ACKNOWLEDGEMENTS

This report of “Study on Invasive Alien Species (IAS) as Drivers to Deforestation and Degradation of Forests in Different Physiographic Regions of Nepal“ has been prepared as per the agreement signed between the Government of Nepal, Ministry of Forests and Soil Conservation, REDD Cell Babarmahal, Kathmandu and the consulting institution BS JV API, Baneshwor-10, Kathmandu. The consulting institution BS JV API is thankful for the opportunity given and appreciates for the valuable suggestions received from the REDD Cell officials.

This work was an outcome of systematic compilation of all relevant information and data collected during the field study as well as from the secondary sources. The study was carried out by the specialists’ team of Dr. Dinesh Raj Bhuju, Dr. Bharat Babu Shrestha and Rabin Raj Niraula. The field survey team included Sanjay Gyawali, Birat Pantha, Santosh Neupane, Janak Chhetri, Hari Neupane and Bharat Dawadi, while Manoj Chand, Birendra Shahi and Santosh Khanal assisted in data analysis. Mr Jhamak Karki (Chief Warden/CNP), Mr Yuvraj Regmi (Warden/SWR), Mr Baburam Lamichane (Conservation Officer/NTNC), and official of various buffer zone community forest users’ groups provided us with much valuable information. Rajendra Sapkota, Shiva Parsad Bhusal, Govinda Poudel, Kamal Shapkota, Suresh Sharma, Balkumal Upreti, Durdarshan Chand, Somnath Sigdel, Sanot Adhikari, Arpan Limbu, Arjun Pandey cooperated in the project conception and implementation.

We are grateful to Department of National Parks and Wildlife Reserve for giving us the permission to work in the aforementioned protected areas. We extend our sincere thanks to District Forests Office, Buffer Zone Management Committee, Community Forest Users Group, and National Trust for Nature Conservation for their support during the survey. Various Stakeholders, key informants, and beneficiary users all enthusiastically cooperated in the study of the project, and provided the necessary information sought by the study team. All of them deserve our heart-felt appreciation.

On the Behalf of:
BS JV API

SYNOPSIS

Expansion of invasive alien species (IAS) is a global problem which has impoverished native biodiversity and disrupted ecosystems from aquatic habitats, wetlands, grasslands to forested areas. Rapid expansion of IAS into forest ecosystems of Nepal in last few decades has posed a serious threat to forest health with possible impact to carbon balance. Though most of the problematic IAS in forest ecosystems have been reported in Nepal for over five decades, their impacts on forest degradation and deforestation have not been assessed at spatially large scale covering different physiographic regions. The present study was first such humble attempt to identify and assess the nature and extent of negative impacts brought by the invasion by IAS in the forests of Nepal. It included five thematic areas pertaining to IAS: distribution, intensity, trends, impacts and archive. A multidisciplinary team of experts was engaged in carrying out the study and to analyze and review the collected primary and secondary information and data

Five protected areas (PA) in the Terai and Chure range, and their adjoining forests were selected for field studies. Forests under different management regimes, viz. protected area forest lying inside the national parks and wildlife reserves, buffer zone community forests, community forests, and the government owned national forests were sampled. Depending on the availability, forests under different management regimes were sampled in the same locality; when not available, relatively far distant forest patches were also considered. Sampling was carried out by square quadrat (size: 20 m × 20 m) method; at least five sampling plots in forests of respective management regimes in each sampling area were inventoried for the species richness and cover of IAS, tree canopy cover, tree seedlings, sampling, disturbance levels, resources utilizations, etc. In total 100 plots were sampled. Focal Group Discussion with local people and stakeholders were done in all five selected sites. Land-use classification was based on field survey and LANDSAT TM images.

Altogether 13 IAS were encountered in the sampling areas. The number of IAS was generally higher in eastern and central Nepal than in the western region. *Lantana camara* was found in all the study areas, the other widely distributed species were *Ipomoea carnea* ssp. *fistulosa* and *Parthenium hysterophorus*. *Chromolaena odorata* and *Mikania micrantha* were the most frequently encountered IAS with high coverage in eastern and central part of Nepal. It was observed that both species richness and cover of IAS declined with the increasing tree canopy cover. Nearly two-third of the sampling plots had >20% cover of IAS, which mainly dominated the forest understory. IAS species richness and coverage were higher in BZCF. Results also indicated that infestation by IAS significantly affected tree regeneration which was evident by declining seedling density with increasing cover of IAS. A general perception of the local people is that IAS is in increasing trend.

It appears that the IAS invades in the degraded forests which then colonize the site gradually. **Thus, IAS seems to be the 'passengers' of deforestation and forest degradation at their early stage of colonization, which later change into 'drivers' by disrupting regeneration process.** The present study was first such effort to cover a wide range of IAS infected forests in order to know their impacts on forest regeneration and carbon stock in line with developing REDD strategy. More intensive studies will further elaborate the problem.

Minimizing the disturbance and avoiding over-exploitation of the biological resources in natural forests, enrichment plantation in shrub lands and degraded forests, community participation and awareness have been recommended as some strategies to cope with the problems of IAS infestation into forest ecosystems

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

BNP	Bardia National Park
BZCF	Buffer Zone Community Forest
CBD	Convention on Biological Diversity
CF	Community Forest
CNP	Chitwan National Park
DNPWC	Department of National Parks and Wildlife Conservation
FGD	Focus Group Discussion
GIS	Geographic Information System
GPS	Global Positioning System
IAS	Invasive Alien Species
KTWR	Koshi Tappu Wildlife Reserve
MFSC	Ministry of Forests and Soil Conservation
NA	National Forest
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NGO	Non Governmental Organization
PA	Protected Area
PWR	Parsa Wildlife Reserve
RVI	Ratio Vegetation Index
SWR	Shuklaphata Wildlife Reserve

CHAPTER ONE: INTRODUCTION

1.0 INTRODUCTION

1.1 Background

Species invasion is profoundly altering communities and ecosystem worldwide (Gurevitch and Padilla 2004). Invasive Alien Species (IAS) are species, native to one area or region, that have been introduced into an area outside their normal distribution, either by accident or on purpose, and which have colonized or invaded their new home, threatening biological diversity, ecosystems and habitats, and human well-being (CBD 1992). Recently, global warming is often credited for its expansion worldwide. The IAS has ecological and evolutionary as well as economic impacts. The ecological and evolutionary impacts include extinction of species, modification of ecosystem process (e.g. nutrient cycling, fire regime, hydrology), and evolution. For example, about 42% of the species on the threatened or endangered species list are at risk primarily due to alien species (Pimentel *et al. 2000*). The economic impacts include the direct damage to resources, and the cost of controlling IAS. The economic damage caused by IAS has been estimated to be more than US$ 138 billion per year *(*Pimentel *et al.* 2000). However, the researchers are not unanimous on the nature and mechanism of impact of IAS on communities and ecosystems (e.g. MacDougall and Turkington 2005, Russell 2012). It has been shown that in some forest ecosystems IAS are more the product than the agent of change (Rogers *et al*. 2008*).* In the context of global change, the aggressiveness of many IAS is likely to increase, with potential feedback effects to various components of global change such as carbon emission, nutrient dynamics, etc. (Dukes and Mooney 1999*).*

It is generally agreed that infestation by IAS alters community structure and ecosystem processes. A few case studies in Nepal have indicated that IAS reduces species diversity and negatively affect forest regeneration. However, an assessment of impact of IAS on forest regeneration, degradation and deforestation at large spatial scale has not been made. As an attempt to this direction, a study was undertaken to identify and assess the nature and extent of negative impacts caused due to invasion by IAS in the forests of Nepal. For this study, five protected areas (three wildlife reserves and two national parks) in the southern lowland of Nepal were selected. Field samplings were conducted in these protected areas as well in their adjoining forests. A rapid assessment comprising a combination of field sapling, focal group discussion, and mapping was conducted. Distribution and intensity of IAS in forest of different management regimes, and their role in deforestation and forest degradation with possible implication in carbon emission have been discussed.

