buddleja asiatica* Lour.	Scrophulariaceae	Raj.2016
633	*Verbascum thapsus* L.	Scrophulariaceae	Raj.2016	634	*Selaginella subdiaphana* (Wall.ex Hook. & Gress) Spreng.	Selaginellaceae	D142

SN	Name of species	Family	Remarks	SN	Name of species	Family	Remarks
635	*Selaginella tamariscina* (P. Beauv.) Spring.	Selaginellaceae	Raj.2016	636	*Smilax aspera* L.	Smilacaceae	Raj.2016
637	*Smilax ovalifolia* Roxb. ex. D.Don.	Smilacaceae	D754	638	*Smilax zeylanica* L.	Smilacaceae	D749
639	*Solanum virginianum* L.	Solanaceae	D264	640	*Symplocos racemosa* Roxb.	Symplocaceae	D566
641	*Ampelopteris prolifera* (Retz.) Copel	Thelypteridaceae	D251	642	*Thelypteris arida* (D.Don.) Morton.	Thelypteridaceae	Raj.2016
643	*Thelypteris dentata* (Forssk.) E.P. John.	Thelypteridaceae	Raj.2016	644	*Thelypteris erubescens* (Wall.ex Hook.) Ching.	Thelypteridaceae	Raj.2016
645	*Daphne bholua* Buch.-Ham. ex D. Don	Thymelaeaceae	Raj.2016	646	*Boehmeria virgata* (G.Forst.) Guill.	Urticaceae	Raj.2016
647	*Debregeasia saeneb* (Forssk.) Hepper & J.R.I. Wood.	Urticaceae	Raj.2016	648	*Girardinia diversifolia* (Link.) Friis.	Urticaceae	D260
649	*Gonostegia hirta* (Blume ex Hassk) Miq.	Urticaceae	Raj.2016	650	*Gonostegia pentandra* (Roxb.) Miq.	Urticaceae	D787
651	*Pilea glaberrima* (Blume) Blume	Urticaceae	D187	652	*Pouzolzia rugulosa* (Wedd.) Acharya & Kravtsora.	Urticaceae	Raj.2016
653	*Pouzolzia zeylanica* (L.) Benn.	Urticaceae	D48	654	*Viola canescens* Wall.	Violaceae	Raj.2016
655	*Viola betonicifolia* Sm.	Violaceae	Raj.2016	656	*Viola pilosa* Blume	Violaceae	Raj.2016
657	*Ampelocissus latifolia* (Roxb.) Planch.	Vitaceae	Raj.2016	658	*Cissus repens* Lam.	Vitaceae	D405
659	*Leea aequata* L.	Vitaceae	Raj.2016	660	*Leea alata* Edgew.	Vitaceae	D409
661	*Leea asiatica* (L.) Ridsdale.	Vitaceae	Raj.2016	662	*Leea macrophylla* Roxb.ex Hornem.	Vitaceae	D192
663	*Parthenocissus semicordata* (Wall.) Planch.	Vitaceae	Raj.2016	664	*Tetrastigma hookeri* (Laws.) Planch.	Vitaceae	D579
665	*Tetrastigma serrulatum* (Roxb.) Planch.	Vitaceae	Raj.2016	666	*Cautleya gracilis* (Sm.) Dandy	Zingiberaceae	Raj.2016
667	*Curcuma angustifolia* Roxb.	Zingiberaceae	Raj.2016	668	*Globba marantina* L.	Zingiberaceae	Raj.2016
669	*Globba racemosa* Sm.	Zingiberaceae	D401	670	*Hedychium ellipticum* Buch.-	Zingiberaceae	D173

***Lam.2014** = Lamsal *et al*., 2014; **Bha.2015** = Bhattrai & Acharya, 2015; **Raj.2016** = Rajbhandari *et al*., 2016; **MoFSC.2017** = MoFSC, 2017.

***D** = Collection from present study.

Appendix 5. List of naturalized plant species with their life form and native range.

