DEPARTMENT OF FOREST AND SOIL SCIENCES
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INVASIVE ALIEN PLANT SPECIES ASSESSMENT IN THE BUFFER ZONE OF THE CHITWAN NATIONAL PARK, NEPAL

(A CASE STUDY FROM TWO BUFFER ZONE COMMUNITY FORESTS IN TERAI NEPAL)

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Dedicated to my family

for their confidence

on my thoughts and decisions.

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ABSTRACT

Invasive alien species (IAS) are any species introduced in areas where they do not occur naturally are causing enormous damage to the ecosystem. The control and management of these species depends on proper ecological investigations in the context of the affected system. Developing countries like Nepal are among those severely threatened IAS. Nepal lacks comprehensive study which focuses on assessment of impacts of these species. Therefore, this study was conducted in two community forests (CFs), Jankauli and Kumroj, in buffer zone of Chitwan National Park to assess the species diversity and abundance of the most aggressive plant species as well as an attempt to rank IAS in different categories. Random nested plot sampling was used as sampling design. Data were collected through direct observation, forest inventory and key informant survey. The analysis showed that in total 18 trees, 18 shrubs and 36 herb species were encountered in Jankauli CF whereas 20 trees, 22 shrubs and 51 herb species in Kumroj CF. The data show that *Dalbergia sissoo* is the most frequently encroached tree species by *Mikania micarantha, the most serious IAS* in both the CFs. In total 17 plant species were identified as IAS in Jankauli and 19 species in Kumroj CFs. In both the CFs, the highest important value index (IVI) was found in *Mikania micarantha*, so it is the most dominating invasive plant species. Species diversity data showed that Kumroj CF is more diverse than Jankauli CF. Jaccard's coefficient was 0.89, which indicates that both CFs share mostly the same species. In both the CFs, the abundance of *Mikania micarantha* and the species richness were highly negatively correlated at the 0.01 level, which indicates that higher coverage of *M. micarantha* in the plot lowers the number of other species. Species ranking assessment showed *Mikania micarantha*, *Ageratina adenophora* and *Chromalaena odorata* to be highly invasive. The threat from *Bidens pilosa*, *Cassia tora, Ipomoea quamoclit, Mimosa pudica*, *Oxalis latifolia* and *Solanum turvum* was not significant. The abundance of seedlings and the high levels of recruitment of *M. micarantha* observed in the study areas indicate that *M. micarantha* will continue to be dominant in the areas where it is established. So it can be concluded that *Mikania* is the most severe weed of the buffer zone at the Chitwan National Park. Thus immediate intervention to control this serious threat should be of high priority.

Keywords: Nepal, Chitwan National Park, invasive plants, *Mikania micarantha*, diversity, Community Forest (CF)

KURZFASSUNG

Invasive Neophyten sind fremdländische Pflanzen, die sich rasch ausbreiten und einheimische Pflanzengemeinschaften nachteilig beeinflussen. Die Kontrolle und das management der Bedrohung bedarf genauer Kenntnisse der Ökologie dieser Pflanzen im betroffenen Gebiet. Entwicklungsländer wie Nepal sind besonders gefährdet, weil zu wenig über diese Pflanzen und deren Schädigungspotential bekannt ist. Im Rahmen dieser Diplomarbeit wurden zwei Gemeindewälder, nämlich Jankauli und Kumroj, in der Pufferzone des Chitwan National Parks untersucht, um die Artenvielfalt und Häufigkeit dinvasiver Pflanzen zu erforschen und sie in Hinblick auf ihre Gefährlichkeit zu bewerten. Geschachtelte Probeflächen wurden quantitativ untersucht, dazu kamen deskriptive Daten aus Feldbeobachtungen und Befragengen. Die Untersuchung ergab in Jankauli 18 Baumarten, 18 Sträucher und 36 krautige Pflanzen und in Kumroj 20 Baumarten, 22 Sträucher und 51 krautige Pflanzen. Insgesamt wurden in Jankauli 17 Pflanzenarten und in Kumroj 19 als gefährliche Invasoren eingestuft. *Dalbergia sisso* war die am stärksten betroffene einheimische Baumart, *Mikania micarantha* der aggressivste Neophyt. Die Artenvielfalt war insgesamt in Kumroj grösser als in Jankauli. Ein Jacard Koeffizient von 0.89 zeigt, das die Artenzusammensetzung in beiden Gebieten recht ähnlich ist. Statistische Untersuchungen ergaben eine signifikante negative Korrelation zwischen dem Auftreten von *Mikania micarantha* und der Häufigkeit der anderen Pflanzen. Die Reihung ergab, dass *Mikania micarantha*, *Ageratina adenophora* und *Chromalaena odorata* die aggrssivsten Neophyten sind, während von *Bidens pilosa, Cassia tora, Ipomoea quamoclit, Mimosa pudica* und *Solanum turvum* keine statistisch signifikante Bedrohung ausging. Das reichliche Vorhandensein von Samen und Keimlinge von *Mikania micarantha* zeigt, dass dieser Neophyt auch in Zukunft die gefährlichste invasive Pflanzenart in der Pufferzone des Chitwan National Parks bleiben wird. Daher sollten Maßnahmen zur Bekämpfung dieser Art höchste Priorität haben

Schlagwörter: Nepal, Chitwan National Park, Invasive Neophyten, *Mikania micarantha*, Diversität, Gemeindewald

ABBREVIATION

ADB	Asian Development Bank
CBD	Convention on Biological Diversity
CBO	Community Based Organization
CF	Community Forest
CNPBZMP	Chitwan National Park and Buffer Zone Management Plan
DNPWC	Department of National Park and Wildlife Conservation
FAO	Food and Agricultural Organization
FINNIDA	Finnish International Development Agency
GEF	Global Environmental Facility
GISP	Global Invasive Species Program
HMGN	His Majesty the Government of Nepal (now modified to GN Government of Nepal)
IAS	Invasive Alien Species
ICSU	International Council for Scientific Union
INGO	International Non- Governmental Organization
IPM	Integrated Pest Management
ISSG	Invasive Species Specialist Group
IUCN	The World Conservation Union
IVI	Important Value Index
JCF	Janakauli Community Forest
KCF	Kumroj Community Forest
MFSC	Ministry of Forest and Soil Conservation
NASA	National Aeronautics and Space Administration
NBS	Nepal Biodiversity Strategy
OESI	Bureau of Oceans and International Environmental Affairs Initiative
RC	Relative Coverage
RD	Relative Density
RF	Relative Frequency

SCOPE	Scientific Committee for Problem of the Environment
SPSS	Statistical Package for Social Science
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organization
VDC	Village Development Committee
WWF	World Wildlife Fund

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CHAPTER ONE: INTRODUCTION

This chapter begins with the physiographic introduction of Nepal followed by the description of the vegetation zones in Nepal and a brief introduction on invasive alien species. The objectives have been formulated keeping in view the problem statement and justification and also the author's assumptions.

1.1 Physiographic introduction of Nepal

Nepal extends along the Himalayan range between the latitudes of 26° 22'N and 30° 27'N and longitudes of 80° 04'E and 88° 12'E between India and China. The country has an area of 147,181 sq km, with a length of about 885 km, and an average width of 193 km. Two-thirds of the area is occupied by hills and mountains, which rise from the Terai, the northernmost part of the Indo-Gangetic plain at about 60 m in the south, to the crest of the Himalaya reaching over 8,000 m altitude in the north. Nepal has a population of 23.2 million out of which 48.5 percent live in the Terai, 44.2 percent in the hills and 7.3 percent in the mountains (CBS, 2001).

Nepal, though small in terms of surface area, is remarkably rich in floral and faunal species and ecosystem diversity. It has high degree of endemism and ecosystem uniqueness, and offers diverse land use patterns and biodiversity use practices. The diversity of the physiographic caused by variations in topography and climate has greatly contributed towards the richness of vegetations in different parts of Nepal which can be divided into five vegetation Zones as follows:

i.) Tropical belt (below 1,000 m altitude): The vegetation is dominated mostly by *Shorea robusta* in association with *Terminalia alata*, *Lagerstroemia parviflora*, *Adina cordifolia*, *Cassia fistula*, *Eugenia* spp., and big lianas such as *Bauhinia vahlii*, *Milletia* spp., etc. About 1500 species of flowering plants, of which 29 are endemic, occur in this zone.

ii.) Subtropical belt (1,000-2,000 m altitude): It occurs along outer foothills, lower parts of Mahabharat Lekh and Midlands. *Schima wallichii-Castanopsis indica-Castanopsis tribuloides* forest in the east and *Pinus roxburghii* forest in the west represent this belt. The major associates in the former are *Engelhardtia spicata, Acer oblongum, Pyrus pashia, Eurya acuminata, Myrica esculenta* etc. In the latter the associates are *Myrica esculenta, Lyonia ovalifolia, Quercus lanata, Q. incana, Rhododendron arboreum* etc. The flora is represented by 2,028 species of flowering plants including 50 endemic.

iii.) Temperate belt (2000-3000 m altitude): This belt is characterised by evergreen oaks, rhododendrons, conifers etc with deciduous maples and magnolias. The characteristic species in the broad-leaved forests of this belt are: *Quercus semecarpifolia*, *Q. lamellosa*, *Q. glauca, Daphniphyllum himalayense*, *Magnolia campbellii* (in east and central Nepal), *Quercus dilatata*, *Aesculus indica, Juglans regia* (in west Nepal). *Pinus wallichiana, Picea smithiana, Cedrus deodara, Abies pindrow* and Tsuga dumosa are the common conifers in the needle-leaved forest. The associated tree species are *Rhododendron arboreum, Lyonia ovalifolia, Carpinus viminea, Taxus baccata, Betula alnoides* etc. *Alnus nepalensis* forest is common in the mid-mountainous Himalayan ecosystem extending from 1,300 to 2,700 m. The species can quickly colonise in barren slopes newly exposed by landslides or erosion.1,990 species are recorded from this belt including 113 endemic ones.

iv.) Sub-Alpine belt (3,000-4,000 m altitude): It covers the part of great Himalayan range. Characteristic species of this region are *Abies spectabilis* and *Betula utilis*. Associated species are *Acer caudatum, A. pectinatum, Sorbus cuspidata, S. microphylla, S. foliolosa* etc. This belt houses 1,645 species including 177 endemic species of flowering plants.

v.) Alpine and Nival belts (above 4,000 m altitude): It is an open area which lies between the tree line and the snowline that characterizes the shrubby vegetation that is usually dominated by rhododendron bushes. Other common shrubs include *Potentilla fruticosa*, *Hippophae rhamnoides*, *Berberis* spp. etc. The common low herbs are

primroses, gentians, poppies, buttercups etc. Loose scree vegetation is usually composed of cushions of *Arenaria*, *Androsace*, *Waldhamia* etc. The area above 5,000 m is usually covered by permanent snow. However, hardy and extreme cold resistant plants are found in the sunny rock crevices. *Stellaria decumbens* has been recorded at an elevation of around 6,100 m. Total of 1075 species of flowering plants with 190 species endemic are reported from this belt.

1.2 The flora of Nepal

Nepal, a Himalayan country, represents one of the world's richest pockets in plant diversity. It is estimated that over 6,500 species of flowering plants exist in Nepal. So far, about 6,000 species of flowering plants and over 4,000 species of non-flowering plants have been recounted from the country. Due to mountainous terrain and topography, Nepal has a great geographical as well as climatic variation.

A wide range of natural attributes in a relatively small area has endowed Nepal with the representation of global ecosystems and habitats. It possess a disproportionately rich diversity of flora and fauna at genetic, species and ecosystem levels (NBS, 2002) and the country has housed 118 ecosystem with following floral species richness.

Table 1: Floral Species Richness in Nepal

Groups	Species reported from Nepal	Nepal's share in globe
Lichens	465	2.3%
Fungi	1,822	2.4%
Algae	687	2.6%
Bryophytes	853	5.1%
Pteridophytes	380	3.4%
Gymnosperms	28	5.1%
Angiosperms	5, 856	2.7%

Source: NBS, 2002

246 flowering plants species have been reported endemic to Nepal (Shrestha and Joshi, 1996). Protected areas house 140 endemic species and remaining 106 species occur outside the protected area system (Shrestha, 1999). It is also reported to have 39 species of lichen, 16 species of fungi, 3 species of algae, 30 species of bryophytes and 8 species of pteridophytes endemic to Nepal (NBS, 2002).

1.3 What are Invasive Alien Species?

Invasive alien species are those species which are non-native, non-indigenous, exotic, and foreign and/or introduced to an ecosystem other than their natural home. Such species may occur in locations beyond their known historical natural ranges. The native or indigenous species, on the other hand, are those that have occurred historically with the evolution of an ecosystem as its natural home. The population of native species that have relatively restricted or limited distribution, or are confined to a particular environment in a geographic region, is considered as endemic species to the defined area.

Introduction of species to a non- native place has been a historical phenomenon both in terms of natural as well as human activities. People from all over the world introduced plants and animal species from one part to the other in pursuit of fulfilling their social, economic and cultural needs. This is an ongoing process, which is increasing in recent years, either intentionally or unintentionally. Intentionally introduced alien species are likely agricultural crops, horticultural, medicinal and ornamental plants where as unintentional introduced species could be through seeds dispersal, or organisms travelling. This is possible in those species that have relatively high dispersal ability and high adaptability to colonize in new habitats or ecosystems.

Many such introduced plants have been naturalized in a new environment and from a part of existing landscapes and ecosystems outcompeting the native species. They have the following characteristics: Strong vegetative growth, abundant seed production capacity, high germination rate, long-lived seeds, rapid maturation of a sexually reproductive stage and high ability to establish over a large area.

Some of the characteristics due to which they are known to be invasive alien plants are as follows-

- They are highly adaptive for wind and insect pollinations.
- They are aggressive colonizers as their seeds get widely dispersed by winds, water, birds and other means enabling them to colonize in new areas and far distances away from their original home.
- They germinate and survive throughout the year.
- They have large production ability coupled with regeneration.
- They lack predators and natural enemies due to which they are usually not attacked by parasites, diseases, herbivores in the newly introduced area.
- They are allopathic in nature and have the ability to outcompete others.

1.4 Problem statement and Justification

The spread of invasive alien species (IAS) is creating complex and all-around challenges that threaten both the natural biological riches of the earth as well as the well being of its citizens. These species are causing enormous damage to biodiversity and the valuable natural systems upon which we depend. Direct and indirect health effects become increasingly serious and the damage to nature is often irreversible. The effects are exacerbated by global change and chemical and physical disturbance to species and ecosystems.

Continuing globalization, with increasing trade, travel, and transport of goods across borders, has brought tremendous benefits to many people. It has, however, also facilitated the spread of IAS with increasing negative impacts. While the problem is global, the nature and severity of the impacts on society, economic life, health, and natural heritage are distributed unevenly across nations and regions. Thus, some aspects of the problem require solutions tailored to the specific values, needs, and priorities of nations while others call for consolidated action by the larger world community. Preventing the international movement of invasive alien species and coordinating a timely and effective response to invasions will

require cooperation and collaboration among governments, economic sectors, non-governmental organizations, and international treaty organizations. Increasing global domination by a relatively few invasive species threatens to create a relatively homogeneous world rather than one characterized by great biological diversity and local distinctiveness.