1.2 IAS in Nepal (with special focus to forests)

High climatic and physiographic diversity make Nepal a suitable habitat for flora and fauna with a wide range of life history strategies and origin. With climate ranging from dry/moist tropical to alpine/nival region, plant and animal from any part of the world may find a suitable habitat in Nepal Most of the IAS, which are currently problematic in Nepal, entered more than 50 years back. Occurrence of *Chromolaena odorata*, one of the most widely distributed and problematic IAS in Nepal was reported as early as in 1825 while the other problematic IAS were mostly reported during 1950s and 1960s by foreign botanical explorers (Tiwari *et al.* 2005). It took several decades for IAS to build up a large population with noticeable impact to native plants and ecosystems. Tiwari *et al*. (2005) listed 166 alien plant species which accounts 2.59% of the reported 6419 flowering plant species in Nepal. Among them, 21 species have been considered important with various levels of impacts on biodiversity and ecosystems. *Ageratina* *adenophora, Chromolaena odorata, Lantana camara,* and *Mikania micrantha* are serious invasive alien plant species disrupting forests and shrub lands; *Eichhornia crassipes, Ipomoea carnea, Alternanthera philoxeroides,* and *Myriophyllum aquaticum* are important invasive seeds in wetlands and aquatic ecosystems; *Parthenium hysterophorus* is problematic in urban areas; and *Ageratum conyzoides* in agriculture lands. Alien species are more common in tropical and subtropical regions of Nepal with high species richness between 700 and 1500 m asl (BB Shrestha *et al*., unpublished data).

Ageratina adenophora and *Chromolaena odorata* are the most widely distributed IAS in forest ecosystem; these species are particularly common in degraded and secondary forests with relatively low tree canopy. In recent decades, *Mikania micrantha* has been rapidly expanding from eastern Nepal to westward in forests and wetlands of Terai and Siwalik range (Tiwari *et al.* 2005). Similarly, *Parthenium hysterophorus* has been also expanding its distribution from urban areas and grasslands to forest ecosystems including the habitats of endangered mammals (Shrestha BB 2012). It appears that richness of IAS and their abundance have been increasing in Nepal. However, a detail survey of IAS across the landscape and ecosystems to evaluate their impact on native species and ecosystem is still lacking. A few species such as *Chromolaena odorata* (Norbu 2004, Joshi *et al*. 2006), *Ageratina adenophora* (Joshi 1982, Chettri 1986), *Mikania micrantha* (Sapkota 2007, Basnet 2011, Shrestha R 2012) and *Parthenium hysterophorus* (Joshi 2005, Maharjan 2006, Karki 2009, Timsina *et al*. 2011) invading forest ecosystems have been studied to some extent in Nepal, while the remaining other species with potential significant impact on forest ecosystem have not been examined.

Chromolaena odorata is the most common IAS in forests of river valleys in the mid hills and the southern part of Nepal. . This weed was first reported (in the name of *Eupatorium acuminatum*) from Nepal by D. Don in 1825 and the first herbarium specimen was collected by JDA Stainton in 1956 (Tiwari *et al.* 2005). Human disturbances leading to reduced understory biomass and canopy opening are responsible for a successful invasion and colonization by *C. odorata* in lowland Nepal (Norbu 2004). If the forest is relieved from the disturbance and trees allowed regenerating, canopy openness decline with eventual reduction in the growth vigour and reproduction of *C. odorata*. Among the six environmental variables measured, high light intensity and grazing pressure significantly increased the cover of *C. odorata* while the other variables such as forest canopy, understory biomass, distance from road/trail and forest edge were negatively correlated with cover of *C. odorata* (Joshi *et al*. 2006). Therefore, with the regeneration of trees after forest conservation, the abundance of *C. odorata* has declined in some community managed sal (*Shorea robusta*) forests of mid hills inner Terai (pers. obs. BB Shrestha).

Mikania micrantha is an aggressive IAS colonizing relatively moist habitats such as wetlands, grasslands, shrub lands, and riverine forests. First observed in Nepal in 1963 by Japanese expedition team in the eastern part (Tiwari *et al*. 2005), the weed, it is advancing westward from eastern Nepal. The westernmost distribution range of *M. micrantha* in Nepal is Kapilvastu district (Tiwari *et al.* 2005, Siwakoti 2008). Siwakoti (2008) reported this species from the Lumbini Sacred Garden of Kapilvastu. More than half of the area of Koshi Tappu Wildlife Reserve (KTWR) has been invaded by *M. micrantha* while in the surrounding community forests in buffer zone; the abundance of *M. micrantha* is relatively low due to the periodic removal of its biomass by forest users' group (Siwakoti 2007). In Chitwan National Park (CNP), *Mikania micrantha* is common in riverine forests, mixed hardwood forests, wetlands, tall grasslands, short grasslands, and sal forest (in order of decreasing abundance of *M. micrantha*) (DNPWC 2009). This weed was present in about 44% of the assessed plots in rhino habitats. In Chiwan NP, Sapkota (2007) also reported high abundance of *M. micrantha* in natural stands of *Bombax ceiba* and plantations of *Dalbergia sissoo* with negative impact to growth of seedlings and sapling (i.e. regeneration). Invasion by this weed also altered species composition of the understory vegetation in forests (Basnet 2011).

1.3 Objective

The principle objective of the study was to identify and assess the nature and extent of negative impacts caused due to invasion by Invasive Alien Species (IAS) in the forests of Nepal. The specific objectives of this study were to:

- Assess distribution, intensity and stages of invasion of IAS (including but not limited to *Mikania micrantha* and *Chromolaena odorata*);
- Analyze the nature and extent of impact by IAS in deforestation and degradation of forests in Terai Landscape (including Siwalik and inner valleys);
- Prepare the archive of IAS photographs.

1.4 Limitations

Followings were the limitations of the present study:

- Very short period (only 10 days) available for field data collection
- Sampling intensity was too low. Therefore, the results obtained from the field sampling cannot be generalized for the entire area.
- Forests of all management regimes could not be found along single transect.
- There was fire at potential sampling sites in Bardia National Park.
- Most of the IAS were in their early stage of growth because the sampling was done during early growing season (June).

CHAPTER TWO: THEMATIC AREAS AND METHODOLOGICAL APPROACHES

2.0 THEMATIC AREAS AND METHODOLOGICAL APPROACHES

2.1 Information Gathering

Information was collected by, i) literature review of existing documents, research papers, theses, articles and other relevant documents available and ii) field survey and sampling.

2.2 Thematic Area and Methodological Approaches

For ease of data collection and analysis, the entire work has been divided into five thematic areas with specific question. Various methodological approaches were implemented to answer the questions. These approaches have been summarized in the following table.

Table 1: Thematic areas and methodological approaches for data collection and analysis

Theme	Specific question	Methodological approaches
Distribution of IAS	What is the extent of spatial distribution of major IAS (*Chromolaena odorata* and *Mikania micrantha*) in Nepal	• Use of remote sending data • Consultation of district forest officials and park authority • Review of literatures • Field sampling
Intensity of IAS	What kind of habitat has high infestation by IAS?	• Ranking of sample plots into various levels of IAS infestation based on cover: low: <20% cover, medium: 20-50%, and high: >50% (similar to one of the several criteria used by Tiwari *et al*. 2005) • Comparison of Intensity of IAS infestation in forests under different management regimes.
Trends of IAS infestation	How does the abundance of IAS change over time? Did new IAS arrive in last 10 years?	Focal group discussion with participation from • fodder collectors • shepherds • members of forest users' group • elderly people of indigenous communities • forestry field staff
Impact of IAS	How is IAS affecting regeneration of major tree species?	Count of seedlings and samplings of tree species in sapling plots; • Regression of density of seedlings and samplings on cover of IAS; • Categorization of plots into different levels of IAS infestation and comparison of seedling/sapling density among them.
Archive of IAS photographs	-	Photographs of field sampling and survey, and IAS

2.3 Study area

Field sampling was done in and around five protected areas lying in Terai and Siwalik (Chure) region (Figure 1). They are:

- Koshi Tappu Wildlife Reserve (KTWR), eastern Nepal
- Parsa Wildlife Reserve (PWR), central Nepal
- Chitwan National Park (CNP), central Nepal
- Bardia National Park (BNP), mid-western Nepal
- Shukla Phanta Wildlife Reserve (SWR), far western Nepal.