SN	Botanical Name	Family	Life form	Origin	Status	Remarks
1	*Agave cantala* (Haw.) Roxb. ex Salm-Dyck	Asparagaceae	Shrub	America	Naturalized non-invasive	Raj.2016
2	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Asteraceae	Herb	America	Invasive	Raj.2016
3	*Ageratum conyzoides* L.	Asteraceae	Herb	America	Invasive	TUCH 00057
4	*Ageratum houstonianum* Mill.	Asteraceae	Herb	America	Invasive	TUCH 00094
5	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	Herb	America	Invasive	Raj.2016
6	*Alternanthera sessilis* (L.) R.Br.ex DC.	Amaranthaceae	Herb	America	Naturalized non-invasive	TUCH 00156
7	*Amaranthus hybridus* L.	Amaranthaceae	Herb	America	Naturalized non-invasive	TUCH 00166
8	*Amaranthus spinosus* L.	Amaranthaceae	Herb	America	Invasive	TUCH 00184
9	*Amaranthus viridis* L.	Amaranthaceae	Herb	America	Naturalized non-invasive	TUCH 00168
10	*Argemone mexicana* L.	Papaveraceae	Herb	America	Invasive	Raj.2016
11	*Asclepias curassavica* L.	Apocynaceae	Herb	America	Naturalized non-invasive	Raj.2016
12	*Axonopus compressus* (Sw.) P.Beauv.	Poaceae	Herb	America	Naturalized non-invasive	TUCH 00167
13	*Bidens biternata* (Lour.) Merr. & Sherff	Asteraceae	Herb	Africa	Naturalized non-invasive	Raj.2016
14	*Bidens pilosa* L.	Asteraceae	Herb	America	Invasive	Raj.2016
15	*Biophytum sensitivum* (L.) DC.	Oxalidaceae	Herb	Asia	Naturalized non-invasive	Raj.2016
16	*Bolboschoenus fluviatilis* (Torr.) Sujak.	Cyperaceae	Herb	America	Naturalized non-invasive	Raj.2016
17	*Cardamine flexuosa* With.	Brassicaceae	Herb	Europe	Naturalized non-invasive	Raj.2016
18	*Cenchrus purpureus* (Schumach) Morrone	Poaceae	Herb	Africa	Naturalized non-invasive	Raj.2016

SN	Botanical Name	Family	Life form	Origin	Status	Remarks
19	*Chenopodium album* L.	Amaranthaceae	Herb	Europe	Naturalized non-invasive	Raj.2016
20	*Cirsium arvense* (L.) Scop.	Asteraceae	Herb	Europe	Naturalized non-invasive	TUCH 00273
21	*Corchorus aestuans* L.	Malvaceae	Herb	America	Naturalized non-invasive	TUCH 00363
22	*Crassocephalum crepidioides* (Benth.) S.Moore.	Asteraceae	Herb	Africa	Naturalized non-invasive	TUCH 00326
23	*Croton bonplandianus* Baill.	Euphorbiaceae	Herb	America	Naturalized non-invasive	Raj.2016
24	*Cyanthillium cinereum* (L.) H. Rob.	Asteraceae	Herb	America	Naturalized non-invasive	Raj.2016
25	*Cynodon plectostachyus* (K.Schum.) Pilg.	Poaceae	Herb	Africa	Naturalized non-invasive	D520
26	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	Herb	Africa	Naturalized non-invasive	TUCH 00221
27	*Datura metel* L.	Solanaceae	Herb	America	Naturalized non-invasive	Raj.2016
28	*Drymaria villosa* Schltdl. & Cham.	Caryophyllaceae	Herb	America	Naturalized non-invasive	TUCH 00230
29	*Drymaria cordata* (L.) Willd.ex Schult.	Caryophyllaceae	Herb	America	Naturalized non-invasive	TUCH 00247
30	*Dysphania ambrosioides* (L.) Mos. & Clem.	Amaranthaceae	Herb	America	Naturalized non-invasive	Raj.2016
31	*Eclipta prostrata* (L.) L.	Asteraceae	Herb	America	Naturalized non-invasive	TUCH 00676
32	*Eichhornia crassipes* (Mart.) Solms.	Pontederiaceae	Herb	America	Invasive	D22
33	*Erigeron canadensis* L.	Asteraceae	Herb	America	Naturalized non-invasive	Raj.2016
34	*Erigeron karvinskianus* DC.	Asteraceae	Herb	America	Invasive	TUCH 01719
35	*Euphorbia heterophylla* L.	Euphorbiaceae	Herb	America	Naturalized non-invasive	TUCH 00827
36	*Euphorbia hirta* L.	Euphorbiaceae	Herb	America	Naturalized non-invasive	TUCH 00723
37	*Euphorbia prostrata* Aiton.	Euphorbiaceae	Herb	America	Naturalized non-invasive	Raj.2016
38	*Evolvulus nummularius* (L.) L.	Convolvulaceae	Herb	America	Naturalized non-invasive	TUCH 01086