Spreading of IAS is a cross-sectoral issue and now of global concern because of their serious economic, social and ecological impacts. IAS are particularly serious in the developing world, where they are compounding a multitude of problems affecting livelihoods. However, in many countries and regions, lack of quantitative impact data and a measure of the scale of the problems is hindering appropriate actions at the national level. There is a need to establish cross-sectoral linkages on IAS, in order to facilitate cooperation and share experiences in appropriate control technologies (Ellison et al., 2004).

It has been well documented that invasive alien species (IAS) are the second greatest threat to biological diversity globally and the highest threat on many island ecosystems. There are also enormous economic losses incurred due to the impacts of invasive species. The Convention on Biological Diversity (CBD) recognizes the importance of this global issue and calls on contracting parties to "prevent the introduction of, control or eradicate those alien species that threaten ecosystems, habitats and species" Article 8 (h)). Many governments, trade sectors, international conventions and institutional instruments are recognizing the importance of this issue and are joining in the efforts with those who have already identified IAS as a serious problem on various scales. Awareness of the issue is still growing (Neville, 2001).

This was the birth of Global Invasive Species Program (GISP) and it was recognized that there are international organizations that can tackle the issues (Murphy, 2004). The GISP is coordinated by the Scientific Committee for Problems of the Environment (SCOPE), in collaboration with the IUCN, CABI with new partners coming on board. GISP has received initial financial support from the United Nations Environment Programme (UNEP), the Global Environmental Facility (GEF), with additional support from the United Nations

Education, Scientific and Cultural Organization (UNESCO), The David and Lucile Packard Foundation, the International Council for Scientific Unions (ICSU), the National Aeronautics and Space Administration (NASA), La Fondation TOTAL, the John D. and Catherine T. MacArthur Foundation, the University of York (U.K.), the U.S. Department of State, Bureau of Oceans and International Environmental Affairs Initiative (OESI), and the Governments of Brazil, Denmark, Norway, New Zealand and the Republic of South Africa. Participating groups and individuals have made substantial in-kind contributions. GISP is a component of DIVERSITAS, an international programme on biodiversity science (Neville, 2001).

Conservation of biological diversity is one of the urgent needs of the present world. At International level, there is a growing agreement that invasion by exotic species is one of the greatest threats to biological diversity conservation (Coblentz, 1990;Diamond and Case, 1986). Massive habitat destruction by invasion of exotic species into areas where they did not evolve is considered to be one of the causes of diversity loss (Huston, 1994).

The adverse environmental impacts such as alteration of habit and species composition have been experienced due to some alien species which are leading towards widespread invasion examples *Mikania macaratha, Lantana camara* etc. Nepal has made very limited comprehensive studies and research for assessing the impacts of IAS. It may help to provide a well-defined description, abundance and categorization of non-native plants that are invading protected area of Nepal. So the reasons behind the study of the assessment of invasive alien species are justifiably appreciable.

1.5 Hypothesis

The presence of *Mikania* in plots greatly reduces the diversity of native plant species in plots.

1.6 Objective

1.6.1 General Objective

To assess the species diversity and invasiveness of invasive alien plant species in the buffer zone of the Chitwan National Park.

1.6.2 Specific objectives

i.) To prepare a list of invasive alien plants along with their biological characteristics (based on the list by Tiwari et al., 2005)
ii.) To assess the diversity of non-native spp. of invasive characters.
iii.) To assess the abundance of the most common or aggressive invasive plant spps of the Chitwan National Park, Buffer Zone.
iv.) To prioritize IAS in different ranks by evaluating their Invasiveness.

CHAPTER TWO: LITERATURE REVIEW

The previous chapter dealt with the research background, problem justification along with the purpose of this study. This chapter provides literature on non-native and invasive species and findings of some relevant studies on IAS. This chapter begins with a general introduction of invasive alien species and some other different words used to describe IAS. Further, this chapter has provided the information on the challenges associated with IAS species based on previous relevant studies. Moreover, this chapter gives a insight into the IAS in Nepal. Highlighting the negative impacts associated with IAS, this chapter to some extent provides the evidences on why this kind of study plays vital role in applying the control measures of IAS.

2.1 Introduction of IAS

Many different words are used to describe species occurring in ecosystems to which they are not indigenous. These include "non-indigenous", "non-native", "exotic", "foreign", "new", "pest" and "alien". The Global Species Programme (GISP) has defined Invasive alien species (IAS) as follows: "IAS are organisms that have been moved from their native habitat to a new location where they cause significant harm to the environment, economic system and/or human health" similarly IUCN has defined that Invasive species means an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity" (IUCN, 2000).

Biological invasion worldwide threatens biodiversity, ecosystem dynamics, resource availability, national economy and human health (Ricciardi et al. 2000). It is a pervasive and costly environmental problem (Larson et al. 2001). Over the past half century it has become the focus of intense management and research activities worldwide (Kennedy et al. 2002). The spread of IAS is now recognized as one of the greatest threat to the natural ecosystems of the earth.

IAS are considered as the second biggest threat, after deforestation, to biodiversity conservation. These species are causing enormous damage to biodiversity and the valuable natural agricultural systems upon which we depend.

IAS may reduce the amount of space, water, sunlight and nutrients that could otherwise be available to native species. They also alter hydrological flows and conditions as well as change characteristics of the soil structure and chemistry (Randall and Marinelli, 1996). In some cases, IAS have been driving many rarest species closer to extinction (http://www.nps.gov/plants/alien/bkgd.html).

The rapidly increasing trade and travel throughout the world has significantly increased the rate at which new species are intentionally or unintentionally moved around the globe. When these species becomes established, adverse economic and environmental impacts will be increased. A study estimates about 8,000 species of plants traded or non-traded are expected to be agricultural weeds, out of which about 2,500 species are considered as potentially dangerous (Yaduraj et al.,2000).

In Mauritius and Hawaii, *Psidium cattleianum* has spread to such an extent that it dominates large tracts of wet evergreen forest (Lorence and Sussman, 1986; Smith, 1989) and has replaced much of the native vegetation with foreign but vigorously reproducing vegetation. Exotic saltcedar *Tamarix* spp. shrubs have replaced much of the native riparian vegetation of the arid western USA, where they consume large quantities of water, narrow river channels, salinize soil and degrade wildlife habitat (Mooney et al. 2001).

2.2 World's Worst Invasive Alien Plant Species

According to the Global Invasive Species Database, Lowe et al. 2000 have identified the world's worst invasive alien plant species. These invasive alien plant species are illustrated in table 2.

Table 2: List of Aquatic and land plants identified as world's worst IAS

AQUATIC PLANTS	
Caulerpa seaweed	*(Caulerpa taxifolia)*
Common cord – grass	*(Spartina angelica)*
Wakame seaweed	*(Undaria pinnatifida)*
Water hyacinth	*(Eichhornia crassipes)*
LAND PLANTS	
African tulip tree	*(Spathodea campanulata)*
Black wattle	*(Acacia mearnsii)*
Brazilian pepper tree	*(Schinus terebinthifolius)*
Cogon grass	*(Imperata cylindrica)*
Cluster pine	*(Pinus pinaster)*
Erect pricklypear	*(Opuntia stricta)*
Fire tree	*(Myrica faya)*
Giant reed	*(Arundo donax)*
Gorse	*(Ulex europaeus)*
Hiptage	*(Hiptage benghalensis)*
Japanese knotweed	*(Fallopia japonica)*
Kahili ginger	*(Hedychium gardnerianum)*
Koster's curse	*(Clidemia hirta)*
Kudzu	*(Pueraria montana var. lobata)*
Lantana	*(Lantana camara)*
Leafy spurge	*(Euphorbia esula)*
Leucaena	*(Leucaena leucocephala)*
Melaleuca	*(Melaleuca quinquenervia)*
Mesquite	*(Prosopis glandulosa)*
Miconia	*(Miconia calvescens)*
Mile-a-minute weed	*(Mikania micrantha)*
Mimosa	*(Mimosa pigra)*
Privet	*(Ligustrum robustum)*
Pumpwood	*(Cecropia peltata)*
Purple loosestrife	*(Lythrum salicaria)*
Quinine tree	*(Cinchona pubescens)*
Shoebutton ardisia	*(Ardisia elliptica)*
Siam weed	*(Chromolaena odorata)*
Strawberry guava	*(Psidium cattleianum)*
Tamarisk	*(Tamarix ramosissima)*
Wedelia	*(Sphagneticola trilobata)*
Yellow Himalayan raspberry	*(Rubus ellipticus*

2.3 Invasive Alien Species in Nepal

Nepal is well known for its diverse flora and many plant species are endemic to the country. However, alien plants have been arriving either intentionally or unintentionally for centuries. Most of the intentional introductions have been for agricultural and soil conservation purposes and some ornamental plants were also introduced. Many species in Nepal got introduced unintentionally through trade, tourism, transport and air because of its land-lockedness nature with India and China. Many of the invasive plants in Nepal are also listed in the ISSG (2000) list of the world's worst invasive species (Lowe et al, 2000) and some of them are more prominent and notorious. Majority of alien plant species in Nepal are confined to the low lands below 2000m whereas the highest concentration of endemic species (upto 91 percent) occurs in sub-alpine zone (3,000-4,000m), particularly in central Nepal (Shrestha, 1999 in Tiwari et al, 2005).

Nepal has, so far, responded to alien invasive species in recent years after the scenario of great threats on biodiversity by IAS. They identified the most widely distributed invasive species of great threats on biodiversity by IAS. They identified the most widely distributed invasive species found in Nepal -*Eupatorium adenophorum*, *Chromolaena odoratum* and *Lantana camera*. There are, altogether, 166 alien plants species naturalized in Nepal as assessed by Tiwari et al, 2005. Out of which, 21 are identified as problematic and *Mikania micrantha, Ageratina adenophora, Eupatorium odoratum* and *Lantana camara* are assessed as one of the six high risk posed invasive alien species (Tiwari et al, 2005).

The legal measures could be more effective for the control of intentional or artificial introduction of invasive species. The Convention on Biological Diversity (CBD), to which Nepal and 177 other countries are party, calls on governments to prevent the introduction, control or eradication of those alien species that threaten ecosystems, habitats or species (Article 8). However, approaches taken to combat this phenomenon and even the data on which they should be based are clearly inadequate to deal with the onslaught of invasive species in Nepal (IUCN/Nepal).

Nepal formulated its Nepal Bio-Biodiversity Strategy (NBS) in 2002 that shows the commitment of the government and people of Nepal to the protection and wise use of the government and biological diversity and resources on a sustainable basis. NBS has indicated that the introduction of alien species tends to be one of the major root causes for the lost of species and genetic resources (NBS, 2002).

The Master Plan for Forestry Sector in Nepal (HMGN/ADB/FINNIDA, 1988) recommends the plantation of wide variety of indigenous trees and some exotic species that grow well to protect land degradation (soil erosion, landslides, floods, etc.) However, promoting the introduction of exotic species goes against the need to control IAS. The Tenth Five Year Plan (2002-2007) recognizes IAS as one of the threats for forest biodiversity and calls for effective awareness programs to control them.

2.4 Impacts of Invasive Alien Plants

2.4.1. Ecological Impacts

IAS disrupt the ecology of natural ecosystem, displace the native plant and animal species as well as degrade the landscape's unique and diverse biological resources (Tiwari et. al., 2005). The greatest impacts are caused by plant species that come to dominate entire ecosystems. *Melaleuca*, which is increasing its range in south Florida by some 35 acres each day, replaces cypress and other native plants and provides poorer habitats for numerous animals. In many regions in and near the Everglades, it forms vast, dense monocultures where no other plant can grow (Simberloff D., 1996). An introduced plant species can bring great changes to an entire ecosystem without dominating in either numbers or biomass. On the island of Hawaii, the tall shrub *Myrica faya*, a native of islands in the eastern Atlantic, has invaded young, nitrogen-poor lava flows and ash deposits on the slopes of Mauna Loa and Mauna Kea. Because it fixes nitrogen, it modifies the normal colonization by other plants, favouring other introduced species. (Simberloff D., 1996). Introduced plants can harm native ones by producing and releasing chemicals. The African crystalline ice plant (*Mesembryanthemum crystallinum*) for example, has devastated native

coastal vegetation in California. The ice plant is an annual that accumulates salt, which leaches from its leaves when the plant dies at the end of the season. (Simberloff D., 1996)

2.4.2 Impacts to Native Fauna

IAS have been driving many of the rarest species closer to extinction (http://www.nps.gov/plants/alien/bkgd.htm). A study conducted by the US Fish and Wildlife Service estimated that 42 percent of the plants and animals on the US Endangered and Threatened Species List are at risk primarily because of IAS, which are termed the second greatest threat for native species decline after habitat loss (Schmitz and Simberloff, 1997).

Many native animal species or organisms are dependent on native plant species for food and shelter. This type of animal-plant association has evolved over thousands of years. It is estimated that at least 12 species of organisms rely on each plant species in temperate region while up to 30 organisms depend on single plant species in tropical region (Gould, 2004).

IAS are likely to create the incidence of disease outbreaks. They may be reservoir of pathogens or may act as a vector to transmit the diseases from one organism to another. Most of the wetland dependent IAS provides breeding ground for mosquito, an important vector and reservoir for malaria disease transmission. There is also a record of Avian malaria (malaria on bird), through mosquito. This has contributed to the extinction of at least 10 native bird species in Hawaii and threatened many more (www.issg.org/database/welcome/content.asp).

Some important fauna are very selective in feeding, eg *Rhinocerous unicornis* is very selective species and is the keystone of CNP. Increasing invasive alien plant species may directly affect the important faunal species. (Sapkota, 2007).

2.5 Control and management of Invasive Alien Plants

Invasive alien species interact with other elements of global change to cause considerable damage to managed and natural systems and to incur huge costs to society. In response, several measures have been developed and deployed to control, or eradicate a wide range of invasive species in affected areas. Where possible, eradication is the favored approach. Control, which reduces the presence of the invader, and containment, which limits further spread, both requires indefinite investments of time, tools and money to keep an invader at bay.

Eradication can require large short-term investments, however successful removal can be achieved within months or years and gives the best chance for native biodiversity to recover (Mooney et al., 2001). Many methods are available for controlling IAS, as detailed in Wittenberg et al (2000). These tools can be applied individually or in various combinations. Given the high complexity of the ecology of invasive species and habitats affected, control measures need to be applied with the fullest possible scientific understanding.