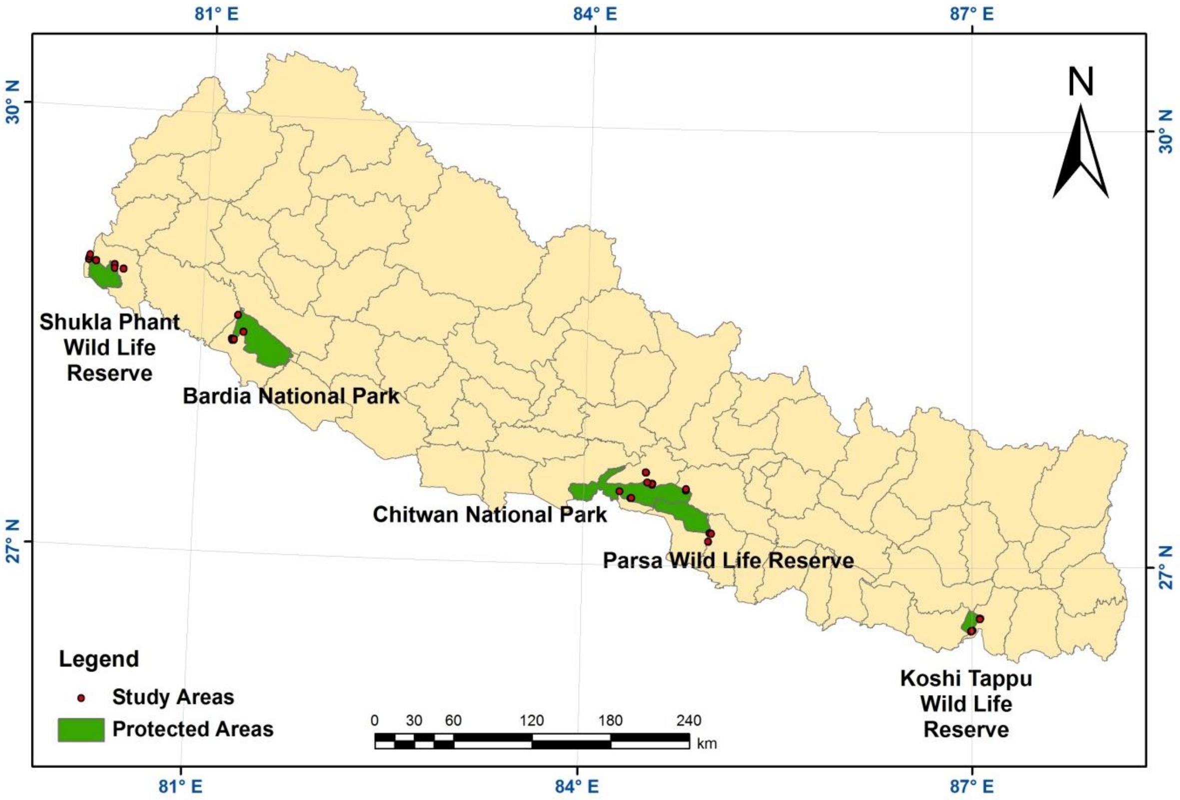

Figure 1: Protected Areas where study was conducted.

Each red dot indicates sampling point. Due to size of the map, there has been overlapping of these points.

Sampling was carried out in the forests of four major management regimes depending on the availability of the forests adjoining to the protected areas. There are:

- Protected area forests: forests inside the core protected areas such as wildlife reserves and national parks.
- Buffer zone community forests: forests managed by community in the buffer zone area of each protected area. All five protected areas (listed above) considered in this study have buffer zone community forests.
- Community forests: national forests managed by the community.
- State-owned (government) forests: Forests under the management of the Department of Forest.

2.4 Site Selection and Field Sampling

A general approach sampling was to get field information from the forests under different management regimes covering two opposite sides, north-south or east -west of the protected areas. Information pertaining to management regime of the forests was obtained from park/wildlife reserve authorities and the local people. Where possible, forests of different management regimes were sampled in the same locality. Otherwise, forests located at relatively far distance were sampled. For example, on the northern part of Chitwan National Park, protected area and buffer zone community forests were sampled at Sauraha area but the national forest was sampled at Barandabhar area. In forests of each management regime, at least five sample plots (20 m × 20 m) were located subjectively in the areas were IAS was relatively common. The sample plots were located at the interval of horizontal distance of 100 to 200 m along an imaginary transect passing along the length of the respective forest. There were altogether one hundred such plots. The sampling intensity in different study sites has been presented in Appendix I. The field data sheet used during the sampling has been attached in Appendix II. Following stand characteristics were noted in each sample plot:

- Invasive alien species (using checklist from Tiwari *et al*. 2005; Appendix III);
- Cover and maximum height of each IAS;
- Tree canopy cover (%);
- Number of stump;
- Grazing (in the scale of 0 to 3);
- Trampling (in the scale of 0 to 3);
- Lopping (in the scale of 0-3);
- Exposed soil surface (%);
- Geographic location (latitude, longitude and elevation).

For the assessment of tree regeneration, a 5 m × 5 m sub-plot was sampled inside each large plot. One of the four corners of the large plot was selected randomly (by lucky draw) and single 5 m × 5 m plot was delineated inside. The number of seedlings (height <137 cm) and saplings (height >137 cm, diameter at breast height <10 cm) of each tree species were recorded. This data was used to calculate total density of tree seedlings and samplings.

2.5 Field Data Analysis

Ecological attributes derived from the field sampling were analyzed by using statistical tools to make the results more reliable. Variation of species richness (number of IAS species/plot) and cover (%) of IAS with tree canopy cover (%, measured as the surrogate of level of forest degradation; lower the tree canopy higher is the forest degradation) was analyzed by linear regression. Impact of IAS cover on density of tree seedlings and samplings was also assessed by linear regression. Species richness and cover of IAS were compared among forests under different management regimes using one way analysis of variance (ANOVA). All these statistical analyses were done using Statistical Package for Social Sciences (SPSS, version 16.1). In addition to above analyses, the sample plots were categorized into three levels of IAS infestations based on cover of IAS: high with IAS cover >50%, medium >20 to 50% and low <20%. This categorization has been used earlier by Tiwari *et al.* (2005). The frequency of occurrence of IAS was calculated for different management regimes as observed in the sites using the following formula:

$$\text{Frequency (F) (\%)} = \frac{\text{No. of plots with individual IAS} \times 100}{\text{Total no. of plots studied}}$$

2.6 Focal Group Discussion (FGD)

Community level

To understand perception of local people on distribution, impact, and control measures of IAS, there were two FGDs for each study site. The participants in the FGD were fodder collectors, shepherds, members of forest users' group and elderly people of indigenous communities. The focal group discussion dwelled on the following areas:

- History of IAS infestation
- Trend of infestation (increasing/decreasing/no change over decades)
- Impact on plant/forest health
- Use of the IAS by local people (medicinal, fodder, firewood, etc.)
- Controlling measures adopted by local people
- Management of the IAS

Other stake holders

One FGD was organized for other stakeholders representing forestry field staffs, park authorities, game scout, local NGOs working on biodiversity conservation and management. Same issues listed for community level FGD were covered in this discussion too. List of individuals who were consulted during the study has been attached in Appendix IV.