SN	Botanical Name	Family	Life form	Origin	Status	Remarks
39	*Galinsoga parviflora* Cav.	Asteraceae	Herb	America	Naturalized non-invasive	Raj.2016
40	*Galinsoga quadriradiata* Ruiz. & Rav.	Asteraceae	Herb	America	Invasive	TUCH 00663
41	*Gomphrena celosioides* Mart.	Amaranthaceae	Herb	America	Naturalized non-invasive	TUCH 00704
42	*Heliotropium indicum* L.	Boraginaceae	Herb	America	Naturalized non-invasive	Raj.2016
43	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	Herb	America	Invasive	TUCH 00969
44	*Ipomoea carnea* subsp. *fistulosa* (Mart.ex Choisy) D.F. Austin.	Convolvulaceae	Shrub	America	Invasive	MoFSC,2017
45	*Ipomoea quamoclit* L.	Convolvulaceae	Climber	America	Naturalized non-invasive	TUCH 00788
46	*Jatropha curcas* L.	Euphorbiaceae	Shrub	America	Naturalized non-invasive	Bha.2015
47	*Lantana camara* L.	Verbenaceae	Shrub	America	Invasive	TUCH 00876
48	*Lemna perpusilla* Torr.	Araceae	Herb	America	Naturalized non-invasive	Raj.2016
49	*Leonotis nepetifolia* (L.) R. Br.	Lamiaceae	Herb	Africa	Naturalized non-invasive	Raj.2016
50	*Ludwigia octovalvis* (Jacq.) P. H. Raven	Onagraceae	Herb	America	Naturalized non-invasive	Raj.2016
51	*Martynia annua* L.	Martyniaceae	Herb	America	Naturalized non-invasive	Raj.2016
52	*Mimosa pudica* L.	Fabaceae	Herb	America	Invasive	TUCH 00940
53	*Mirabilis jalapa* L.	Nyctaginaceae	Herb	America	Naturalized non-invasive	Raj.2016
54	*Nasturtium officinale R. Br.*	Brasicaceae	Herb	Europe	Naturalized non-invasive	TUCH 01558
55	*Nicandra physalodes* (L.) Gaertn.	Solanaceae	Herb	America	Naturalized non-invasive	Raj.2016
56	*Nicotiana plumbaginifolia* Viv.	Solanaceae	Herb	America	Naturalized non-invasive	Raj.2016
57	*Oenothera rosea* L.Her.ex Aiton	Onagraceae	Herb	America	Naturalized non-invasive	Raj.2016
58	*Oxalis corniculata* L.	Oxalidaceae	Herb	America	Naturalized non-invasive	TUCH 01046
59	*Panicum dichotomiflorum* Michx.	Poaceae	Herb	America	Naturalized non-invasive	Raj.2016