2.5.1 Mechanical control

It involves directly removing the species by hand or with appropriate machines such as harvesting vehicles (e.g., for water hyacinth) or firearms (e.g., for large mammals), or traps (for animals). In Nepal, people remove plant mechanically by early stages particularly from agricultural land. But if it spreads, it is difficult to remove because the roots form dense mats, hard to remove. For many of the weeds this method is used eg for *Ageratina adenophora, Cassia tora, Eupatorium odoratum, Ageratum conyzoides* etc. Attempts have been made to hand seed or to use slashing in plantations but this has been found to be ineffective and costly in labour terms (Sen Sarma and Mishra 1986, Muniappan and Viraktamath 1993 in Matthew et al., 200). All the stems need to be destroyed because of the weed's ability to grow from even the tiniest fragments (Holm et al., 1977 in Matthew et al., 200). Also, the creeping and climbing habits of *Mikania* enable it to penetrate into the crowns of bushes or trees where it is difficult to apply mechanical methods without damage to the crops (Matthew et al., 200).

Removing *M. micrantha* manually is most effective as herbicides and mechanical removal can have undesirable effects on non-target species and the environment. *Mikania* vines should be cut near the ground once a month for three consecutive months in summer and autumn and then in winter and spring. This can eliminate 90% of vines (Kuo et al., 2002)

2.5.2 Chemical control

This involves the use of herbicides, insecticides, and rodenticides that primarily affect the target species, are delivered in a way that avoids the potential problem of resistance developing over time, and do not accumulate in the food chain. The development of pesticide-resistant strains of pests, diseases and weeds may reduce the effectiveness of the chemical management option for their control. Chemical control using herbicides (triclopyr) applied at the seedling stage or on early re-growth for *Eupatorium odoratum* has given encouraging results (www.hear.org./pior/species/chromolaena_odorata.htm). The most commonly used herbicides for *Eichhornia crassipes* are 2,4-D and glyphosphate. Herbicides are effective but has significant risk for other wetland biodiversity (Tiwari et.al., 2005). For *Mikania macarantha*, herbicides like glyphosphate and 2,4-D are used before flowering while contact herbicides such as paraquat is used in seedling stage. Despite, established plants can grow from the base (Swarbrick, 1997).

2.5.3 Biological control

This control involves the intentional use of populations of natural enemies of the target invasive alien species or other methods that include, for example, mass release of sterile males of the target species, inducing resistance in the host against the IAS that is attacking it, or releasing a natural enemy to control the IAS. It is essential to ensure that the species used for biological control does not in turn become itself invasive. There have been significant success with the 25 or so exotic fungal pathogens that have been exploited (Evans, 2002). A number of these have been responsible for spectacular financial and environmental returns. *Mikania* is an excellent example where this new generation of classical biological control agents, namely fungal pathogens, can make a real difference to the lives of farmers since, even with no inputs, it is anticipated that significant control will

be achieved by the release of the rust fungus *Puccinia spegazzinii* (Ellison, 2004). *Chromolaena odorata* is a good candidate for its biological control by the introduction of natural enemies, such as *Pareuchaetes pseudoinsulata*. natural enemy, the fly *Cecidochares connexa* has also been successful to control the weed in Indonesia and Phillippines (Muniappan and Nandwani, 2002)

2.5.4 Integrated pest management (IPM) and Habitat management

Involves a combination of the methods described above, based on ecological research, regular monitoring, and careful coordination. IPM is likely to achieve the best results in many situations. Habitat management involves measures such as prescribed burning, grazing and other activities.

CHAPTER THREE – METHODS AND MATERIALS

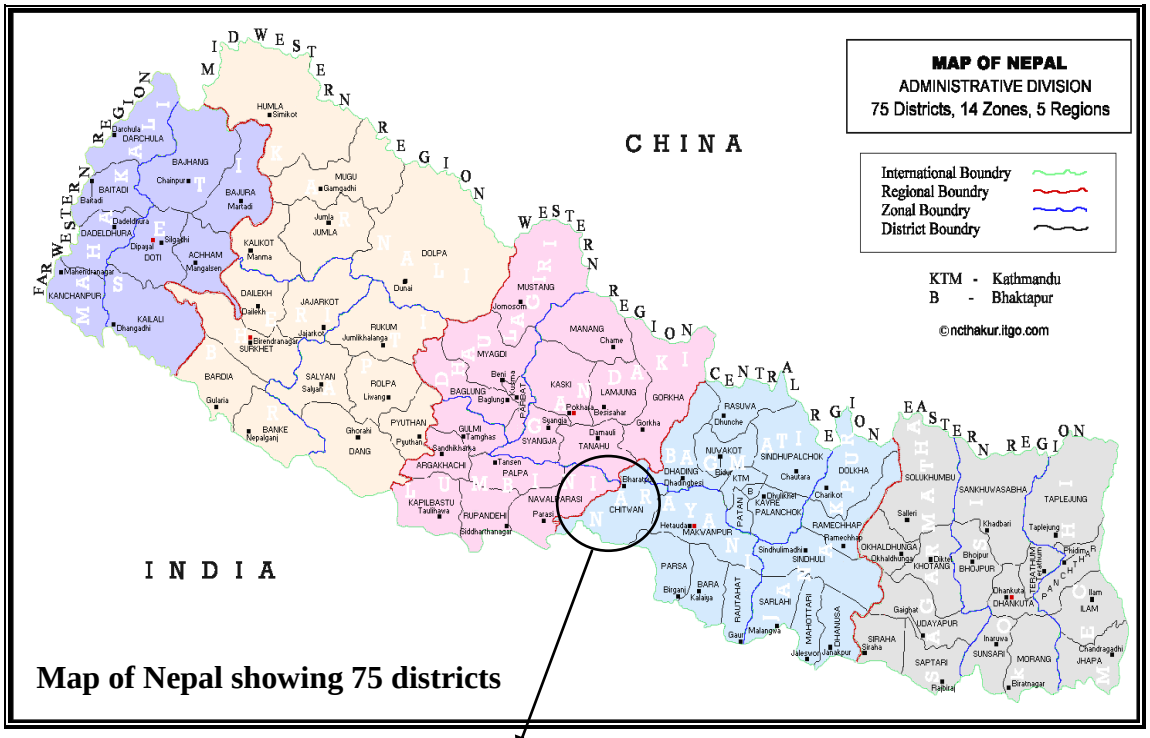
The previous chapter dealt with the literatures on *IAS* and finding of some relevant studies on IAS. This chapter has presented the methods used during data collection and analysis. It is divided into 3 sections namely study area, data collection and data analysis. The study area section deals with the description of Chitwan district and two of its CF namely Janakauli CF and Kumroj CF. The data collection section describes the type of data collected along with the method of data collection to achieve the aim of this study. The data analysis section explains how the raw data was processed in various stages to achieve the result along with providing information on the statistical analysis used in this study.

3.1 Study area

The study was conducted in two community forests in Buffer Zone of Chitwan National Park called Janakauli and Kumroj Community Forests in Chitwan District. Chitwan District is one of the seventy-five districts of Nepal, which is a landlocked country of South Asia. It lies in the lowlands or Inner Terai of southern central Nepal on the international border with India. It covers an area of 2,218km² and has a population (2001) of 472,048. (http://en.wikipedia.org/wiki/Chitwan#Geography).

3.1.1 Chitwan National Park and its features

The Chitwan National Park has the boundaries that extend (27°20-27°40'N, 83°52'-84°45'E) from the Dauney Hills on the west bank of the Narayani River eastward 78km to Hasta and Dhoram rivers. The park is bounded to the north by the Narayani and Rapti rivers and to the south by the Panchnad and Reu rivers and a forest road. Parsa Wildlife Reserve is contiguous to the eastern boundary of the park and extends (27°15'-27°35'N, 84°45'-84°58'E) as far eastwards as the Bheraha and Bagali rivers (http://www.unep-wcmc.org/sites/wh/chitwan.html).



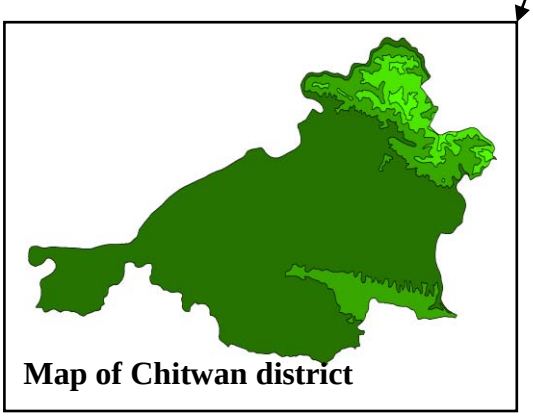


Figure 1: Map of Nepal, map of Chitwan district and entire study area

CNP was declared as the first protected area in 1973. It has a long history of over 3 decades in park management and rich experiences in nature conservation. The main reason to establish CNP in 1973 was to conserve the indigenous Terai fauna and in particular the conservation of endangered species (Rhinoceros, Tiger, Gaur, Gharial, Gangetic dolphin etc) in their natural habitat (Bolton, 1975). In recognition of its unique biological resources of outstanding universal value, UNESCO designated CNP as a World Heritage Site in November 1984 and the Beeshazari Tal contained within the park system is a Ramsar Site (Shrestha, 2006).

The park covers a pristine area with a unique ecosystem of significant value to the world. It encompasses the Churiya hills, ox-bow lakes and flood plains of the Rapti, Reu and Narayani Rivers. Approximately 70% of the park vegetation is sal (*Shorea robusta*) forest. The remaining vegetation types include grassland (20%), riverine forest (7%), and sal with chirpine (3%), the latter occurring at the top of the Churiya range. The riverine forests consist mainly of khair (*Acacia catechu*), sissoo (*Dalbergia sissoo*) and simal (*Bombax ceiba*). The grassland forms a diverse and complex community with over 50 species. Saccharum sp., often called elephant grass, can reach 8 m. in height.

There are more than 43 species of mammals in the park. The park is especially renowned for the endangered one-horned rhinoceros, the tiger and the gharial crocodile along with many other common species such as gaur, wild elephant, four-horned antelope, striped hyena, pangolin, Gangetic dolphin, monitor lizard and python. Other animals found in the park include the sambar, chital, hog deer, barking deer, sloth bear, palm civet, langur and rhesus monkey.

There are over 450 species of birds in the park. Among the endangered birds are the Bengal florican, giant hornbill, lesser florican, black stork and white stork. Common birds seen in the park include the peafowl, red jungle fowl, and different species of egrets, herons, kingfishers, flycatchers and woodpeckers. The best time for bird watching is March and December. More than 45 species of amphibians and reptiles occur in the park, some of

which are the marsh crocodile, cobra, green pit viper and various species of frogs and tortoises. (http://www.talismantrails.com/safari/Nat_parks.html)

3.1.2 Soil

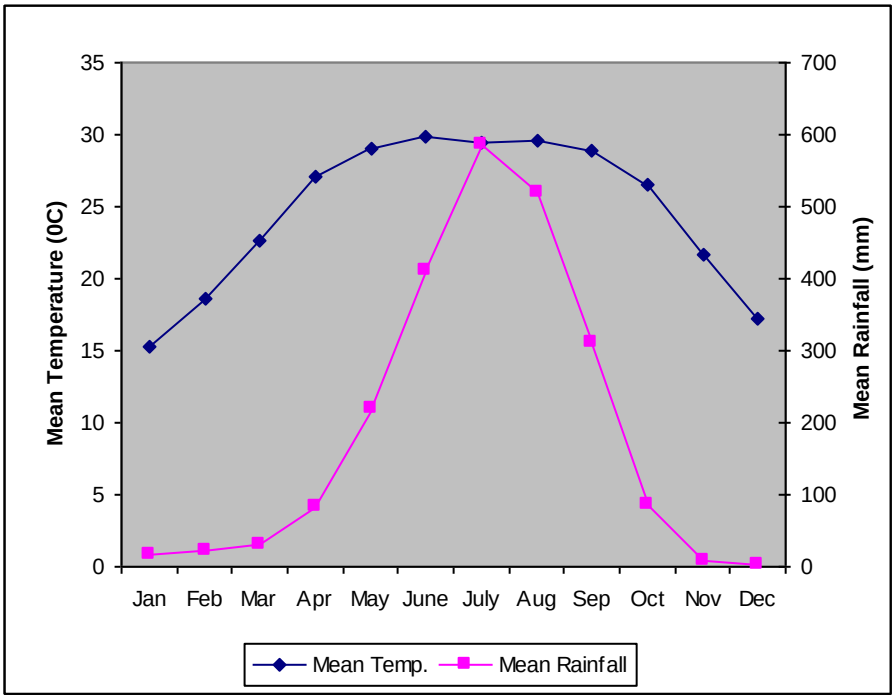
The Churia, Someswar and Dauney hills constitute part of the Siwaliks which are characterized by outwash deposits carried from the north. All the rocks are of Pliocene or Pleistocene, fluviatile origin, and consist mainly of sandstones, conglomerates, quartzites, shales and micaceous sandstone. The Siwaliks show a distinctive fault pattern that has produced steep cliffs on the south-facing slopes, where vegetation cover is poorer than the northern slopes.

The Mahabharat Range consists of severely eroded pre-Siwalik quartzites, phyllites and sandstones. The flood plains comprise a series of ascending alluvial terraces laid down by the rivers and subsequently raised by Himalayan uplift. The terraces are composed of layers of boulders and gravels set in a fine silty matrix. There is a rough gradient from the higher-lying boulders and gravels to sands and silts and then to the low-lying silt loams and silty clay loams (Bolton, 1975; Laurie, 1978).

3.1.3 Climate

In the climatic diagram (MAP: MAT=20:1), the temperature curve roofes the precipitation curve all year indicating subtropical summer monsoon climate at the study site (figure 2). The summer is wet as most of the rainfall occurs from June to September and the winter is dry from November to May although there may be shower all around the year. The total annual precipitation is 2297.56 mm and the average annual temperature is 24.64 degree c.

The figure 2 is drawn based on the rainfall and temperature data from 1998 to 2007 and it was obtained from Department of Meteorology, Government of Nepal.



Location: Rampur, Chitwan District, Nepal
Latitude 27’37″ Longitude 84’25’’ Elevation 256m

Figure 2: Climatic diagram of the study sites

3.1.4 Buffer Zone

As of March 1997, the Nepal government has implemented Buffer Zone Management Program in CNP under the NPWC Act 1973 as amended in 1993 and the Buffer Zone Management Regulations 1997. Under the regulations, the Management Committee receives 30% to 50% of the park revenue for the implementation of conservation and community development programs in the buffer zone. To protect the core area of the park through community based natural resource management in the periphery is the major intervention of implementing the buffer zone program.

The most conspicuous intervention of buffer zone promoted encouraging results in mobilizing public participation. The local inhabitants have turned from foes to friends of the park in about 25 years of time. The buffer zone includes 35 Village Development

Committees and 2 Municipalities covering 766.1 sq km of area and extending 27 16'56" to 27 42'13" North latitudes and 83 50'23" to 84 46'25" East longitudes in the park vicinity. The goal of buffer zone management is to develop CBOs for forging government community partnership for self sufficient supply of forest resources in the buffer zone and conservation of biodiversity in and around the park.