2.7 GIS Analysis for understanding spatial distribution of IAS

GPS survey

GPS survey was carried out to locate IAS during the vegetation sampling and observations. At each study area 20-30 GPS locations were recorded with high coverage of IAS which was fully exposed to ensure accurate signatures for classification of satellite images.

Landcover mapping of Study Areas:

Spatial distribution of IAS can be affected by various factors which may not be accommodated by the scope of this study. To put light upon the spatial distribution and its status based on the study sites, this study has used Landcover mapping for the study areas where Landcover classifications are based on the training samples collected during field survey and triangulated with Google earth for extensive sample collections (Table 2).

Landcover classification enhanced the information of spatial distribution of IAS that occurred in different vegetation classes. This related the status of IAS with the Landcover class or vegetation though it was limited in the study sites and could not be interpolated for the whole areas.

Table 2: Data sources

Type	Database	Resolution	Source
LANDSAT TM	Landsat TM	30m	Landsat Archive, 2010
Google Earth Image	Geoeye, Spot, Digital globe	0.5m	Google, 2012

LANDSAT TM images from USGS LANDSAT archive for the date of 2010 March and April were acquired. Further these images were used to obtain subset of images for study areas. Landcover classification was done based on field survey and Google earth imagery for verification.

Field Survey

Also, field based data were acquired by a Global Positioning System (GPS) survey in the study areas. Such survey generated data for validation as well as verification of the results. Also camera photography was applied to collect real world scenario from the field.

Methods

ArcGIS 9.3 and ENVI 4.7 were major computer softwares applied for the GIS and Remote sensing based application. Object based image analysis was applied to obtain the classification. Unlike the conventional pixel-based methods which only use pixel values, the object-based techniques can not only use the spectral feature but also texture information, neighborhood information, context information, and other related ancillary data to gain higher accuracy of land cover mapping (Bajracharya and Uddin, 2010). Development of methodology was largely based on trial of image scene, spectral characteristics, changing pattern of spectral characteristics from tiles to tiles and size of subset area.

Segmentation

The study area imageries were masked for the area of interest which needs segmentation action that generates an object level either quadtree or the multiresolution segmentation. The multi-resolution segmentation, which generates objects resembling ground features very closely, was used for this study. As a first step, the software links pixels to produce image objects by extracting homogeneous areas. The outcome of the segmentation is dependent on several parameters, such as scale, colour, shape, compactness and image layer weights. These parameters are defined manually by the user. The scale parameter determines the maximum allowable heterogeneity for the resulting image objects and, consequently, their size.

Indices

After performing segmentation, specific rule sets are developed so as to classify the images. This was performed by using spectral values of all available layers as well as customized object features of different indices were developed.
The major indices used in the study are as follows:

1. **Normalized Difference Vegetation Index (NDVI) :**

The NDVI is one of the oldest, most well known and most frequently used vegetation index. NDVI is defined by following equation:

NDVI = (Near Infrared Band – Red Band) / (Near Infrared Band + Red Band)

2. **Normalized Difference Water Index (NDWI)**

NDWI is the water index based on the Near Infrared Band and the Green Band.
NDWI is defined by following equation:

NDWI = [1- (Near Infrared Band / Green Band)] /[1+ (Near Infrared Band/ Green Band)

3. Ratio Vegetation Index (RVI)

RVI uses simple proportion of Near Infrared band and Red band to be used as index.
RVI is defined by following equation:
RVI = Near Infrared Band / Red Band
(Sources for all indices information: ENVI online help user guide and landscapetoolbox.org)

Classification

Landcover classification consists of 8 different classes as: Bare, Bushes/Grassland, Water bodies, Dense forest, Sparse forest, Open forest, cultivation and settlement. Rules for each class were developed according to its feature characteristics. Forest was categorized into 3 different classes based on difference in vegetation structure and texture observed in satellite images. This can be further explained according to observation from field survey as: Dense forest includes land covered by forest with more than 40% observed canopy cover. Sparse forest includes land covered by forest with less than 40% observed canopy cover. Open forest includes land covered by shrubs and trees that resembles dense forest in satellite images/ Google images due to dense vegetation cover.

Mosaicking

Classified results were exported as Erdas imagine file and were processed for mosaicking of all classified tiles. Then the mosaicked layer was analyzed in ArcGIS 9.3 for different classes, features and attributes. Mosaicking was preferred in the final classified results so that data handling was easy and manageable.

Exporting Results

Classified Images were exported as Raster for preparation of Layouts and the landcover maps. Evaluation of Landcover areas was not in line with the selection of sampling sites, so the area table is not presented.

The method for the classification can be illustrated as follows (Figure 2):

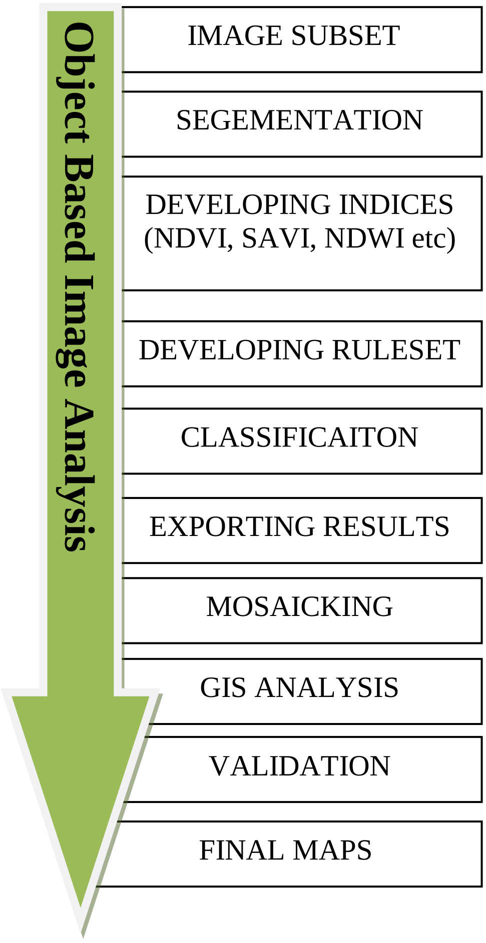

Figure 2: Method of Land cover Classification

Land cover classification consists of eight different classes, *viz*. Bare, Bushes/Grassland, Water bodies, Forest, Forest-2, Forest-3, cultivation and settlement. Forest was categorized into three different classes based on difference in vegetation structure and texture observed in satellite images. This can be further merged or reclassified according to observed distribution of IAS in field survey.

CHAPTER THREE: RESULTS AND DISCUSSIONS

3.0 RESULTS AND DISCUSSION

3.1 Distribution of Invasive Alien Species (IAS)

Altogether 13 invasive alien species (IAS) were encountered in the sampling areas (Table 3). The number of IAS was generally higher in sampling areas of eastern and central Nepal than in western. Among the IAS observed in the study areas, *Lantana camara* was found in all the study areas; it had the highest cover in community forests in and outside the buffer zone of Shuklaphanta WR. Other species with wide distribution from east Nepal to west were *Ipomoea carnea* ssp. *fistulosa* and *Parthenium hysterophorus*. *Chromolaena odorata* and *Mikania micrantha* were the most frequently encountered IAS with high coverage in eastern and central part of Nepal. *C. odorata* had the highest cover in all the forests sampled in Parsa WR and the adjoining area. Koshi Tappu WR and Chitwan NP had the highest cover of *Mikania micrantha* in forests of both protected area and buffer zone. High cover of *M. micrantha* in these two areas might be due to high proportion of wetlands and other moist habitats which are the suitable habitats for this weed

Table 3: Average cover (%) of IAS in sampling plots under various management regimes.