SN	Botanical Name	Family	Life form	Origin	Status	Remarks
60	*Parthenium hysterophorus* L.	Asteraceae	Herb	America	Invasive	TUCH 01155
61	*Paspalum distichum* L.	Poaceae	Herb	America	Naturalized non-invasive	TUCH 01612
62	*Peperomia pellucida* (L.) Kunth.	Piperaceae	Herb	America	Naturalized non-invasive	TUCH 01093
63	*Physalis angulata* L.	Solanaceae	Herb	America	Naturalized non-invasive	TUCH 01562
64	*Pistia stratiotes* L.	Araceae	Herb	America	Invasive	Raj.2016
65	*Psidium guajava* L.	Myrtaceae	Tree	America	Naturalized non-invasive	TUCH 01179
66	*Ricinus communis* L.	Euphorbiaceae	Shrub	Africa	Naturalized non-invasive	Raj.2016
67	*Sambucus canadensis* L.	Adoxaceae	Shrub	America	Naturalized non-invasive	Raj.2016
68	*Schoenoplectiella supina* (L.) Lye.	Cyperaceae	Herb	Europe	Naturalized non-invasive	Raj.2016
69	*Scoparia dulcis* L.	Plantaginaceae	Herb	America	Naturalized non-invasive	TUCH 01589
70	*Senna occidentalis* (L.) Link.	Fabaceae	Shrub	America	Invasive	TUCH 01519
71	*Senna sophera* (L.) Roxb.	Fabaceae	Shrub	America	Naturalized non-invasive	Raj.2016
72	*Senna tora* (L.) Roxb.	Fabaceae	Herb	America	Invasive	TUCH 01500
73	*Setaria parviflora* (Poir.) M. Kerguelen	Poaceae	Herb	America	Naturalized non-invasive	D44
74	*Sida acuta* Burm.f.	Malvaceae	Shrub	America	Naturalized non-invasive	TUCH 01328
75	*Sida cordifolia* L.	Malvaceae	Shrub	Australia	Naturalized non-invasive	TUCH 01335
76	*Sida rhombifolia* L.	Malvaceae	Shrub	America	Naturalized non-invasive	TUCH 01381
77	*Solanum aculeatissimum* Jacq.	Solanaceae	Herb	America	Naturalized non-invasive	TUCH 01307
78	*Solanum torvum* Sw.	Solanaceae	Herb	America	Naturalized non-invasive	TUCH 01406

SN	Botanical Name	Family	Life form	Origin	Status	Remarks
79	*Spergula arvensis* L.	Caryophyllaceae	Herb	Europe	Invasive	Raj.2016
80	*Spermacoce alata* Aubl.	Rubiaceae	Herb	America	Invasive	TUCH 01452
81	*Sphenoclea zeylanica* Gaertn.	Sphenocleaceae	Herb	Africa	Naturalized non-invasive	D17
82	*Stellaria media* (L.) Vill.	Caryophyllaceae	Herb	Europe	Naturalized non-invasive	Raj.2016
83	*Tridax procumbens* L.	Asteraceae	Herb	America	Naturalized non-invasive	TUCH 01531
84	*Trifolium repens* L.	Fabaceae	Herb	Europe	Naturalized non-invasive	Raj.2016
85	*Vachellia farnesiana* (L.) Wight & Arn.	Fabaceae	Tree	America	Naturalized non-invasive	Raj.2016
86	*Vachellia nilotica* (L.) P.J.H. Hurter & Mabb.	Fabaceae	Tree	Africa	Naturalized non-invasive	Raj.2016
87	*Xanthium strumarium* L.	Asteraceae	Herb	America	Invasive	TUCH 01462

***Lam.2014** = Lamsal et al., 2014; **Bha.2015** = Bhattrai & Acharya, 2015; **Raj.2016** = Rajbhandari et al., 2016; **MoFSC.2017** = MoFSC, 2017.

***TUCH** = already digitized barcode for naturalized species; ***D** = Collection from present study.

Appendix 6. List of Cryptogenic plant species and their families.