The buffer zone management has been prescribed under a set of 17 specific objectives and 17 program components to ensure people's participation in resource management and community development contributing to biodiversity conservation in and around the park (DNPWC/MFSC, 2002).

3.1.5 The Janakauli Community Forest

The Janakauli Community Forest, which is the buffer zone community forest in the Sauraha area of CNP has an area of 65 hectares. The forest is surrounded by Dhungre khola in the east and southern part, Whereas 6 & 7 of the Bacchauli vdc lie in the northern and (hattisarko ghol) in the western part. The CFUG includes 950 households of Bacchauli vdc as users, which includes 4 wards. Forest is divided into 5 blocks.

Looking at the historical background, initially it was a dense forest with different types of tree species like Khayer (*Acacia catechu*), Simal (*Bombax ceiba*), Vellar (*Trewia nudiflora*). Later, the forest was gradually exploited. The pressure by population growth and people migration to terai areas led to severe degradation of the forest. In addition to cutting down the trees heavy, intensive grazing by cattle was also another reason for severe destruction of the forest. Ultimately the forest was almost completely cleared for grazing pasture and only a few trees and bushes were left as remnants. In 1991, local people with the help and support of national trust for nature conservation, biodiversity conservation centre had made an effort to restore their forest by enrichment planting and other silvicultural operations. According to the buffer zone regulation of 1996, it was named "Janakauli buffer zone community forest" in 1996, and formally handed over to the community by formulating a forest user group in 2003.

3.1.6 The Kumroj Community Forest

This Community forest lies about 6 km east of the Sauraha area that consists of 9 wards. It comprises 1127.7 hectares of forest area. It is surrounded by Kathar vdc in the east, CNP and Dhungre Khola in the west. The Northern Part is surrounded by the Avadi land of Kumroj VDC and Rapti Khola in the Southern part. Historically, the study site was a dense forest until 1971. Afterwards, the forest was gradually exploited. Pressure by population growth and urbanization led to the severe degradation. In 1995, the forest was declared as a buffer zone community forest and the local people with the help and support of national trust for nature conservation, biodiversity conservation centre had made an effort to restore their forest.

3.2 Data Collection Methods

The data collection section describes on how data were collected including sampling strategy, data collection methods and analysis methods. Various formulas on data analysis and statistical procedures are explained in this section too.

3.2.1 Sampling Strategy - Plot Division and Sample Intensity

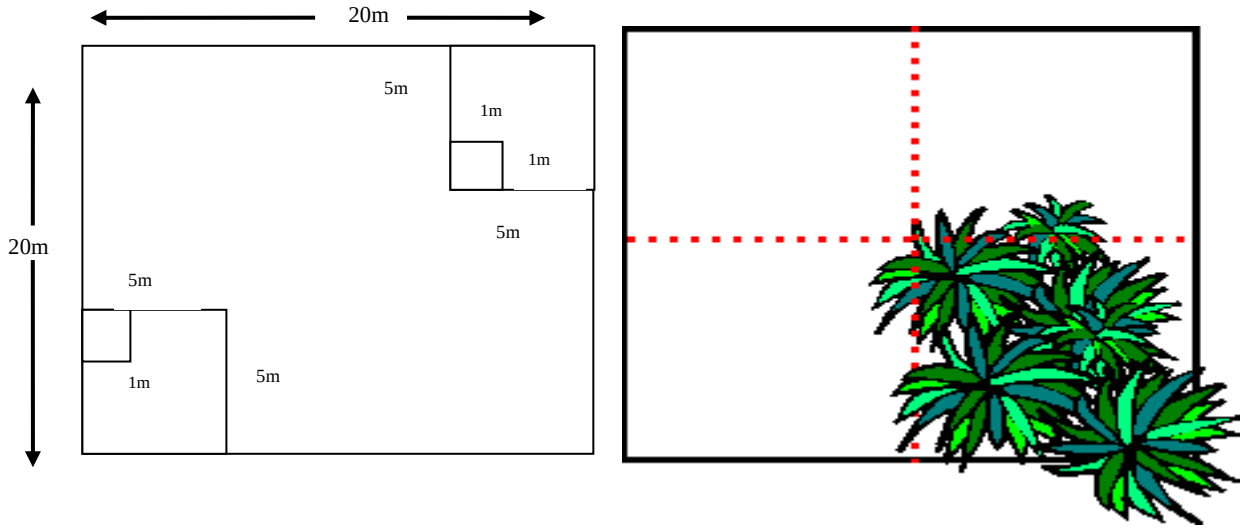


Figure 3: Layout of quadrates

Each plot was divided into various quadrates of 20*20m and these quadrates were randomly selected. Within this quadrate, 5*5m quadrates were allocated randomly in two corners for the assessment of shrubs. Likewise herbs and regeneration were recorded from nested sampling of 1*1m quadrate within the 5*5m quadrate representing 0.01% intensity for Jankauli and 0.001% for Kumroj CF. Figure 3 shows the distribution of nested sampling within main quadrate.

3.2.2 Quantitative data collection

All plant species within each quadrate were identified then counted and estimated their cover percentage. The quantitative data such as density, frequency and coverage were collected from sampling plots. In case of grassland, *Mikania micarantha* the number was assumed to be 1 plant per $25m^2$ at 100% coverage (Tiwari et al., 2005).

The plant species were identified with the help of standard literature of plant identification in Nepal and visual inspection by taxonomists. Herbarium in National Trust for Nature Conservation in Sauraha, Chitwan was consulted for the further identification of the species.

3.2.3 Qualitative Data Collection

The qualitative data collection was focused on Ranking of the alien plants and control and management of IAS. Primary and secondary data were collected.

a. Primary data collection

The primary data collection included the Participatory Rapid Appraisal (PRA) and survey techniques like view from local key person, farmers, nature guides, park personnel and field observation. Open interview was used to know their ideas on control and management of the weeds. Discussion was made focusing on management and control aspect, ranking for the species and trends in distribution and ecological impact etc.

b. Secondary data collection

The secondary data includes the existing research literature and document survey. Related websites and INGOs such as GISP, CABI, IUCN, and ISSG etc. were consulted to receive literature and document on biological characteristics and management and control issue on IAS found in the study area.

3.2.4 Magnitude of Invasiveness

A modified form of invasiveness rank, developed by Virginia Department of Conservation and Recreation Division of Natural Heritage in June 2001 and adopted by Tiwari et al., 2005 was used to estimate the magnitude of invasiveness of a species. The form is shown in the annex 7.

3.3 Data Analysis

To calculate frequency, relative frequency, density and relative density and coverage the collected data were tabulated, processed and analyzed qualitatively using Microsoft Excel 2003. The following quantitative characteristics of the vegetation were determined using the following formula given by Zobel et al., 1987.

3.3.1 Importance Value Index (IVI)

Importance Value Index is an index of vegetation importance of any species to express ecological success with a single value within a stand. It is a function of Relative Density (RD), Relative Frequency (RF) and Relative Coverage (RC). This index provides a quantitative basis for the classification of community.

Importance value index (IVI) = RF+RD+RC

Where, RF = Relative Frequency, RD = Relative Density and RC = Relative Coverage
Relative frequency, relative density and relative coverage can be determined in the following ways.

Frequency = No. of plots with the individual species X 100
Total no. of plots studies

Relative frequency (RF) = Frequency of any one species X 100
Total frequency of all species

Density = Total no. of individual species in all plots X 100
Total no of plots× area of plots

Relative Density (RD) = Density of a species X 100
Total density of all species

Relative Coverage (RC) = Coverage of a species X 100
Total coverage

3.3.2 Diversity Indices

Diversity indices for the alien plant diversity were calculated from the information of the forest inventory. Simpson's index was used as a dominance index. It weighs towards the abundance of the most common species and measures the probability of two individuals randomly selected from a sample will belong to the same category. In this form as the index goes up, so does diversity. Simpson's index "D" (Simpson 1949) and Shannon-Weiner's diversity index "H" (Shannon and Weiner 1963), was calculated from the formula given below.

Simpson's diversity $\mathbf{D = 1- \sum} pi2$**.....1**

Shannon-Wiener index $\mathbf{H = - \sum} pi \times \log pi$**……2**

Where, *pi* represents the proportional abundance of the i^{th} species in the community.

3.4 Statistical analysis

SPSS (Statistical Package for Social Science) version 15.0 for Windows was used for some statistical analysis. The data was checked for outliers using box-plots and scatter-grams. Kolmogorov-Smirnov (KS) tests were used to test for normal distribution. Since most of the data were not normally distributed, statistical analyses were performed using non-parametric tests. Spearman's rho correlation was applied to define the magnitude and direction of relationship between species richness and abundance of invasive alien in both of the CFs.

Research Process

For organizing the work, a structured research process flow chart was prepared. The series of steps which were followed during research from the development of an idea to the completed research paper are presented as flow chart in figure 4.

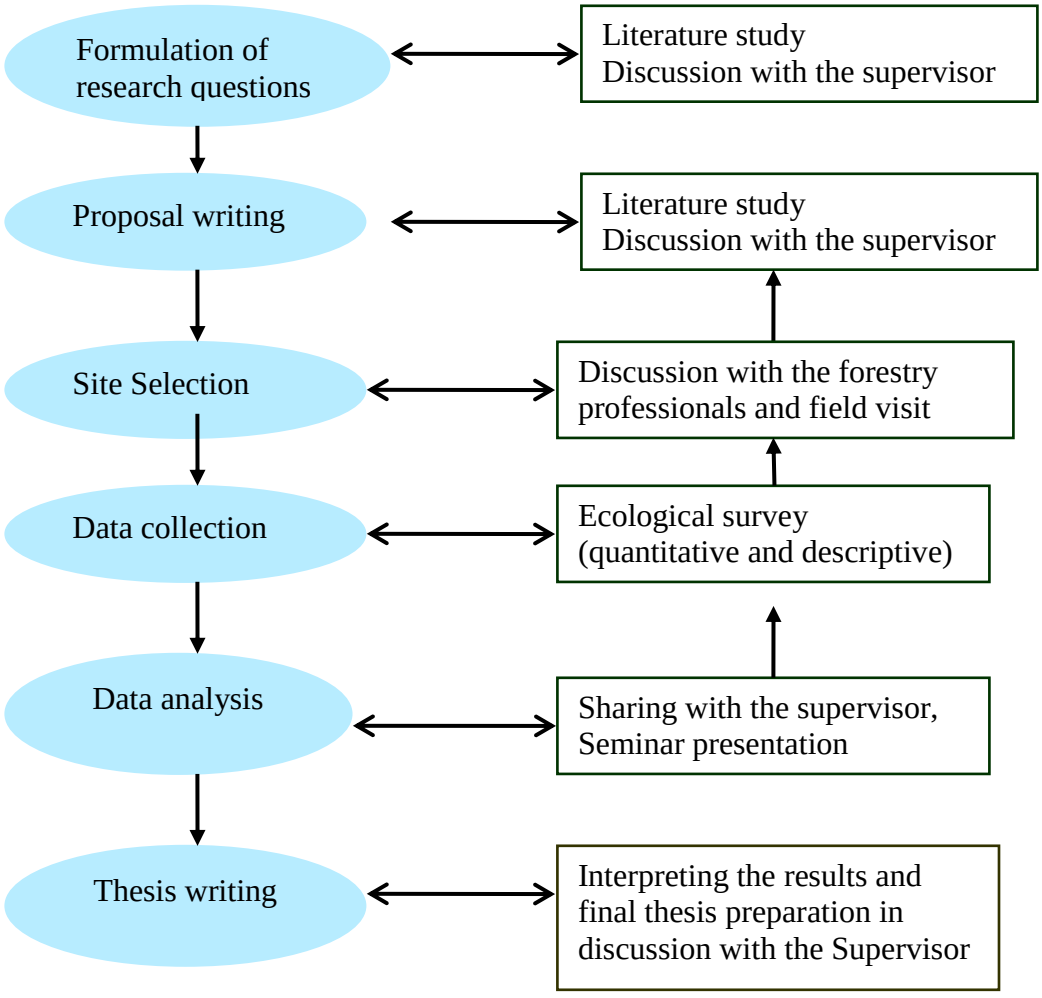


Figure 4: **Research process flow chart**

CHAPTER FOUR- RESULTS

Methods and materials used in order to achieve the results have been presented in the previous chapter and results for both of community forests i.e. Jankauli and Kumroj have been presented in this chapter. Main results included list of floral diversity, Invasive alien plant species along with their biological characteristics and their abundance in both of the CFs. The abundance of invasive species has been interpreted in terms of dominance diversity curve, diversity index i.e. Shannon-Wiener's index and Simpson's Index. Moreover a Spearman's correlation has been used to show the magnitude and direction of relationship between species richness and abundance of Invasive alien species in Janakauli and Kumroj CF. Moreover the magnitude of invasiveness has also been interpreted using different ranking criteria.

4.1 Floral diversity in Janakauli and Kumroj CF

Altogether 18 tree species were identified in Jankauli and 20 tree species were found in Kumroj Community Forest. *Albizia odoratissimum* and *Myrsine semiserrata* were only found in Jankauli where as *Morus alba*, *Murraya koenigii* and *Dysoxylum binecteriferum* in Kumroj CF.

Besides, 18 and 22 shrub species were recorded in Jankauli and Kumroj CF respectively. *Coffea bengalensis* was recorded only in Jankauli where as *Ziziphus mauritiana* and *Osyris wightiana* in Kumroj CF. Their composition and distribution is given in the annex.

4.2 Invasive alien plants

Total of 17 invasive alien plants were recorded in Jankauli and 19 species in Kumroj CF. These invasive alien plants are presented in the table 3.The name list of the IAS is prepared according to the standard information by Tiwari et al., 2005.

Table 3: Composition, distribution & life form of alien Plants in both JCF & KCF

	Species	Local name	Growth/ life form	Janakauli (JCF)	Kumroj (KCF)
1	*Achyranthes aspera*	Datiwan	Annual/Perennial	+	+
2	*Ageratina adenophora*	Kalo banmara	Perennial shrub	+	+
3	*Ageratum conyzoides*	Gandhe	Annual herb	+	+
4	*Alternanthera sessilis*	Bheringijhar	Perennial herb	+	+
5	*Bidens biternata*	Kuro	Annual herb	+	+
6	*Cassia tora*	Tapre	Annual herb	+	+
7	*Chromalaena odorata*	Seto banmara	Perennial herb	+	+
8	*Coccinea grandis*	Golkakri	Perennial herb	-	+
9	*Digitaria ciliaris*	Bonso	Annul herb	+	+
10	*Ipomoea camea*	Besaram	Perennial shrub	-	+
11	*Ipomoea quamoclit*	Jyanti	Annual/Perennial	+	+
12	*Lantana camara*	Ban phanda	Perennial shrub	+	+
13	*Mikania micarantha*	Bakhre lahara	P. herbaceous climber	+	+
14	*Mimosa pudica*	Lajjawati	Annual herb	+	+
15	*Oxalis latifolia*	Chariamilo	Perennial herb	+	+
16	*Phyllanthus amarus*	Bhui amala	Annual herb	+	+
17	*Sida cordifolia*	Balu	Perennial herb	+	+
18	*Solanum aculeatissimum*	Kantakari	Herb/subshrub	+	+
19	*Solanum torvum*	Bihi	Perennial shrub	+	+
Total				17	19

+ = presence of spp - = absence of spp

The table 3 presents the list of only invasive alien species plants along with their life form, composition and distribution in both the community forests. Species richness of both the species i.e. native and invasive alien plants has been presented in the figure 5. This figure

clearly indicates that the number of native species is higher than those of invasive alien species.