Note: P – Protected area forest, B – Buffer zone community forests, C – Community forests, and N – National (state owned) forests.

SN	Name of IAS	KTWR		PWR			CNP			BNP		SWR		
		PA	BZCF	PA	BZCF	NF	PA	BZCF	NF	PA	BZCF	PA	BZCF	CF
1	*Ageratina adenophora*	-	-	3	-	-	1	3	-	-	-	-	-	-
2	*Ageratum conyzoides*	-	-	-	2	-	-	2	-	12	55	6	-	9
3	*Bidens pilosa*	-	-	1	-	-	-	-	-	-	-	-	-	
4	*Cassia occidentalis*	25	3	-	-	-	-	-	-	-	-	-	-	-
5	*Cassia tora*	-	2	-	-	-	-	-	-	-	-	-	-	-
6	*Chromolaena dordata*	9	19	27	21	22	3	12	24	-	-	-	-	-
7	*Eichhornia crassipes*	-	-	-	-	-	-	-	-	1	-	-	-	-
8	*Ipomoea carnea* ssp.	6	4	-	-	-	-	-	-	-	-	3	2	10
9	*Lantana camara*	11	15	4	5	-	11	7	-	5	-	-	20	-
10	*Mikania micrantha*	39	31	9	1	-	32	49	-	-	-	-	-	-
11	*Mimosa pudica*	3	-	-	-	-	-	1	-	-	-	-	-	-
12	*Parthenium*	2	5	-	-	-	7	1	-	3	-	1	-	-
13	*Xanthium strumarium*	-	-	-	8	-	-	-	-	-	-	-	-	-
Total number of species		7	8	5	5	1	5	7	1	5	1	3	2	3

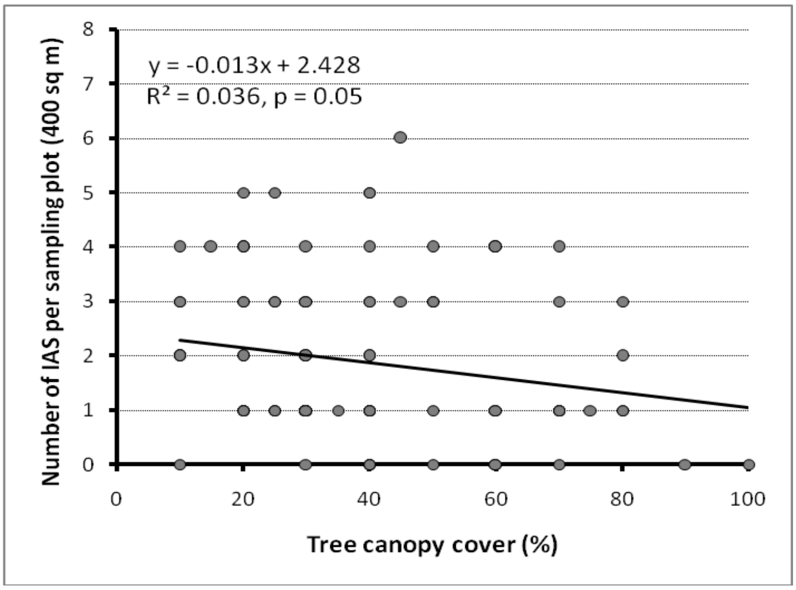

Figure 3: Variation of species richness of IAS with tree canopy cover.

Each point in the figure represents a sample plot and the total number of sample plots was 100. Less number of points in the figure is due to overlapping of the data among the plots. The fitted line is based on the linear regression.

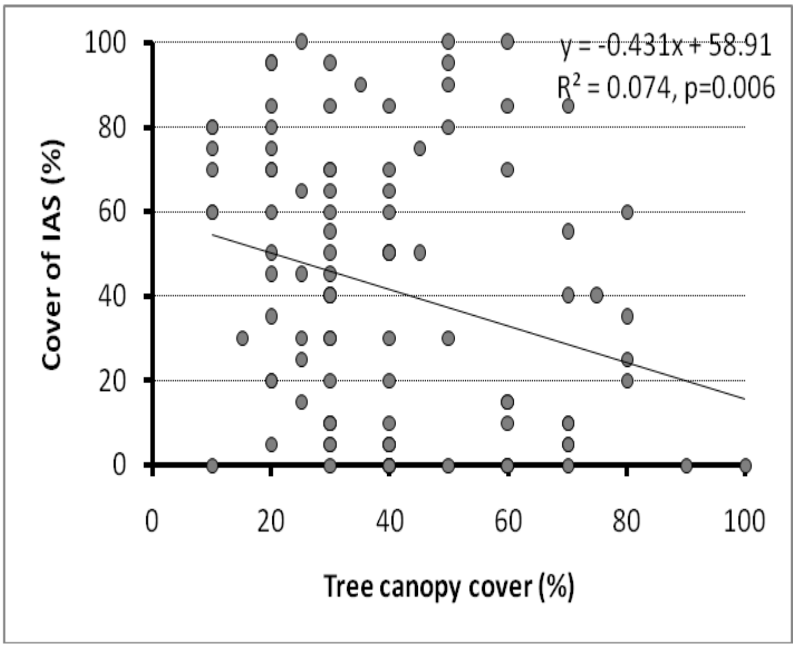

Figure 4: Variation of cover of IAS with tree canopy cover.

Each point in the figure represents a sample plot and the total number of sample plots was 100. Less number of points in the figure is due to overlapping of the data among the plots. The fitted line is based on the linear regression.

With the increasing tree canopy cover both species richness and cover of IAS declined (Figure 3 and 4). Often the invasive species are ruderal and require direct light for growth and reproduction. In forests, the tree canopy determine the amount of light available on the ground surface. High tree canopy cover means low availability of light on the ground surface which is less favorable for the growth of most of the invasive alien species. For example, abundance and reproductive efficiency of *Chromolaena odorata* is high in those micro habitats where canopy is open and light intensity is high (Norbu 2004, Joshi *et al*. 2006). Present data and earlier reports thus indicates that maintaining high tree canopy and/or understory vegetation of native species can be an effective approach to minimize the infestation and colonization by IAS in forest ecosystems. In degraded forests, where canopy closure by natural process could be much delayed, enrichment plantation of native tree species can be accomplished to speed up the canopy closure.

3.2 Intensity of Infestation by IAS

Intensity of IAS infestation measured as cumulative cover of all IAS showed a wide range of variation; 36% of total plots sampled had high infestation (cover>50%), 26% medium (cover 20-50%) and 38% low (cover<20%). Since the field sampling was done during early growing season (June), the IAS cover did not reach to the peak. Even then, nearly 2/3rd of the sampling plots had >20% cover. It indicates that IAS is a dominant component of forest understory vegetation. Infestation was higher in forests of protected areas and buffer zone of Koshi Tappu WR and Chitwan NP than in forest of other areas studied (Table 4). This could be due to rapid expansion of *Mikania micrantha* in recent decades in these two protected areas. In Chitwan NP, the abundance of *M. micrantha* was high towards northern part of the Park, particularly in moist habitats along forest edges, riverine forests and grasslands (DNPWC 2009).

Table 4: Percentage of sampling plots belonging to various levels of IAS infestation.

Percentage of sampling plots belonging to various levels of IAS infestation.
The level of IAS infestation was based on the cover if IAS; high: >50% cover of IAS in the sampling plot, medium: >20 to 50%, low: <20%.