SN	Botanical Name	Family	Remarks	SN	Botanical Name	Family	Remarks
1	*Acmella paniculata* (Wall. ex DC.) R. K. Jansen	Asteraceae	D244	2	*Acorus calamus* L.	Acoraceae	Raj.2016
3	*Adiantum philippense* L.	Pteridaceae	D98	4	*Aeschynomene indica* L.	Fabaceae	Raj.2016
5	*Alopecurus aequalis* Sobol.	Poaceae	Raj.2016	6	*Ammannia auriculata* Willd.	Lythraceae	D29
7	*Bacopa monnieri* (L.) Pennell	Plantaginaceae	Raj.2016	8	*Bidens bipinnata* L.	Asteraceae	D122
9	*Boerhavia diffusa* L.	Nyctaginaceae	D407	10	*Thelypteris interrupta* (Willd.) K.Iwats.	Thylipteridaceae	Raj.2016
11	*Cyperus compressus* L.	Cyperaceae	D602	12	*Cyperus corymbosus* Rottb.	Cyperaceae	D653
13	*Cyperus cuspidatus* Kunth	Cyperaceae	Raj.2016	14	*Cyperus cyperoides* (L.) Kuntze	Cyperaceae	Raj.2016
15	*Cyperus digitatus* Roxb.	Cyperaceae	Raj.2016	16	*Cyperus distans* L.f.	Cyperaceae	D16
17	*Cyperus esculentus* L.	Cyperaceae	Raj.2016	18	*Cyperus squarrosus* L.	Cyperaceae	Raj.2016
19	*Echinochloa colona* (L.) Link.	Poaceae	Raj.2016	20	*Euphorbia thymifolia* L.	Euphorbiaceae	D665
21	*Fimbristylis complanata* (Retz.) Link	Cyperaceae	Raj.2016	22	*Fimbristylis dichotoma* (L.) Vahl.	Cyperaceae	D51
23	*Fimbristylis ovata* (Burm.f.) J.Kern	Cyperaceae	Raj.2016	24	*Lemna minor* L.	Araceae	Lam.2014
25	*Lessingianthus plantaginodes* R. Parker.	Asteraceae	Raj.2016	26	*Ludwigia adscendens* (L.) H. Hara	Onagraceae	Raj.2016
27	*Ocotea lancifolia* (Scott.) Mez.	Lauraceae	Raj.2016	28	*Ophioglossum reticulatum* L.	Ophioglossaceae	D465
29	*Peperomia tetraphylla* (G. Forst) Hook. & Arn.	Piperaceae	Raj.2016	30	*Persicaria glabra* (Willd.) M. Gomez	Polygonaceae	Raj.2016
31	*Phyla nodiflora* (L.) Greene.	Verbenaceae	D527	32	*Ranunculus sceleratus* L.	Ranunculaceae	Raj.2016
33	*Torenia crustacea* (L.) Cham. & Schltdl.	Linderniaceae	Raj.2016	34	*Typha angustifolia* L.	Typhaceae	MoFSC,2017
35	*Urtica dioica* L.	Urticaceae	D294				

Lam.2014 = Lamsal et al., 2014; **Bha.2015** = Bhattrai & Acharya, 2015; **Raj.2016** = Rajbhandari et al., 2016; **MoFSC.2017** = MoFSC, 2017.

Appendix 7. Diversity of vascular plants across different land use types.

Land use types	Native	Naturalized	Invasive	Cryptogenic	Total
Agriculture land	66	29	6	24	119
Roadside grazing land	79	**32**	**11**	16	127
Degraded Sal forest	85	19	3	10	114
Agriculure fallow land	74	14	2	9	97
Mixed broad leaved forest	123	14	2	13	150
Riverine forest	81	12	2	7	100
Shorea-Terminalia forest	101	**9**	2	1	111

Appendix 8. Total vascular plant species recorded in 35 selected sample plots.

SN	Land-use types	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Total species
1	*Shorea-Terminalia* forest	44	40	50	56	58	111
2	Riverine forest	40	47	52	45	45	100
3	Agriculture land	57	26	41	47	66	119
4	Agriculture fallow land	43	42	49	47	52	97
5	Mixed broad leaved forest	59	57	63	59	64	150
6	Roadside grazing land	61	66	52	48	57	127
7	Degraded Sal forest	48	56	59	52	51	114

Appendix 9. Cover of invasive species from selected seven land use types.