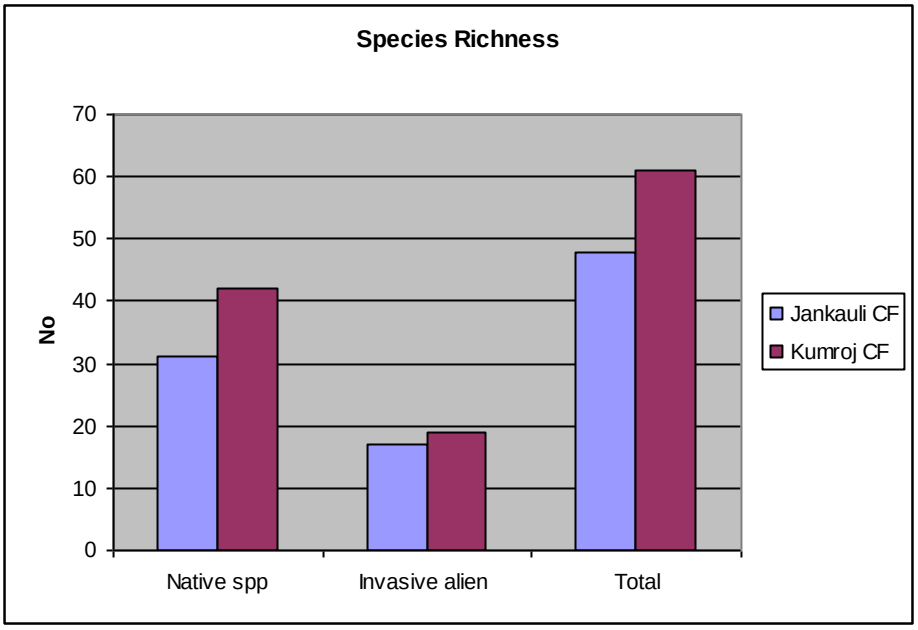


Figure 5 : Species richness of native and invasive alien species in Janakauli and Kumroj CF

4.3 Biological characteristics of alien plants found in the study area:

	Scientific name: *Mikania micarantha* Common/Eng name: mile-a-minute weed / American rope Family: Asteraceae Origin: Central and South America. Introduced in Nepal through north-east India.
Ecological and Biological characteristics: This species has been nominated as among 100 of the "World's Worst" invaders. Mainly occurs in agricultural areas, coastland, natural forests, planted forests, riparian zones, ruderal/disturbed, scrub/scrublands, urban areas, wetlands. It is a fast growing perennial herbaceous climber which grows 27 mm a day. It grows	

best where fertility, organic matter, soil moisture and humidity are all high. It damages or kills other plants by cutting out the light and smothering them. Especially it damages young plantations and nurseries. So its known as a plant killer as it spreads fast, blocking sun lights for other plants, and strangles many plants. Its intolerant of heavy shade and water logging condition, it readily colonizes gaps. It also competes for water and nutrients, but even more importantly, it is believed that the plant releases substances that inhibit the growth of other plants. Its flowering and fruiting period is in February. It Reproduces sexually by seeds and vegetatively by rooting at nodes. A single plant may cover over 25 square metres within a few months, and release as many as 40,000 viable seeds every year. (www. Issg.org/plantlibrary/invasives). In some locations flowering and seed production are during short days only. Seed dispersal is mainly by wind and by animals.	
Uses	Used as fodder for goat and pigs sometimes.

	Scientific name: *Ageratum conyzoides* Common name: Billy goat Family: Asteraceae Origin: South America
Its annual, aromatic hispid herb of 20-60cm high. Stem terete, whitish pubescent. Plant is commonly found in various habitats such as fallowlands, forests, agriculture and pastures. The dense stands of this plant may reduce the population of native flora. Flowering and fruiting: June- March (almost round the year). Plant reproduces sexually by seeds. Seed dispersal is by wind or contamination with various biotic and abiotic agents and is numerous in number.	
Uses:	Plant is used as fodder for cattle. It is also used as antiseptic to stop bleeding in cuts and wounds, and to increase appetite.

Scientific name: *Chromolaena odoratum/ Eupatorim odoratum*

Common name: Siam weed, Bitter bush

Family: Asteraceae

Origin: Tropical America, Jamaica, West Indies. Introduced in Nepal through the plains of northeast India through people's movement for labourers

It is generally found at the edges of disturbed forests, fallowlands, shrublands, agricultural and grasslands. It is a perennial herb which is normally upto 2.5 m in height. The plant grows well in sunny open and well-drained areas like forest margins and roadsides. It requires disturbances to native vegetation in order to become established. It suppresses regeneration of tree species if it becomes well established. It reduces species diversity both due to competition and allelopathic effects. When dry it promotes wild fires which may destroy native flora of forest edges. The time of flowering and fruiting is from December to April. Sexual reproduction starts from the time the plant is one year. Seed dispersal is mainly by wind. windy weather is necessary to release fruit. Most see dispersal is local and seeds can travel long distances with contaminated crop plants or vehicles. It has abundant seed production.

Uses:	Leaves are used to control bleeding and young plant used to make compost.

Scientific name: *Ageratina adenophora*

Common name: Crofton weed

Family: Asteraceae

Origin: Central America (Mexico)

Introduced to Nepal via the India as there is open and landlinked border through commercial routes.

Generally it occurs in disturbed open forest margins, grasslands, agricultural lands and fallowlands. It's a perennial, erect subshrub with stem erect, branched, dark purple or purplish brown glandular-pubescent. The plant occurs in moist areas but also occurs in

open areas. The plant grows so densly that it prevents the establishment of other species both due to competition and alleopathic effects. It absorbs most of the nourishment of soil to support the rampant expansion of the plant. It also decreases the soil fertility by absorbing nutrients from the soil. Its flowering and fruiting occurs between March to May. It reproduces sexually by seeds and vegetatively by roots. Seed dispersal is by wind. Seeds also cling to fur, hair and clothing.	
Uses:	It is used as fodder for goat, but reported as poisonous to domestic animals. Fresh juice is used to stop bleeding.

	Scientific name: *Lantana camara* Common name: Lantana Family: Verbenaceae Origin: Native to West Indies, Pacific Islands, Australia Introduced to Nepal via the plains of north-east India.
It is a perennial flowering plant with sub-erect shrub upto 3 m high. Aromatic flower clusters of this plant are called as umbels which are a mix of red, orange, yellow, or blue and white florets. The flowers typically change color as they mature, resulting in inflorescences that are two- or three-colored. Fruit is small, drupaceous, shining, blue black when ripe, with 2-nutlets.It occurs mainly in pastures, forests and margins of agricultural lands. The plant forms dense understorey vegetation in open forests that crowds out and inhibit and establishment of other species. Shoots and roots produce allelopathic substances and altered habitat and threatens the population of native flora and fauna. The plant grows well in dry as well as moist areas. It tolerates moderate shade. It has sexual reproduction by seeds, which are about 1.5mm. The fruit is delicacy for many birds and is dispersed by the frugivorous birds and rodents, Seed germinates easily.	
Uses:	Bark and leaves are used for some medicinal values. Young stems are used for brushing teeth.

	Scientific name: *Mimosa pudica* Common name: Sensitive plant Family: Fabaceae (Leguminosae) Origin: South America and Central America.
The plant is commonly found in moist waste ground, in dry lawn and open plantation. It forms a dense ground cover preventing dissemination of other species. It is a creeping annual or perennial herb often grown for its curiosity value: the compound leaves fold inward and droop when touched, re-opening within minutes. The stem is erect in young plants, but becomes creeping or trailing with age. The stem is slender, branching, and sparsely to densely prickly, growing to a length of 1.5 m (5 ft). The leaves of the *Mimosa pudica* are compound leaves. The petioles are also prickly. On close examination, it is seen that the floret petals are red in their upper part and the filaments are pink to lavender. The fruit consists of clusters of 2-8 pods from 1-2 cm long each, these prickly on the margins. Plant reproduces sexually by seeds. The flowers are pollinated by the wind and insects.	
Uses:	Roots are used in asthma, fever, dysentery, abdominal pain and skin diseases.

	Scientific name: *Cassia tora* Common name: The Sickle senna, Wild senna Family: Fabaceae Origin: South America
Plant is commonly found in dry wasteland, croplands and pastures. It is an annual herb, fruiting is between July to December. It produces a large number of seed, which fall after maturation. So its found in dense thickets. The dense stand of plant replaces the native flora. The plant reproduces sexually by seeds. Hand pulling is common	

management practice in Nepal.	
Uses:	The plant as burning material and also used as medicine. Seeds are used to cure gastric.

	Scientific name: *Oxalis latifolia* Common name: Purple wood sorrel, broad- leaf wood sorrel Family: Oxalidaceae Origin: Central and South America
It is commonly found in Agricultural lands, orchards and nursery. It is a perennial herb. It has the Flower of a clover shaped leaf with petals are reddish pink or purple. It has its flowering and fruiting time between June and November. The plant is a problematic agricultural weed in sub-tropical region of Nepal. It grows well in moist field. Bulb consists of many bulbils which remain dormant and germinate under favourable condition. It reproduces vegatatively by bulbils and sexually by seeds. The plant spreads rapidly during ploughing in agricultural fields.	
Uses:	Young leaves are used as pickle for its acidic taste; root is used to make colors.

	Scientific name: *Sida cordifolia* Common name: Ballu jhar Family: Malvaceae Origin: Northeast Brazil
Sida cordifolia is a herb that grows upto 0.75-1.5 metres in height. Mainly grows in transitional or waste areas. Leaves are heart shaped with a single leaf at each node. The flowers are produced at the growing ends and are yellow in color. Once the plant becomes established, it is very competitive, holding and denying sites to other plants. The plant grows well in many soils, including some heavy clay, and can tolerate dry as well as high rainfall conditions. Plant germinates from seeds throughout the growing	

season. *Sida* rapidly infests overgrazed areas near troughs and underneath shade trees.	
Uses	It is often assumed to treat fever, headache, skin diseases, diarrhea & dysentery

	Scientific name: *Phyllanthus amarus* Common name: Niruri Family: Euphorbiaceae Origin: Pantropical
It is an annual, glabrous herb that grows to between 30 and 60 cm. Known as "Kilanelli" by local people, it is found in tropical areas, in subtropical regions, and is usually quite scattered in its distribution. It grows well in moist, shady and sunny places as a weed in villages, gardens and cultivated fields. It propagates through seed.	
Uses	Fresh leaves are ground and mixed with a cup of cow or goat's milk and taken internally to cure jaundice.

	Scientific name: *Solanum torvum* Common name: Turkeyberry, Susumber Family: Solanaceae Origin: West Indies
It is an evergreen, widely branched and prickly shrub which prefers moist fertile soil and can tolerate drought. It is a weed which is mainly found in pastures, open native vegetation, swamps, roadsides and waste places. This plant forms impenetrable thickets in pastures, preventing animals from grazing. Sprouts from roots, forming thickets. Seed dispersal is by bats and birds. Its growth can be controlled by hand pull or by digging up small plants. *Leptinotarsa undecimlineata* is the host specific & may be useful as a biological control agent.	
Uses:	Fruits are edible and are cultivated in the tropics.

<table>
<tr><td>  </td><td>Scientific name: Solanum aculeatissimum
Common name: Love apple
Family : Solanaceae
Origin: Tropical and South North America</td></tr>
<tr><td colspan="2">It is a herb/sub- shrub with 1-2 m. tall which is mainly found along the ditches and roads, wasteland, grasslands, thickets and open forests. It grows throught the world. It reproduces by seed. Hand pulling or digging is one of the common management adopted in Nepal.</td></tr>
<tr><td>Uses:</td><td>Fruit and root liquid is a medicine for Jaundice. Burning seeds produce a smoke that is helpful to relieve nose ulcers.</td></tr>
</table>

<table>
<tr><td>  </td><td>Scientific name: Achyranthes aspera
Common name: Prickly Chaff- flower
Family: Amaranthaceae
Origin: Tropical America</td></tr>
<tr><td colspan="2">It is an erect, branched herb which mainly grows in wastelands, along roadsides and sand dunes. It often infests fence rows, open woodland, and the boarders of forests that has adapted to a wide range of environments. It can grow in semi-shade or without shade & it requires moist soil. It grows rapidly dominating other native plants. It flowers in Aug- Dec. propagation is from seeds. Hand pulling is a common management system in Nepal.</td></tr>
<tr><td>Uses:</td><td>It’s said to be useful in treatment of vomiting, bronchitis, heart disease, piles, itching abdominal pains and dysentery.</td></tr>
</table>

<table>
<tr><td>  </td><td>Scientific name: Alternanthera sessilis
Common name: Dwarf copperleaf
Family: Amaranthaceae
Origin: Tropical America</td></tr>
<tr><td colspan="2">It is a perennial herb that occurs around the world. It occurs mostly in damp places, ditches, roadsides and agricultural land. It has stems that lie flat and are 1-10 cm long. The leaves are sometimes spear-shaped but mostly elliptic and are 0.3-3 cm wide. Seeds are dispersed by wind, water and through horticultural activities. It produces many utricles that spread with wind and water. The wind blows utricles of it to new locations. It can be dispersed through horticultural activities.</td></tr>
<tr><td>Uses:</td><td>Young shoots and leaves are eaten as a vegetable in Southeast Asia. Occasionally it is cultivated for food or for use in herbal medicines.</td></tr>
</table>

<table>
<tr><td>  </td><td>Scientific name: Digitaria cilliaris
Common name: Crabgrass
Family: Poaceae
Origin: Tropical America</td></tr>
<tr><td colspan="2">It is a creeping annual herb up to 60 cm.high. It is commonly found on waste ground, old farmland and on roadsides. It usually occurs in lower elevations in warm regions. It can be a major problem in irrigated lands. Due to its prolific growth rate and spreading morphology it is considered as a weed. The plant produce many seeds and several seed crops may be produced each year if grazing or mowing occurs. It also spread and reproduces by rooting at the nodes and can form thick, nearly prostrate mats 0.6 m or more in diameter. It is commonly considered as a weed due to its prolific growth rate and spreading morphology.</td></tr>
<tr><td>Uses:</td><td>Fodder for animals</td></tr>
</table>

4.4 Diversity of invasive alien plants in Jankauli CF

As presented in the table 4, the highest IVI was found for the *Mikania micarantha* with 52.317 followed by *Digitaria ciliaris* with 49.839. Highest RF and RC were also found for *Mikania micarantha* with 15.463% and 34.38% respectively. The higest RD was found for *Digitaria ciliaris* with 30.768% and lowest for *Ipomoea quamoclit* and *Solanum turvum* with 0.062%. Similarly, the lowest IVI was found for *Ipomoea quamoclit* with 0.486.