Study site	Management regime	Level of IAS infestation		
		High	Medium	Low
Koshi Tappu WR	Protected area forests	85	15	-
	Buffer zone community forests	100	-	-
Parsa WR	Protected area forests	40	20	40
	Buffer zone community forests	20	60	20
	National forest	-	60	40
Chitwan NP	Protected area forests	71	14.5	14.5
	Buffer zone community forests	70	20	10
	National forest	-	60	40
Bardia NP	Protected area forests	-	20	80
	Buffer zone community forests	40	30	30
Shuklaphanta WR	Protected area forests	-	20	80
	Buffer zone community forests	-	20	80
	Community forest	40	-	60

Species richness (i.e. number of IAS per sampling plot) and cover (%) of IAS were the highest in the buffer zone community forests, followed by the forests in the protected areas. The difference was particularly significant in Chitwan and Bardia NP and their adjoining areas. High anthropogenic activities in the buffer zone areas in the form of tourism and resource utilization by local residents (e.g. grazing, vehicle movements) might be responsible for high intensity of IAS in forests of buffer zone. However, species richness and cover of IAS did not differed among forest of different management regimes when data for all study areas were combined together (Table 5 and 6). This indicates that even the forests inside the protected areas are colonized by invasive species as equally as the forests outside it, and the management strategies of the protected areas had not effectively addressed the expansion of IAS. Among the study areas, both species richness and cover of IAS were the highest in forests of Koshi Tappu WR and its buffer zone.

Table 5: Species richness of IAS (Number of IAS/400 m2) various management regimes.

Mean values were compared by one way analysis of variance (ANOVA).

SN	Study area	Protected area*	Buffer zone Community Forest	Community forest	National Forest	Significance level (p)
1	Koshi Tappu WR and adjoining area	3.4 ± 1.4	3.8 ± 0.8	NA	NA	0.51
2	Parsa WR and adjoining area	2.0 ± 1.3	2.4 ± 1.5	NA	1.0 ± 0.0	0.19
3	Chitwan NP and adjoining area	2.4b ± 1.5	3.3b ± 1.0	NA	1.0a ± 0.0	**0.005**
4	Bardia NP and adjoining area	0.4 ± 0.7	1.1 ± 0.3	NA	NA	**0.01**
5	Suklaphanta WR and adjoining area	0.7 ± 0.9	1.0 ± 0.0	1.4 ± 0.5	NA	0.17
All sites combined		1.8 ± 1.6	2.3 ± 1.4	1.4 ± 0.5	1.0 ± 0.0	**0.07**

*It refers to the core area of respective national park and wildlife reserve.
Note: NA – data not available. Mean values were compared by one way analysis of variance (ANOVA).

Table 6: Cover of IAS (%) in forest of various management regimes.

Mean values were compared by one way analysis of variance (ANOVA).

SN	Study area	Protected area*	Buffer zone Community Forest	Community forest	National Forest	Significance level (p)
1	Koshi Tappu WR and adjoining area	72 ± 16	74 ± 11	NA	NA	0.76
2	Parsa WR and adjoining area	40 ±28	27±18	NA	21±13	0.33
3	Chitwan NP and adjoining area	61 ± 37	70 ± 32	NA	28 ± 13	0.07
4	Bardia NP and adjoining area	8 ± 15	46 ± 27	NA	NA	**0.001**
5	Suklaphanta WR and adjoining area	11 ± 18	20 ± 17	36 ± 32	NA	0.16
All sites combined		39 ± 35	52 ± 31	36 ± 32	25 ± 13	0.07

*It refers to the core area of respective national park and wildlife reserve. Note: NA – data not available.

3.3 Trends of IAS infestation

A general perception of the people who participated in the FGD was that majority of the IAS such as *Ipomoea carnea* ssp*. fistulosa*, *Lantana camara* and *Parthenium hysterophorus* have been increasing in their abundance and distribution range, while few others such as species of *Cassia tora* and *C. occidentalis* remained constant in abundance over the recent decade (Table 7). One of the noteworthy observations was that abundance of *Mikania micrantha* and *Chromolaena odorata* was declining in comunity managed buffer zone forest at Chitwan (i.e. Kurose BZCF).

Table 7:People's perception on the trend of IAS infestation on different management regime.

Species	CNP			KTWR		BNP		PWR			SWR		
	PA	BZCF	NF	PA	BZCF	PA	BZCF	PA	BZCF	NF	PA	BZCF	CF
Ageratina adenophora	I	C											
Ageratum conyzoides		C				I					I		I
Bidens pilosa													
Cassia occidentalis				C	C			C	C				
Cassia tora					C	C			C				
Chromolaena odordata	c	I	I		I	I		C	I				
Eicchornia crassipes						I							
Ipomoea carnea ssp. fistulosa				I	I			I	I		I	I	I
Lantena camara	I	I		I	I	I		I	I			I	I
Mikania micrantha	I	D		I	I			I	I				
Mimosa Pudica		C		C	I			C	I				
Parthenium hysterophorus	I	I		I	I	I		C	I		I		
Xanthium strumarium									C				

Note: I – IAS increasing/expanding, D – decreasing in abundance, C – remained constant for in recent times

According to the local pemanual removal of these weeds and tree plantation in the shrub land were responsible for that decline. Earlier the scrubland was dominated by IAS but the growth of tree after plantation reduced the light availability to understory vegetation which is generally unfavorable for growth of the invasive species such as *M. micrantha* and *C. odorata.*

3.4 Impact of Infestation by IAS

Tree regeneration is affected by the abundance of IAS. Seedling density declined with increasing cover of IAS (Figure 5 and 6). Dense growth of IAS modifies the micro-habitat in such a way that it becomes hostile for seed germination and seedling growth. Besides changing physical environmental conditions, the invasive species also release certain secondary metabolites (i.e. allelochemical) that make the chemical environment of soil unsuitable for germination of other species (Inderjit *et al.* 2008). Density of tree saplings, however, was not affected significantly by cover of IAS (linear regression, p=0.286) in the present sampling areas. It appears that growth of seedling into sampling is critical for tree regeneration under the influence of invasive species. Once the individual grows to sapling, the effect of invasive species would be insignificant.

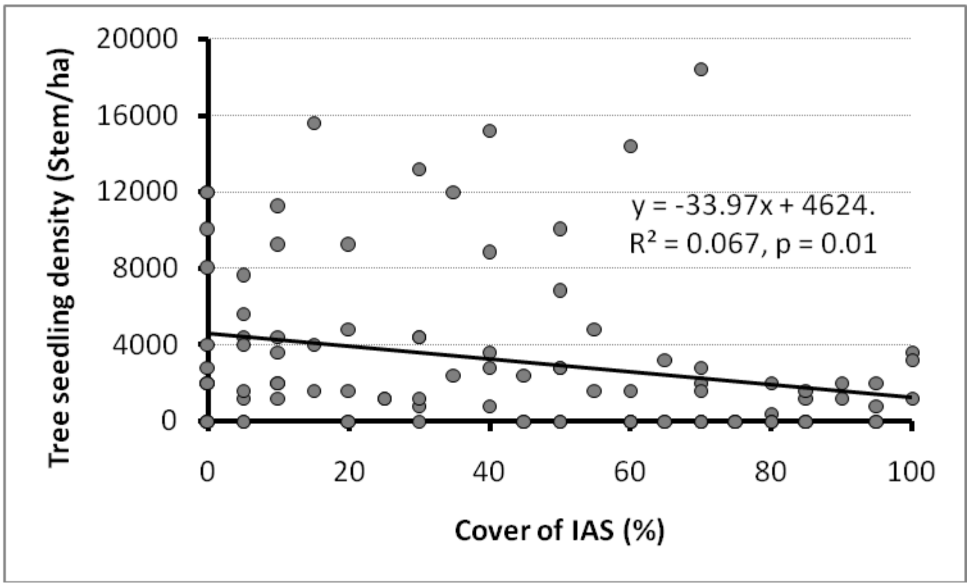

Figure 5: Decline in seedling density of tree species with increasing cover of IAS.