SN	Invasive species	Sho-Ter.	Rivrine	Agriculture	Ag. Falw.	Mixed	Roadside	Deg. Sal	Cover (%)
1	*Ageratum houstonianum*	48.33	5	98.5	2.5	16.25	103.5	116.5	30.04
2	*Senna tora*	2.5	15	12	6.87	52.5	**711**	30.5	63.87
3	*Ipomoea carnea subsp. fistulosa*	0	0	2.5	0	0	15	0	1.35
4	*Bidens pilosa*	0	0	2.5	0	0	2.5	0	0.38
5	*Pistia stratiotes*	0	0	2.5	0	0	0	0	0.19
6	*Eichhornia crassipes*	0	0	2.5	0	0	2.5	0	0.38
7	*Parthenium hysterophorus*	0	0	0	0	0	24	0	1.85
8	*Hyptis suaveolens*	0	0	0	0	0	58	0	4.46
9	*Lantana camara*	0	0	0	0	0	9.17	0	0.71
10	*Senna occidentalis*	0	0	0	0	0	3.75	2.5	0.48
11	*Xanthium strumarium*	0	0	0	0	0	4.5	0	0.35
12	*Amaranthus spinosus*	0	0	0	0	0	2.5	0	0.19

*** Sho-Ter.** = *Shorea -Terminalia* forest; **Rivrine** = Riverine forest; **Agriculture** = Agriculture land; **Ag. Falw.**= Agriculture fallow land; **Mixed** = Mixed broad leaved forest; **Roadside** = Roadside grazing land; **Deg. Sal** = Degraded Sal forest

Appendix 10. Frequency of invasive species in selected land use types.

SN	Invasive species	Sho-Ter.	Rivrine	Agriculture	Ag. Falw.	Mixed	Roadside	Deg. Sal	F (%)
1	*Ageratum houstonianum*	0.359	0.154	0.692	0.077	0.308	0.596	0.708	41.34
2	*Senna tora*	0.077	0.206	0.215	0.211	0.154	0.985	0.477	33.22
3	*Parthenium hysterophorus*	0	0	0	0	0	0.354	0	5.05
4	*Senna occidentalis*	0	0	0	0	0	0.115	0.077	2.74
5	*Hyptis suaveolens*	0	0	0	0	0	0.169	0	2.41
6	*Ipomoea carnea* subsp. *fistulosa*	0	0	0.077	0	0	0.077	0	2.2
7	*Eichhornia crassipes*	0	0	0.077	0	0	0.077	0	2.2
8	*Lantana camara*	0	0	0	0	0	0.154	0	2.2
9	*Pistia stratiotes*	0	0	0.077	0	0	0	0	1.1
10	*Xanthium strumarium*	0	0	0	0	0	0.138	0	1.97
11	*Bidens pilosa*	0	0	0.077	0	0	0.077	0	2.2
12	*Amaranthus spinosus*	0	0	0	0	0	0.077	0	1.1

*** Sho-Ter.** = *Shorea -Terminalia* forest; **Rivrine** = Riverine forest; **Agriculture** = Agriculture land; **Ag. Falw.**= Agriculture fallow land; **Mixed** = Mixed broad leaved forest; **Roadside** = Roadside grazing land; **Deg. Sal** = Degraded Sal forest

Appendix 11. Regration statistics between different variables; GLM was run upto 2nd order unimodel analysis.

Response variable	Polyn. order	Df	Res.Dev.	Deviance	F	p-value
Natu. with dis. road	0	34	111.632	-	-	-
	1	33	97.67	13.955	5.4714	0.02553
	2	32	91.54	20.092	4.1217	0.02554
Natu. with dis. settlement	0	34	111.63	-	-	-
	1	33	104.12	7.6176	2.5972	0.1166
	2	32	50.154	61.4778	21.97	<0.0001
Natu. with dis. river	0	34	111.63	-	-	-
	1	33	104.12	17.512	12.5709	0.0118
	2	32	100.78	10.857	10.857	0.1638
Natu. with tree canopy	0	34	111.632	-	-	-
	1	33	78.418	33.214	16.046	0.00033
	2	32	78.157	33.476	7.8367	0.00169
Natu. with grazing	0	34	111.632	-	-	-
	1	33	85.116	26.516	10.400	0.00283
	2	32	79.912	31.721	6.6672	0.00379
Natu. with soil pH	0	34	111.632	-	-	-
	1	33	90.067	21.565	8.4951	0.0063
	2	32	89.503	22.129	22.129	0.0205
Natu. with SOC	0	34	111.632	-	-	-
	1	33	99.233	12.399	4.1896	0.0487
	2	32	99.167	12.465	2.0331	0.1475
Natu. with soil Nitrogen	0	34	111.63	-	-	-
	1	33	110.76	0.8712	0.2676	0.6084
	2	32	96.654	14.978	2.6531	0.0858