Table 4: Quantitative structure of Invasive alien plant species of Jankauli CF

SN	**Species**	**Local Name**	**RF**	**RD**	**RC**	**IVI***
1	*Mikania micarantha*	Lahare banmara	15.463	2.473	34.38	52.317
2	*Digitaria ciliaris*	Banso	8.591	30.768	10.48	49.839
3	*Ageratum conyzoides*	Gandhe	4.467	2.814	2.57	9.851
4	*Lantana camera*	Banphada	1.718	0.343	2.85	4.912
5	*Eupatorium odorata*	Seto banmara	2.405	0.469	1.23	4.104
6	*Achyranthus aspera*	Datiwan	2.405	0.625	1	4.030
7	*Eupatorium adenophora*	Kalo banmara	2.061	0.406	1.15	3.618
8	*Mimosa pudica*	Lajjawati	1.030	0.406	1.46	2.897
9	*Sida acuta*	Balujhar	1.374	0.156	0.77	2.300
10	*Bidens biternata*	Kuro	0.343	1.250	0.46	2.054
11	*Cassia tora*	Tapre	0.343	0.187	1.23	1.761
12	*Oxalis latifolia*	Chari amilo	0.687	0.437	0.54	1.665
13	*Solanum aculeatissium*	Kantakari	0.343	0.125	0.77	1.238
14	*Phyllanthus amarus*	Bhui amala	0.687	0.218	0.15	1.056
15	*Alternanthera sessilis*	Bheringejhar	0.343	0.281	0.15	0.775
16	*Solanum turvum*	Bihi	0.343	0.062	0.15	0.556
17	*Ipomoea quamoclit*	Jyanti	0.343	0.062	0.08	0.486

RF- Relative Frequency, RD- Relative Density, RC- Relative Coverage, IVI- Important Value Index

***** Values are presented in the decreasing order of Importance Value Index (IVI)

This result (table 4) clearly indicates that the *Mikania micarantha* is most threatening invasive alien species in Janakauli CF. Similarly, the quantitative structure of native plants is also shown in the table in the annex 5. Altogether 31 native herb plants were identified and among them, *Callicarpa macrophylla* showed the highest RF, RC and IVI as 9.278, 6.26 and 21.291 respectively.

4.5 Diversity of Invasive Alien Species in Kumroj CF

Among the 19 alien species recorded in Kumroj CF, the highest RC and IVI were found in *Mikania micarantha* with 14.87% and 18.84% respectively. Similarly after *Mikania*, *Alternanthera sessilis* occupies the second highest IVI with 13.22% and highest RD with 8.20% where as *Coccinea grandis* has the lowest IVI with 0.314.

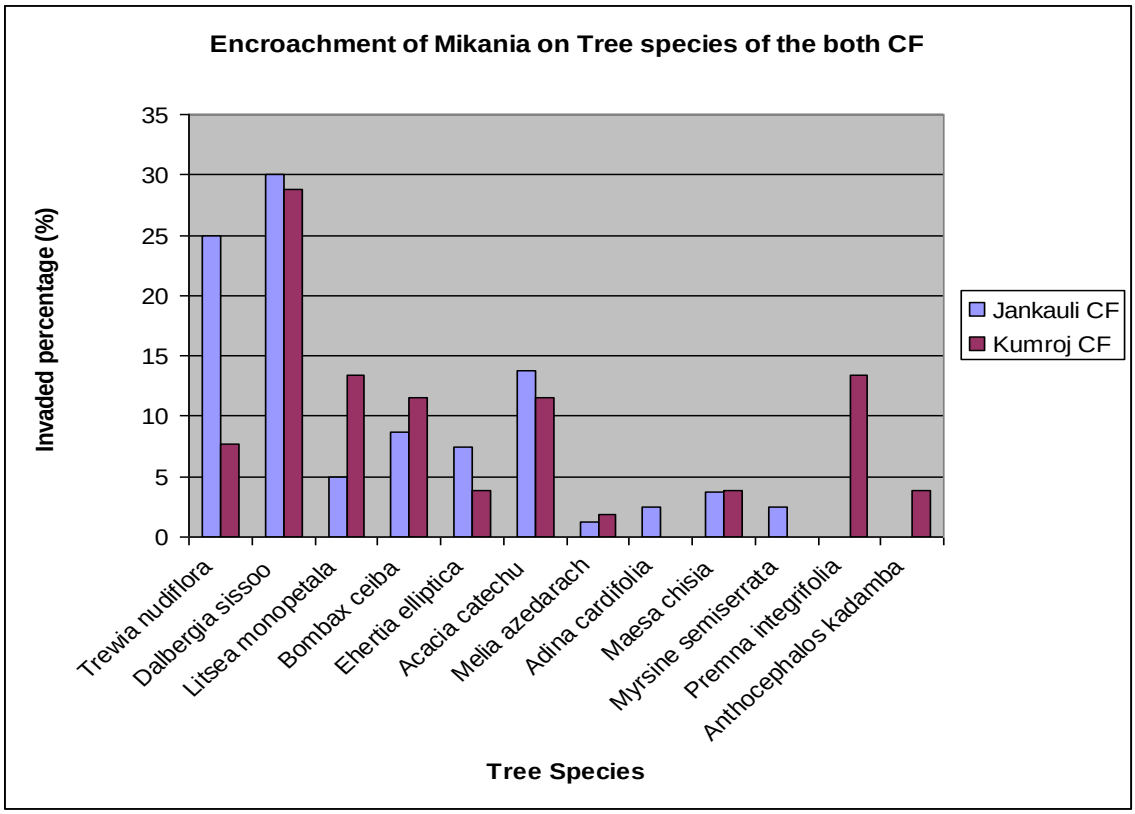
Table 5: Quantitative structure of Invasive alien plant species of Kumroj CF

	Species		**RF**	**RD**	**RC**	**IVI***
1	*Mikania micarantha*	Mikania	3.553	0.416	14.872	18.841
2	*Alteranthera sessilis*	Bhirangijhar	2.030	8.200	2.993	13.224
3	*Ageratum conyzoides*	Gandhe	4.399	3.421	4.754	12.574
4	*Bidens biternata*	Kuro	2.707	6.254	2.918	11.879
5	*Oxalis latifolia*	Chariamilo	1.353	5.439	1.881	8.674
6	*Digitaria grandis*	Bonso	3.214	4.045	1.3	8.560
7	*Eupatorium*	Kalo banmara	1.861	0.425	3.287	5.573
8	*Eupatorim odorata*	Seto banmara	1.692	0.190	2.99	4.872
9	*Cassia tora*	Tapre	1.692	0.298	2.409	4.399
10	*Imomoea camea*	Besaram	1.861	0.398	1.69	3.949
11	*Sida acuta*	Balu	2.030	0.253	0.881	3.164
12	*Mimosa pudica*	Lajjawati	0.676	0.343	1.5	2.520
13	*Solanum aculeatissium*	Kantakari	1.353	0.434	0.727	2.515
14	*Achyranthus aspera*	Datiwan	1.353	0.226	0.7	2.279
15	*Lantana camera*	Lantana	0.338	0.099	1.545	1.982
16	*Solanum turvum*	Bihi	0.169	0.018	0.772	0.959
17	*Phyllanthus amarus*	Bhui amala	0.676	0.036	0.136	0.849
18	*Ipomoea quamoclit*	Jyanti	0.169	0.027	0.181	0.377
19	*Coccinea grandis*	Golkakri	0.169	0.009	0.136	0.314

The result (table 5) clearly indicates that the *Mikania micarantha* is most threatening invasive alien species in Kumroj CF as well. Similarly, the quantitative structure of native plants is also shown in the table in the annex 6. Altogether 43 native plant species were recorded from Kumroj CF and the highest IVI was recorded in *Imperata cylindrica* with 27.035.

4.6 Invasion ability of Mikania micarantha in Janakauli and Kumroj CFs

The figure 6 shows that *Dalbergia sissoo* is the tree most severely encroached by *Mikania micarantha* in both the community forests with 30% of the trees being affected in Jankauli and 28.84% of trees being affected in Kumroj CF. It has been followed by *Trewia nudiflora* with 25% in Jankauli and Litsea monopetala and Premna integrifolia with 13.46% while the least encroachment has been found for the *Melia azedarach* in both the CFs with 1.25% and 1.9% in Jankauli and Kumroj CF respectively.



**Trees totally covered were only considered.*

Figure 6: Encroachment of Mikania on Tree species of the both CF

4.7 Diversity Index

The Shannon-Weiner's Diversity Index shows that diversity was relatively higher for Kumroj CF than Jankauli CF which clearly indicates that the Kumroj CF was more diverse in compared to Jankauli CF (Table 6).

Table 6: Diversity Indices for Invasive alien and Native species in both CFs

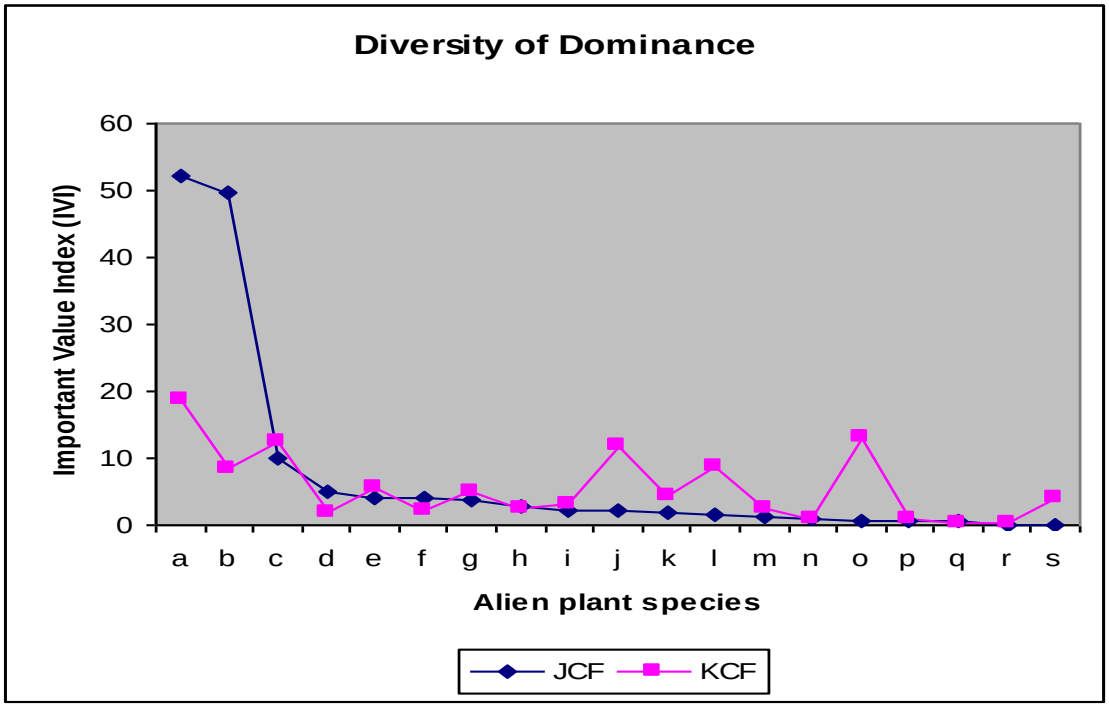
Spp type	Shannon- Wiener's Index		Simpon's Index (1-D)	
	Jankauli	Kumroj	Jankauli	Kumroj
Invasive alien	0.533	0.629	0.86	0.96
Native	0.66	0.871	0.99	0.982
Overall	1.201	1.501	0.858	0.952
Species	17	19		
Jaccard's coefficient	0.89			

Besides, the diversity was relatively high for native species in compare to invasive species in both the community forests, which shows native plants were more diverse than invasive species in both cases.

The complement of Simpson's index also identified that Kumroj CF as more diverse than Jankauli CF. Similarly, Jaccard's coefficient showed 0.89, which means Jankauli shared 89% of the similar species found in Kumroj CF.

4.8 Diversity of Dominance

The most dominant species in both the community forests was *Mikania micarantha* with IVI of 52.31 in Jankauli CF and 18.84 in Kumroj CF. The second highest dominant species was *Digitaria ciliaris* with 49.839 and the least dominating species was *Ipomoea quamoclit* with 0.48. In Kumroj CF, *Alternanthera sessilis* was the second highest dominant with 13.22 and *Coccinea grandis* was the least dominant species with 0.31. Dominance diversity curve has further interpreted the result on abundance of different alien species in the study area (figure 7).



a- Mikania micarantha, b- Digitaria ciliaris, c- Ageratum conyzoides, d- Lantana camera, e- Eupatorium adenophora, f- Achyranthus aspera, g- Eupatorium odorata, h- Mimosa pudica, i- Sida acuta, j- Bidens biternata, k- Cassia tora, l- Oxalis latifolia, m- Solanum aculeatissium, n- Phyllanthus amarus, o- Alternanthera sessilis, p- Solanum turvum, q- Ipomoea quamoclit, r- Coccinea grandis, s- Imomoea camea

Figure 7 : Diversity of Dominance for alien plant species

4.9 Spearman's rho correlation in Kumroj CF

Table 7: Spearman's rho correlation between species richness & Abundance of Invasive alien in Kumroj CF

			Species Richness	Abundance invasive
Spearman's rho	Species Richness	Correlation Coefficient	1.000	-.512(**)
		Sig. (2-tailed)	.	.000
		N	110	110
	Abundance invasive	Correlation Coefficient	-.512(**)	1.000
		Sig. (2-tailed)	.000	.
		N	110	110

** Correlation is significant at the 0.01 level (2-tailed).

As shown in table 7, the abundance of invasive alien species is highly negatively correlated with species richness at 0.01 level. The result indicates that if the coverage of invasive plants is higher, species richness i.e. number of species gets lower.

Table 8: Spearman's rho correlation between species richness & *Mikania micarantha* in Kumroj CF

			Species Richness	*Mikania micarantha*
Spearman's rho	Species Richness	Correlation Coefficient	1.000	-.463(**)
		Sig. (2-tailed)	.	.000
		N	110	110
	Mikania micarantha	Correlation Coefficient	-.463(**)	1.000
		Sig. (2-tailed)	.000	.
		N	110	110

** Correlation is significant at the 0.01 level (2-tailed).

From the result presented in Table 8, abundance of *Mikania micarantha* was highly negatively correlated with species richness at 0.01 level. This result clearly indicates that as the coverage of *Mikania micarantha* increases in the plot, then number of species gets lower.