Each point in the figure represents a sample plot and the total number of sample plots was 100. Less number of points in the figure is due to overlapping of the data among the plots. The fitted line is based on the linear regression.

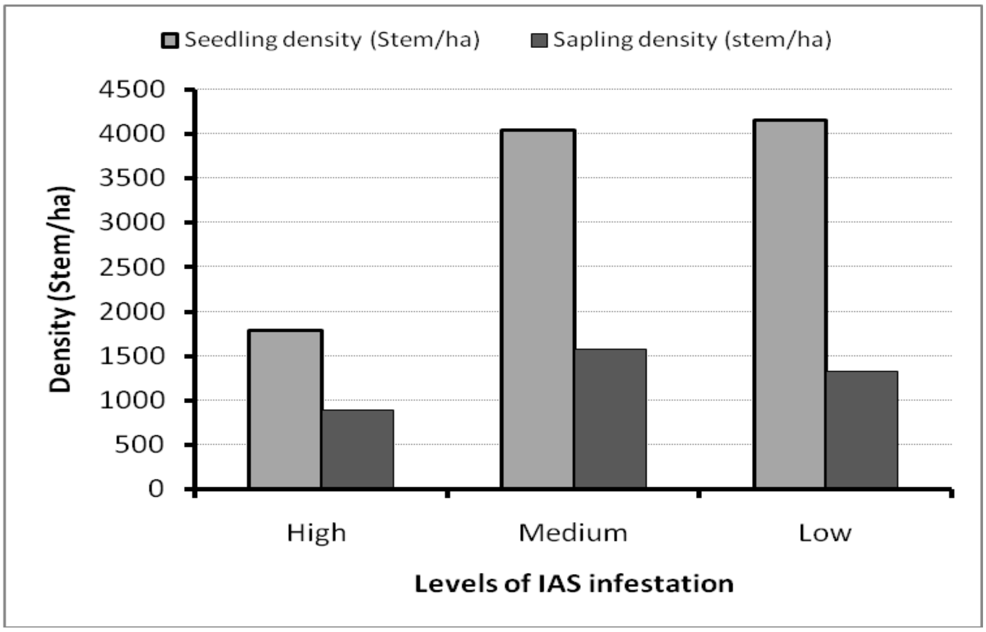

Figure 6: Density of tree seedlings and samplings in plots of different levels of IAS infestation

When plot of different levels of IAS infestation were compared, density of both tree seedling and sapling were lowest in the plots having the highest level of IAS infestation (Figure 6). Both these results indicate that infestation by IAS significantly affects tree regeneration. The situation could be more extreme if the forests infested by IAS are also subjected to other kind of anthropogenic disturbances such as grazing, logging, etc.

3.5 Role of IAS in Deforestation and Forest Degradation

Old-growth primary forests with intact canopy are less susceptible to infestation by IAS. However, even the protected areas such as the national parks are subjected to significant anthropogenic disturbances. Any kind of disturbance that increases resources supply or periodically fluctuate resources supply increases susceptibility of community to infestation (Davis *et al*. 2000). In the context of rapid population increase in Terai landscape of Nepal, most of the forests areas including those inside the protected areas have been exposed to varying levels of anthropogenic disturbance, and thus they are susceptible to infestation by IAS. When disturbances coincide with the arrival of propagules of IAS, they can easily colonize the niche and alter community structure and disrupt ecosystem process. In forests, reduced regeneration of tree species, as evident by low seedling and sapling density, is the most prominent impact of IAS. Therefore, IAS further deteriorates the already degraded forests and prevent from natural regeneration. In other words, IAS are the 'passengers' of deforestation and forest degradation at their early stage of colonization, which later change into 'drivers' by disrupting regeneration process.

3.6 Archives of IAS photographs

Photographs of individual IAS and the habitats they colonized have been taken during the field sampling to prepare an archive of IAS. Short description of 13 IAS encountered in the study area with their selected photographs have been present in Appendix VI.

3.7 Spatial Distribution of Invasive Alien Species

This study on spatial distribution of IAS covers the selected sites of KTWR, PWR, CNP, BNP and SWR, where the presence of IAS was observed during field survey. To locate the IAS, land-cover maps with different types of vegetation were overlapped with GPS positions where the spatial distribution of IAS was observed and their coverage intensity (low, moderate or high) was determined.

Table 8: Frequency of different IAS in the sampling areas..

SN	Name of IAS	KTWR		PWR			CNP			BNP		SWR		
		PA	BZCF	PA	BZCF	NF	PA	BZCF	NF	PA	BZCF	PA	BZCF	CF
1	*Ageratina adenophora*	-	-	20	-	-	20	63	-	-	-	-	-	-
2	*Ageratum conyzoides*	-	-	-	40	-	-	56	-	100	100	80	-	80
3	*Bidens pilosa*	-	-	40	-	-	-	-	-	-	-	-	-	
4	*Cassia occidentalis*	40	40	-	-	-	-	-	-	-	-	-	-	-
5	*Cassia tora*	-	40	-	-	-	-	-	-	-	-	-	-	-
6	*Chromolaena odordata*	69	80	100	100	100	20	67	100	-	-	-	-	-
7	*Eichhornia crassipes*	-	-	-	-	-	-	-	-	20	-	-	-	-
8	*Ipomoea carnea* ssp. *fistulosa*	20	40	-	-	-	-	-	-	-	-	20	20	60
9	*Lantana camara*	85	80	60	60	-	80	88	-	20	-	-	80	-
10	*Mikania micrantha*	100	100	80	20	-	80	83	-	-	-	-	-	-
11	*Mimosa pudica*	80	-	-	-	-	-	17	-	-	-	-	-	-
12	*Parthenium hysterophorus*	20	20	-	-	-	40	25	-	20	-	20	-	-
13	*Xanthium strumarium*	-	-	-	20	-	-	-	-	-	-	-	-	-

Note: PA – Protected area forest; BZCF – Buffer zone community forest; CF – Community managed forest; NF - National (state owned) forest

Table 8 presents the list of IAS and their frequency of occurrence (%) recorded during the field survey in selected five PA sites representing Siwalik (Chure) and lowland Terai regions of Nepal. Among the 13 IAS recorded, *Lantana camara* was found in all five study sites KTWR, PWR, CNP, BNP and SWR, while *Chromolaena odordata* was recorded in all management regimes of three sites, KTWR, PWR and CNP. The highly notorious IAS, *Mikania micrantha* was observed in three survey sites, KTWR, PWR and CNP. Similarly, the frequency of occurrence of *Ageratum conyzoides* was high in BNP and SWR. By management regime, the frequency of occurrence of IAS was observed high in the buffer zone forests than in the protected area forests. Thus, the central and eastern parts of Nepal seem to have high infestation by IAS with comparison to the western parts. However, it should be noted that the survey was conducted in pre-monsoon. More surveys covering post monsoon may give better picture of the IAS occurrence and their distribution.

Landcover classification maps were prepared for understanding IAS coverage and their spatial distribution. In the map, the intensity coverage of IAS is illustrated in three categories, *viz*. low (<25%), moderate (25%-60%) and high (>60%). In the map, the low intensity is seen in green circle, while moderate in yellow and high intensity in red . When observed at survey site level, KTWR contained 16 high intensity IAS cover and two moderate (Figure 7), while PWR contained five high, eight moderate and seven low (Figure 8). Similarly, CNP contained 12 high, six moderate and four low (Figure 9), BNP contained four high, five moderate and 11 low (Figure 10), and SWR contained two high, three moderate and 15 low (Figure 11).

As observed in the maps, high intensity of IAS occurrence was found in 39 sites (out of 100 sampling sites), while moderate intensity was found in 24 sites. Among these 39 high intensity sites, the central (CNP and PWR) and eastern (KTWR) sites presented 84% of the total. This suggests for priority intervention in central and eastern parts of Nepal.