Response variable	**Polyn. order**	**Df**	**Res.Dev.**	**Deviance**	**F**	**p-value**
Natu. with native richness	0	34	111.63	-	-	-
	1	33	101.76	9.8689	3.3755	0.075
	2	32	92.56	19.065	3.6808	0.036
Natu. with elevation	0	34	111.632	-	-	-
	1	33	98.338	13.295	4.6573	0.038
	2	32	96.505	15.127	2.6757	0.084
Non.inv with IAPs richness	0	34	111.632	-	-	-
	1	33	46.989	64.643	16.247	0.0003
	2	32	43.32	68.312	8.3195	0.001

Appendix 12. Field data sheet used for vegetation sampling in Kailali district.

Naturalized plant species across land use types (Darwin Initiative Project)

S.N: ……… Date: ……….. Site: …………….. Land use: ………………………

Plot no: ………. Latitude: ……………. Longitude: …………… Elevation: …………

Slope: …………. Aspect: ………… Tree canopy (%): …. /…… /……/ ……/… = ….

Fire marks: Y/N Grazing: 0/1/2/3 Logging: Y/N. Other disturbances: ……………

Inventory of species in 0.5m × 2m plots (herb, shrubs, tree seedling, and tree saplings)

S.N	Name of the species	Habit #	**Cover class of species in plot number:**									
			1	2	3	4	5	6	7	8	9	10
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Habit, H: herb, C: climber; S: Shrub, Sd: tree seedling, Sp: tree sapling

* Daubenmire Cover class- **1)** 0-5%, **2)** 5-25%, **3)** 25-50%, **4)** 50-75% **5)** 75-95% **6)** 95-100%

Remarks: ……………………………………………………………………………………..……

Inventory of species in 2m × 5m plots (All Life forms)

S.N.	**Name of species**	**Habit #**	**Cover class* in plot**	
			1	**2**
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

Habit, **H**: herb, **S**: Shrub, **C**: Climber, **Sd**: tree seedling, **Sp**: tree sapling

* Daubenmire Cover class- **1**) 0-5%, **2**) 5-25%, **3**) 25-50%, **4**) 50-75% **5**) 75-95% **6**) 95-100%

Remarks: ………………………………………………………………………………

…………………………………………………………………………………………
……….………………………………………………………………………………..

Inventory of species in 5m × 20m plots (All life forms)

S.N.	Name of species	Habit #	Cover class*
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

Habit, H: herb, C; Climber, S: Shrub, Sd: tree seedling, Sp: tree sapling

* Daubenmire Cover class- **1**) 0-5%, **2**) 5-25%, **3**) 25-50%, **4**) 50-75% **5**) 75-95% **6**) 95-100%

Remarks: …………………………………………………………………….…………

……………………………………………………………………………………

……………………………………………………………………………………..

Name of field investigator: ………………………

Diameter of tree species at breast height (DBH, 137 cm) in 50m × 20 m plot (DBH ≥ 5cm)

S.N.	Name of species	DBH (cm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

Remarks:……………………………………………………………………………… ……………………………………………………………………………………………… ………………………………………………………………………………………………

Name of investigator: ……………………………………..

To be filled as early as possible after returning back from the field

Attribute	Value
Number of invasive alien plant species	
Number of naturalized [$] species	
Number of native species	
Number of fern species	
Number of herbaceous species	
Number of shrub species	
Number of climber species	
Number of tree species	
Average number of species in 0.5m × 2m plot	
Average number of species in 2m × 5m plot	
Total number of vascular plant species	
Total number of trees with DBH ≥ 5cm	

[$] Naturalized species include all alien species which are regenerating without human assistance. This includes both invasive as well as non-invasive species.

Remarks: ....

…………………………………………………………………………………………
…………………………………………………………………………………………..

Name of the field investigator: ……………………………

Appendix 13. Photo plates

Field activities: Plant collection and identification




Field work: Vegetation sampling




Vield work: Vegetation sampling

Lab work: Soil analysis

Research presentation: Conference / Workshop