4.10 Spearman's rho correlation in Jankauli CF

Table 9: Spearman's rho correlation between species richness & Abundance of Invasive alien in Janakauli CF

			abundance invasive	Species richness
Spearman's rho	Abundance invasive	Correlation Coefficient	1.000	-.309(*)
		Sig. (2-tailed)	.	.012
		N	65	65
	Species richness	Correlation Coefficient	-.309(*)	1.000
		Sig. (2-tailed)	.012	.
		N	65	65

* Correlation is significant at the 0.05 level (2-tailed).

From the table 9, there is a negative correlation of abundance of invasive alien species with species richness at 0.05 level, it indicates that when the coverage of invasive plants increases, then the species richness gets lower. Significant difference is lower as compared to Kumroj CF.

Table 10: Spearman's rho correlation between species richness & *Mikania micarantha* in Janakauli CF

			Species richness	*Mikania macarantha*
Spearman's rho	sdiversi	Correlation Coefficient	1.000	-.527(**)
		Sig. (2-tailed)	.	.000
		N	65	65
	Mikania	Correlation Coefficient	-.527(**)	1.000
		Sig. (2-tailed)	.000	.
		N	65	65

** Correlation is significant at the 0.01 level (2-tailed).

From the table 10, *Mikania micarantha* is highly negatively correlated with species richness at 0.01 level. This result indicates that if the coverage of *Mikania micarantha* increases in the plot, the number of species decreases.

4.11 Magnitude of Invasiveness

Invasive Alien species were ranked in one of four categories of invasiveness: high, medium, low, and insignificant. Altogether, 17 identified alien plant species of Jankauli (table 11) and 19 species of Kumroj (table 12) were prioritized for assessment of magnitude of invasiveness.

Among the species found in both CFs, three species are considered as high threat to the native species and ecosystems. These species include *Ageratum adenophora*, *Chromolaena odorata* and *Mikania micarantha*. *Lantana camara* was recorded as a medium threat whereas eight species with insignificant rank in Jankauli were found to be as follows: *Achyranthus aspera*, *Alternanthera sessilis*, *Bidens pilosa*, *Cassia tora*, *Ipomoea quamoclit*, *Mimosa pudica*, *Oxalis latifolia* and *Solanum turvum*.

Table 11: Ranking criteria score for alien species of Janakauli CF

S.N	Scientific name	Local name	Impact	Biology and Ecology	Distribution & Abundance	Difficulty to control	Invasiveness
1	*Achyranthus aspera*	Datiwan	I	M	L	L	I
2	*Ageratina adenophora*	Banmara	H	H	H	M	H
3	*Ageratum Conyzoides*	Gandhe	M	M	H	L	L
4	*Alternanthera sessilis*	Bheringijhar	L	L	L	I	I
5	*Bidens pilosa*	Kuro	L	L	M	I	I
6	*Cassia tora*	Tapre	M	M	L	L	L
7	*Chromolaena odorata*	Banmara	H	H	H	M	H
8	*Digitaria ciliaris*	Banso	L	M	L	I	L
9	*Ipomoea quamoclit*	Jyanti	I	L	I	I	I
10	*Lantana camera*	Banmara	H	H	M	M	M
11	*Mikania micarantha*	Lahare banmara	H	H	H	H	H
12	*Mimosa pudica*	Lajjawati	I	M	I	I	I
13	*Oxalis latifolia*	Chari amilo	I	M	L	L	I
14	*Phyllanthus amarus*	Bhui amala	L	M	I	I	L
15	*Sida cordifolia*	Ballu	L	M	L	I	L
16	*Solanum aculeatissimum*	Kantakari	L	M	M	I	L
17	*Solanum torvum*	Bihi	L	L	M	I	I

Note: I = Insignificant, L = Low, M = Medium, H = High

Table 12: Ranking criteria score for alien species of Kumroj CF

S. N	Scientific name	Local name	Impact	Biology and Ecology	Distribution & Abundance	Difficulty to control	Invasiveness
1	*Achyranthus aspera*	Datiwan	I	M	L	L	I
2	*Ageratina adenophora*	Banmara	H	H	H	M	H
3	*Ageratum Conyzoides*	Gandhe	M	M	H	L	L
4	*Alternanthera sessilis*	Bheringijhar	L	L	L	I	I
5	*Bidens pilosa*	Kuro	L	L	M	I	I
6	*Cassia tora*	Tapre	M	M	L	L	L
7	*Chromolaena odorata*	Banmara	H	H	H	M	H
8	*Coccinea grandis*	Golkakri	L	M	I	L	L
9	*Digitaria ciliaris*	Banso	L	M	L	I	L
10	*Ipomoea camea*	Besaram	L	M	L	I	
11	*Ipomoea quamoclit*	Jyanti	I	L	I	I	I
12	*Lantana camera*	Banmara	H	H	M	M	M
13	*Mikania micarantha*	Lahare	H	H	H	H	H
14	*Mimosa pudica*	Lajjawati	I	M	I	I	I
15	*Oxalis latifolia*	Chari amilo	I	M	L	L	I
16	*Phyllanthus amarus*	Bhui amala	L	M	I	I	L
17	*Sida cordifolia*	Ballu	L	M	L	I	L
18	*Solanum aculeatissimum*	Kantakari	L	M	M	I	L
19	*Solanum torvum*	Bihi	L	L	M	I	I

Note: I = Insignificant, L = Low, M = Medium, H = High

CHAPTER FIVE- DISCUSSION

5.1 Discussion

The Main goal of this study was the assessment of the status of invasive species in Janakauli and Kumroj CF. According to Tiwari et al, 2005, there are altogether 166 alien plants which are permanently naturalized in Nepal. This study found that massive numbers of invasive species that was found in these areas and *Mikania micarantha* is the most threatening species.

The Result showed that most dominant/aggressive species in both the community forests was *Mikania micarantha* with the highest Importance Value Index. This result is verified with some other studies, *Mikania micrantha* is well established in the grassland and riverine forest in Chitwan National Park. High invasion of *Mikania* has been observed in the northern part of core and buffer zone of the park. It should be categorized as most serious weed of Chitwan National Park and it needs to take immediate action to control the weed (Sapkota, 2007). The abundance of seedlings and the high levels of recruitment observed in the study areas also suggest that it will continue to be a dominant in the areas where its established.

Result of invasive alien species abundance and its relation to species richness shows that there is high negative correlation between them at the 0.01 level, it indicated that if coverage of Invasive plants is higher, then the number of species gets lower. The result is consistent to most studies, which find significant negative associations between exotic species and community richness (Richardson et al. 1998, Woods 1993). Dominance or cover of exotic species to assess invasion impacts tends to find negative relation between invasion and diversity (Richardson et al. 1998, Woods 1993). Exotic species removals generally result in an increase in the abundance and diversity of native species (McCarthy 1997, Pickart et al. 1998). Exotic invasion is often associated with declines in local plant diversity (Richardson et al. 1998)

Further, the result showed that *Mikania micarantha* has the high negative significance with species richness at the 0.01 level. This indicates that higher the coverage of the aggressive

weed *Mikania micarantha*, lower is the species richness in the plot. It can be verified by its characteristics mentioned in different literatures.

Mikania micrantha damages or kills other plants by cutting out the light and smothering them. In this respect it is especially damaging in young plantations and nurseries. It also competes for water and nutrients, but perhaps even more importantly, it is believed that the plant releases substances that inhibit the growth of other plants. The ground gets totally covered by *Mikania micarantha*, which prevent the regeneration of other plants. The plant spreads appallingly fast and becomes dense within 8-10 years according to local inhabitants. (Tiwari et.al., 2005). It is also reported that, the coverage of grassland in CNP is very low and furthermore, it is being invaded by *Mikania*, the nature of invasion of the weed and its preferred habitat shows the serious threat to the Park management as well as environment. (Sapkota, 2007).

The result for the magnitude of Invasiveness showed that some IAS like *Mikania micarantha, Ageratina adenophora* and *Chromolaena odorata* were found to be high threat to native habitats and ecosystem, this resembles to one of the recent assessment carried out by IUCN Nepal, which identified 166 different non native invasive plant species and 6 species were considered as high risk invaders. (Tiwari et al., 2005). *Mikania micarantha* and *Chromalaena odorata* are considered to be the world's worst weed (Lowe et al., 2000).

Regarding the Invasion ability of alien species, *Mikania micarantha* is an extremely serious weed with an exceptionally fast growth rate, 8-9 cm per day has been recorded (Chowdhary, 1972). Many moist parts of Chitwan National Park, including Bhimle Checkpost to Devital are seriously invaded by *Mikania micarantha*. (Tiwari et al 2005).

5.2 Limitation of the methods and data

During data collection, sample size were not consistent for Janakauli and Kumroj CF due to inconvenience of large area of Kumroj CF. Smaller sample size was taken from Kumroj CF due to limited availability of time and resources.

5.3 Conclusion and Recommendations

5.3.1 Conclusion

Altogether 18 individual tree species and 18 shrubs were found in Jankauli CF where as 20 tree species and 22 shrubs were identified in Kumroj CF. Similarly, total 36 and 51 herb plants were identified in Jankauli and Kumroj CF respectively. 17 plants species in Jankauli and 19 plant species in Kumroj CF were identified as alien plants with invasive characteristics. Looking at their life form diversity, more perennial plants are found as compared to annuals. In both the CFs, the highest Important Value Index (IVI) was found in *Mikania micarantha*, so it proved as the most dominating plant species. But the IVI and coverage value of *Mikania micarantha* is comparatively more in Jankauli than in Kumroj CF, as it is 52.317 in Jankauli and 18.84 in Kumroj. Although its less as compared to Jankauli, it's the highest IVI among all other species in Kumroj CF. Thus, Jankauli CF is more severely invaded by *Mikania micarantha* as compared to Kumroj CF. Nevertheless, most of the small trees, shrubs and herbs are severely smothered in invaded area. It has suppressed the growth of other plants, and has affected the biodiversity.

Species diversity showed that Kumroj CF is more diversified as to Jankauli CF. Jaccard's coefficient (J) showed 0.89, which means Jankauli CF shared 89% of invasive alien plants species of Kumroj CF. In both the CFs, Spearman correlation between the coverage of *Mikania micarantha* and species richness showed its high negatively significance with species richness at 0.01 level. Which means when the coverage of *Mikania micarantha* is high in the plot, number of species is lower. The Magnitude of species ranking assessment showed *Mikania micarantha*, *Ageratina adenophora* and *Chromalaena odorata* to be highly invasive. Similarly *Lantana camara* found to be have medium threat. The threat from *Achyranthus aspera*, *Alternanthera sessilis*, *Bidens pilosa*, *Cassia tora*, *Ipomoea quamoclit*, *Mimosa pudica*, *Oxalis latifolia* and *Solanum turvum* is not significant.

5.3.2 Recommendations

It is very necessary that a high level body at the national level should be aware and be responsible for the issue of control and management of the most aggressive alien plants like *Mikania micarantha*. There is a need to form IAS Experts group from different relevant fields for the technical inputs. An effective policy framework is necessary to regulate, manage and control the introduction of alien species as well as existing laws, policies and regulations should be reviewed to address the weed and other issues. Intensive research need to be promoted so a regular assessment and monitoring of the invasive weed *Mikania micarantha* is necessary to understand its root cause and its impact. Researches and results from various control programs which are implemented in other countries should be carefully studied for their replicability in Nepal. Besides, it is also equally important to involve local and indigenous communities and other relevant stakeholders in the identification, prevention and control of IAS. Besides, International networking is important for the control and management of IAS.

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Annex 1: Data collection Sheet

Plot No.				Date:	
Name of the CF					
Latitude		Longitude		Altitude	
Illegal Activities				Grazing	
Tree Species			For 20 *20m Plot Size		
Local Name	Scientific Name	Trees affected by invaders			Remarks
Shrub Species (1st plot)		5*5m	Plot Size		
Local Name	Scientific Name	No. of Individuals	Cover Percent (%)	Use Value	Remarks
Herb Species (1st plot)		1*1m	Plot size		
Local Name	Sci. Name	No. of individuals	Cover Percent	Use Value	Remarks
Herb Species		1*1m	Plot size		
Local Name	Scientific Name	No. of Individuals	Cover Percent	Use value	Remarks

Annex 2: Composition and distribution of tree species in Janakauli & Kumroj CFs

Species	Local Name	Janakauli CF	Kumroj CF
Acacia catechu	Khair	+	+
Adinacardifolia	Karma	+	+
Albizia odoratissimum	Padke	+	-
Bombax ceiba	Simal	+	+
Corneabichotoma	Bohori	+	+
Dalbergia sissoo	Sissoo	+	+
Dysoxylum binecteriferum	Dhamina	-	+
Duabanga grandiflora	Lampate	+	+
Ehertia elliptica	Dadrung	+	+
Ficus bengalensis	Bel	+	+
Ficus hirta	Khasru	+	+
Litsea monopetala	Kutmero	+	+
Maesa chisia	Bilaune	+	+
Mallotus philippenis	Sindure	+	+
Melia azedirachta	Bakaino	+	+
Michelia Champaca	Champ	-	+
Morus alba	Kimbu	-	+
Murraya koenigii	Ashare	-	+
Myrsine semiserrata	Kalikath	+	-
Premna barbata	Gidari	+	+
Trewia nudiflora	Vellar	+	+
Bridellia retusa	Gayo	+	_
Bambusa vulgaris	Bans	-	+
Total		**18**	**20**

Annex 3: Composition and distribution of Shrub in the Study area

Species	Local Name	Jankauli	Kumroj
Ardisia Solanacea	Damai phul	+	+
Bohmeria platyphylla	Kamle	+	+
Bridelia retusa	Gayo	+	+
Calcicorpus macrophylla	Dahi kamala	+	+
Chlerodendron viscocum	Bhanti	+	+
Chromolaena odorata	Banmara	+	+
Coffea bengalensis	Baramasey coffee	+	-
Colebrookia oppositifolia	Dhursil	+	+
Equisetum debile	Ankhle	+	+
Ipomoea carnea	Besaram	+	+
Mimosa pudica	Lajjawati	+	+
Murraya koenigii	Kadipatta	+	+
Osyris wightiana	Nundhiki	-	+
Pocus bengalensis	Rhudilo	+	+
Rubus ellipticus	Ainselu	+	+
Solanum aculeatissium	Kantakari	+	+
Solanum turvum	Thulo bihee	+	+
Trichosathes wallichiana	Indreni	+	+
Xeromphis spinosa	Main kanda	+	+
Citrus paradise	Grapefruit	-	+
Ziziphus mauritiana	Bayer	-	+
*(*miscellaneous)	Ban tulsi	-	+
Citrus limon	Lemon tree	-	+
Total		18	22

Annex 4: Fern species found in the study area

Species	Local Name	Jankauli CF	Kumroj CF
Diplazium esculentum	Neuro	+	+
Lepisorus bicolor	Dhule unyo	+	+
Pterish vittata	Bis unyo	+	+
Tectarai macrodonta	Kalo neuro	+	+

Annex 5: Quantitative structure of Native Plant species of the Janakauli CF

Species name	Local name	RF	RD	RC	IVI
Hermertheria comparusa	Ghode dubo	1.374	13.726	1.15	16.251
Imperata cylindrical	Siru	3.436	3.971	0.92	8.327
Calicarpa arborea	Guyalo	9.278	5.753	6.26	21.291
Calicarpa macrophylla	Dahikamala	1.718	0.875	0.54	3.133
Aqisetum debile	Ankhle	0.687	10.037	0.58	11.304
Chlerodendron viscocum	Bhanti	3.092	0.781	2.08	5.954
Diplazium esculentum	Niuro	2.061	0.625	0.88	3.567
Colocasia esculenta	Karkalo	3.436	0.562	2.08	6.079
Boymera platifera	Kamle	3.092	0.906	1.54	5.539
Trichosanthes wallichiana	Indreni	0.687	0.125	0.38	1.192
Dioscorea species	Ban tarul	2.405	1.532	2.15	6.087
Eleusine indica	Kode banso	1.374	3.752	1.08	6.206
Tectoria macrodonta	Kali neuro	1.718	1.125	1.15	3.993
Parthenocissus	Charchare	5.841	3.189	4.46	13.491
Lepisorus bicolor	Dhule uneu	2.405	2.595	1.69	6.690
Ceropegia pubescens	Ban simi	0.343	0.312	0.46	1.116
Piper longum	Pipla	1.718	0.562	1.54	3.821
Jinospora sinensis	Batulpate	2.061	0.281	1.46	3.803
Colebrookia	Dhursil	1.718	0.218	1.08	3.017
Dioscorea bulbulifera	Githa	1.374	0.156	0.69	2.220
Saccharum spontaneum	Kans	2.061	2.907	0.08	5.049
Kalanchoe spathulata	Hattikane	0.343	3.126	0.46	3.930
Cyperus species	Mothe	0.343	0.625	0.15	1.119
Vitex cerdivus	Kutile kosa	0.343	0.125	0.38	0.848
Curcuma species	Ban besar	0.687	0.031	0.69	1.408
Cirsium walichii	Gainde kanda	0.687	0.093	0.31	1.091
Pterish vittata	Bish uniu	0.343	0.031	0.23	0.604
Pogostemon bengalensis	Rudilo	1.374	0.375	1.23	2.979
Hyptis suaveolens	Silam	0.343	0.062	0.46	0.866
Flemingia strobilifera	Bhatmas pate	0.343	0.312	1.23	1.886
Pterish vittata	Bish unyu	0.343	0.125	0.77	1.238

Annex 6: Quantitative structure of Native Plant species of the Kumroj CF

Species name	Local name	RF	RD	RC	IVI
Rungia parviflora	Ukuchijhar	0.507	0.072	0.045	0.625
Cirsium walichii	Gainde kada	0.338	0.036	0.272	0.646
Canotis cristata	Kaneghans	3.891	6.897	2.272	13.060
Jinospora sinensis	Batulpate	1.353	0.072	0.227	1.653
Ziziphus mauritiana	Bayer	0.169	0.009	0.181	0.359
Coffea bengalensis	Baramase	0.338	0.072	0.181	0.591
Chlerodendron viscocum	Bhanti	4.568	0.579	2.209	7.356
Flemingia strobilifera	Bhatmaspate	1.692	2.443	2.772	6.907
Aquisetum debile	Ankhle	0.846	1.855	1.981	4.682
Centella asiatica	Godhtapre	1.522	0.805	2.555	4.883
Callicarpa arborea	Callicarpa	0.169	0.018	0.181	0.368
Parthenocissus semicordata	Charchare	1.522	0.108	1.002	2.633
Rernwardtia trigyan	Paulighans	1.861	0.470	0.672	3.003
Motoneuron cucullata	Boksi kanda	0.846	0.543	0.354	1.743
Callicarpa macrophylla	Dahikamala	1.692	0.425	0.7	2.817
Hyptis suaveolens	Silam	0.169	0.090	0.09	0.349
Imperata cylindrica	Siru	5.752	16.292	4.99	27.035
Colebrookia	Dhursil	0.676	0.063	0.236	0.976
Hermertheria comparusa	Ghode dubo	2.876	12.608	0.781	16.266
Lepisorus bicolor	Dhule unyu	0.338	0.027	0.636	1.001
Vitex cerdivus	Kutile kosa	4.230	6.345	8.136	18.711
Ceropegia pubescens	Ban simi	0.169	0.009	0.09	0.268
Pericamplylus semicordata	Pate lahara	0.169	0.036	0.181	0.386
Dioscorea bulbifera	Githa	0.169	0.009	0.045	0.223
Desmodium species	Badam pate	0.169	0.633	0.272	1.074
Trichosanthes wallichiana	Indreni	1.522	0.208	0.854	2.585
Cynodon dactylon	Dubo	1.522	0.190	0.745	2.457
Tectoria macrodonta	Kali neuro	3.553	0.669	1.245	5.468

Bohmeria platyphylla	Kamle	5.076	2.525	3.663	11.264
Bridelia retusa	Gayo	0.338	0.217	0.772	1.327
Saccharum spontaneum	Kans	0.676	0.144	0.19	1.011
Colocasia esculenta	Karkalo	0.169	0.027	0.045	0.241
Pterish vittata	Bish unyu	0.338	0.036	0.109	0.483
Dioscorea species	Ban tarul	0.846	1.321	2	4.167
Curcuma species	Ban besar	1.353	0.099	0.636	2.089
Kalanchoe spathulata	Hatti kane	2.199	6.797	1.227	10.224
Cyperus species	Mothe	1.353	2.860	0.454	4.667
Diplazium esculentum	Niuro	0.169	0.054	0.327	0.550
Poncirus trifoliate	Tin pate	1.015	0.072	0.045	1.132
Artemisia vulgaris	Pati	5.583	2.172	4.381	12.137
Piper longum	Pipla	3.214	0.742	1.454	5.411
Pogostemon benghalensis	Rudilo	3.384	0.696	2.836	6.917
Phragmites karka	Narkot	0.338	0.099	1.363	1.800

Annex 7: Ranking Criteria

Section 1: Impact of Native Species, Habitats and Ecosystems

A. Ability to Invade Natural Systems

Choose one answer that best describes the ability of this species to invade natural systems:

I. Not known to spread into natural areas on its own (e.g., species may persist from former cultivation).

L. Establishes only in areas where major disturbance has occurred in last 20 years (e.g., highway corridors).

M Often establishes in mid- to late- successional natural areas where minor disturbances may occur (e.g., highway corridors), but no major disturbance in last 20-75 years

H. Often establishes in intact or otherwise healthy natural areas with no major disturbance for at least 75 yrs

B. Impact on Ecosystem Processes

I. No perceivable impact on ecosystem processes

L. Influences ecosystem processes (e.g., has perceivable but mild influence on soil nutrient availability)

M. Significant alteration in ecosystem processes (e.g., increases sedimentation rates along coastlines, reducing open water areas that are important for waterfowl)

H. Major, possibly irreversible, alteration or disruption of ecosystem processes (e.g., the species drains water from open water or wetland systems through rapid transpiration, making these areas more fire prone and unable to support native wetland species; species fixes nitrogen in the soil making soil unlikely to support certain native plants)

Comments:

C. Impacts on Natural community Structure

I. No impact; establishes in an existing layer without influencing its structure

L. Influences structure in one layer (e.g., changes density of a layer)

M. Significant impact on at least one layer (e.g., creation of a new layer, elimination of an existing layer)

H. Major alteration of structure (e.g., covers canopy, eradicating most or all layers below)

D. Impact on Natural Community Composition

I. No impact; causes no perceivable change in native populations

L. Influences community composition (e.g., reduces the number of individuals in one or more native populations by reducing recruitment)

M. Significantly alters community composition (e.g., produces a significant reduction in the population size of one or more native species in the community)

H. Causes major alteration in community composition (e.g., results in the extirpation of one or several native species, reducing biodiversity or changing the community composition towards species exotic to the natural community)

E. Conservation Significance of the Natural Area(s) and Native Species Threatened

I. Insignificant (e.g., found in human-disturbed habitats and is not known to impact any vulnerable or high quality native species or communities)

L. Low significance (e.g., usually inhabits common, unthreatened habitats and rarely impacts vulnerable or high quality species or communities)

M. Moderately significant (e.g., may occasionally threaten vulnerable or high quality species or communities)

H. Highly significant (e.g., known to inhabit one or more vulnerable or high quality communities and/or often threatens rare native species)

Comments:

Impact Sub rank: enter Insignificant, Low, Medium or High

Subrank Guidance

Minimum ranking information: to determine Impact Subrank, you must answer both categories A and B as well as at least one other category in this section.

If H in A and B, Subrank = High

If H in A or B, and M or H in at least one other category (A-E), Subrank = High

If M in A and B, and H in at least one other category, Subrank = High

If M in A or B, and M or H in at least one other category, Subrank = Medium

If L in A or B, and H in at least one other category, Subrank = Medium

If M in at least one category, Subrank = Low

All others, Subrank = Insignificant

Section II: Biological characteristics: Reproduction, Competition Ability, and Dispersal

Reproduction:

Reproduces readily both vegetatively and by seed

If reproduction is by seed, produces over 1,000 seeds per plant annually

Reproduces more than once per year

Rapid growth to reproductive maturity

Seeds remain viable in soil for 2 or more years

Has quickly spreading rhizomes that may root at nodes

Resprouts readily when cut, grazed or burned

Other (please discuss in comments)

Competitive ability:

Highly successful competitor for limiting resources

Tolerance of a wide range of conditions or tolerance of stressful conditions

Ability to germinate in vegetated areas under a wide range of conditions

Allelopathic

Known to hybridize with native species

Lack of natural predators or control agents in the Nepal

Other (please discuss in comments)

Dispersal ability:

Rapid local proliferation of seeds

Long-distance dispersal ability (e.g., bird dispersed seed, small seeds carried by water)
Other (please discuss in comments)

Choose one answer that best describes the biological characteristics of this species:

I. Not aggressive (e.g., has none of the above characteristics or only one or two to a very small extent)

L. Somewhat aggressive (e.g., has only one or two of the above and to a small extent)

M. Moderately aggressive (e.g., has two or more of the above characteristics, but has only one or two to a great extent)

H. Extremely aggressive (e.g., has three or more of the above characteristics and has them to a great extent)

B. Other Region Invaded

Is this species known to be invasive beyond its native range in other areas outside Nepal? If yes, briefly list the other countries or region invaded: India, Bangladesh, Srilanka, Thailand, Malaysia, Indonesia etc.

C. Dispersal Ability and Speed of Spread

1. Speed of spread (increase in range) once reported as escaped

Choose one answer that best describes the speed of spread:

I. Does not spread

L. Slow -- doubling time (new local reports) > 50 years

M. Moderate -- doubling time (new local reports) 10-50 years

H. Rapid -- doubling time (new local reports) < 10 years

2. Current trend in total range within the Chitwan District

Choose one answer that best describes the current trend:

I. Declining or Historical

L. Stable

M. Increasing

H. Increasing rapidly

Comments:

3. **Potential to be spread by human activity**

Is this species frequently spread or does it have has high potential to be spread by human activity (e.g., species is sold commercially for use in agriculture or ornamental horticulture; species takes advantage of transportation corridors such as highways; species is aquatic and is transported by boats or boat trailers)?

Comments:

Biology/Dispersal Ability Subrank (enter Insignificant, Low, Medium or High)**:**

Subrank Guidance

Minimum ranking information: to determine this Subrank, you must answer at least 4 of the 5 questions above.

Use the following scoring system: 3 points for H, 2 for M, 1 for L; 2 for Yes. Highest possible score = 13

If total score is 9-13, Subrank = High

If total score is 6-8, Subrank = Medium

If total score is 3-5, Subrank = Low

If total score is 0-2, Subrank = Insignificant

Section III: Distribution and abundance in Chitwan District

A. **Approximate number of distinct natural areas Infested in Chitwan Districts**

Choose one answer that best matches the number of sites infested:

I. 0-5%

L. 6-12%

M. 20-50%

H. Greater than 50%

B. Extent of the species in Chitwan in which it had been identified as a problem by land managers.

I. 0 to 5%

L. 6 to 20%

M. 20 to 50%

H. Greater than 50%

Potential cover of the species in strata where it occurs

I. Infrequent (less than 10%)

L. Fair coverage but less than half (10 - 50%)

M. Dominant (50 - 90%)

H. Monospecific stand (90 - 100%)

Distribution and Abundance Subrank (enter Insignificant, Low, Medium or High):

Subranking Guidance

Minimum ranking information: to determine this Subrank, you must answer A. and at least 1 other question in this section.

If H in A, and M or H in at least one other category, Subrank = High

If H in A, and L or I in all other categories, Subrank = Medium

If M in A, and H in at least one other category, Subrank = High

If M in A, and M in at least one other category, Subrank = Medium

If M in A, and L or I in all other categories, Subrank = Medium

If L in A, and H in at least one other category, Subrank = Medium

If L in A, and M in at least one other category, Subrank = Low

If I in A, and H in at least one other category, Subrank = Low
All others, Subrank = Insignificant

Section IV: Management Potential

Given the current state of knowledge regarding management methods, how difficult is it to control this species?
I. Management is not required
L. Management is relatively easy and inexpensive; requires a minor investment in human and financial resources
M. Management requires a major short-term investment of human and financial resources, or a moderate long-term investment
H. Management requires a major, long-term investment of human and financial resources

Management Subrank (enter Insignificant, Low, Medium or High):

Comments;

Section V: Overall Ranking Procedure for Plant Species.
Invasiveness Rank

The Plant Species Invasiveness Rank is a rating of the overall significance of the threat caused by this species to native species and native plant habitat in Nepal, based on the four subranks below.

Sub-ranks
I. Impact subrank: 4
II. Biology and dispersal ability subrank: 3
III. Distribution and abundance subrank: 0
IV. Management subrank: 2

Weighted average/point system

I. Impact H = 4, M = 3, L = 2, I = 0
II. Biology H = 3, M = 2, L = 1, I = 0
III. Distribution H = 1, M = 0, L = 0, I = 0
IV. Management H = 2, M = 1, L = 0, I = 0

Add up these scores to get overall Plant Species Invasiveness Rank.

Overall ranking scale:

I. Insignificant: total score = 0-3 Species represents an insignificant threat to natural communities
L. Low: total score = 4-6 Species represents low threat to natural communities
M. Medium: total score = 7-8 Species represents moderate threat to natural communities
H. High: total score = 9-10 Species represents high threat to natural communities

Examples: A species with the significance category of "I" may be exotic but poses little or no threat to natural communities. A species with the significance category of "H" poses a serious threat to native species and communities in Chitwan, Nepal

Plant Species Invasiveness Rank (Enter Insignificant, Low, Medium or High)

Annex 8: Field photos

Mikania micarantha encroaching *Dalbergia sissoo* tree (up) researcher in field (down)