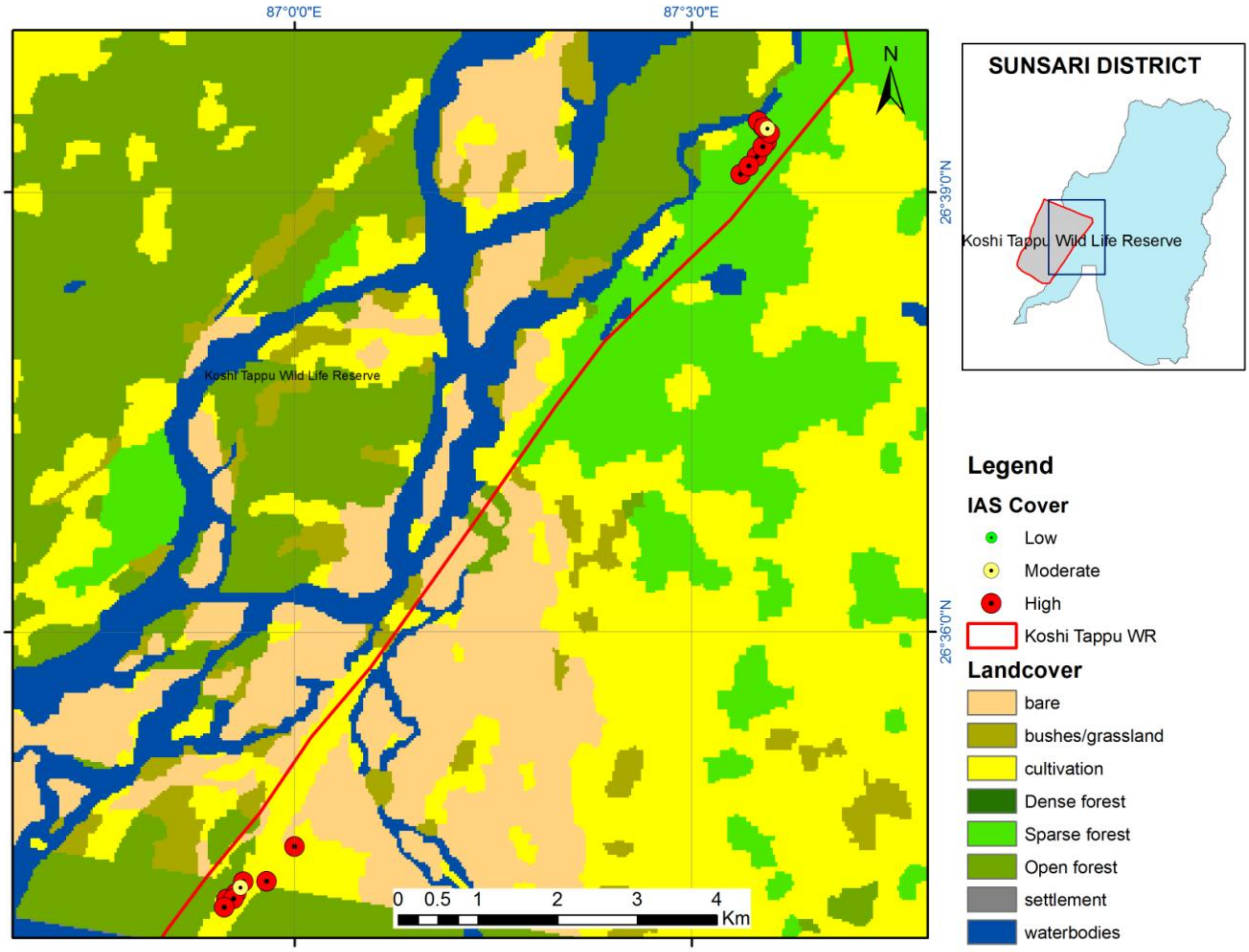

Figure 7: Landcover map of Koshi Tappu WR and study areas with IAS cover

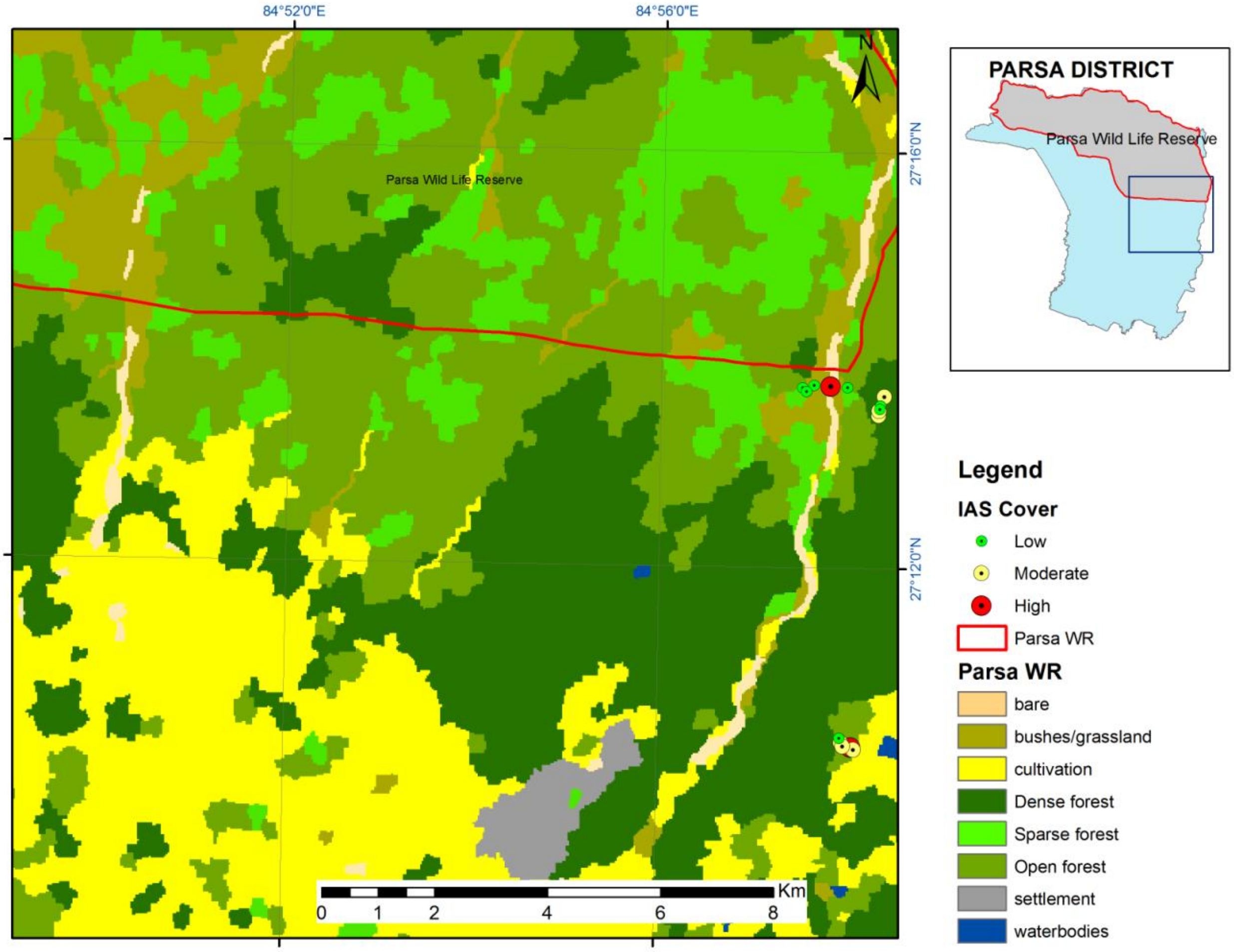

Figure 8: Landcover map of Parsa WR and study areas with IAS cover

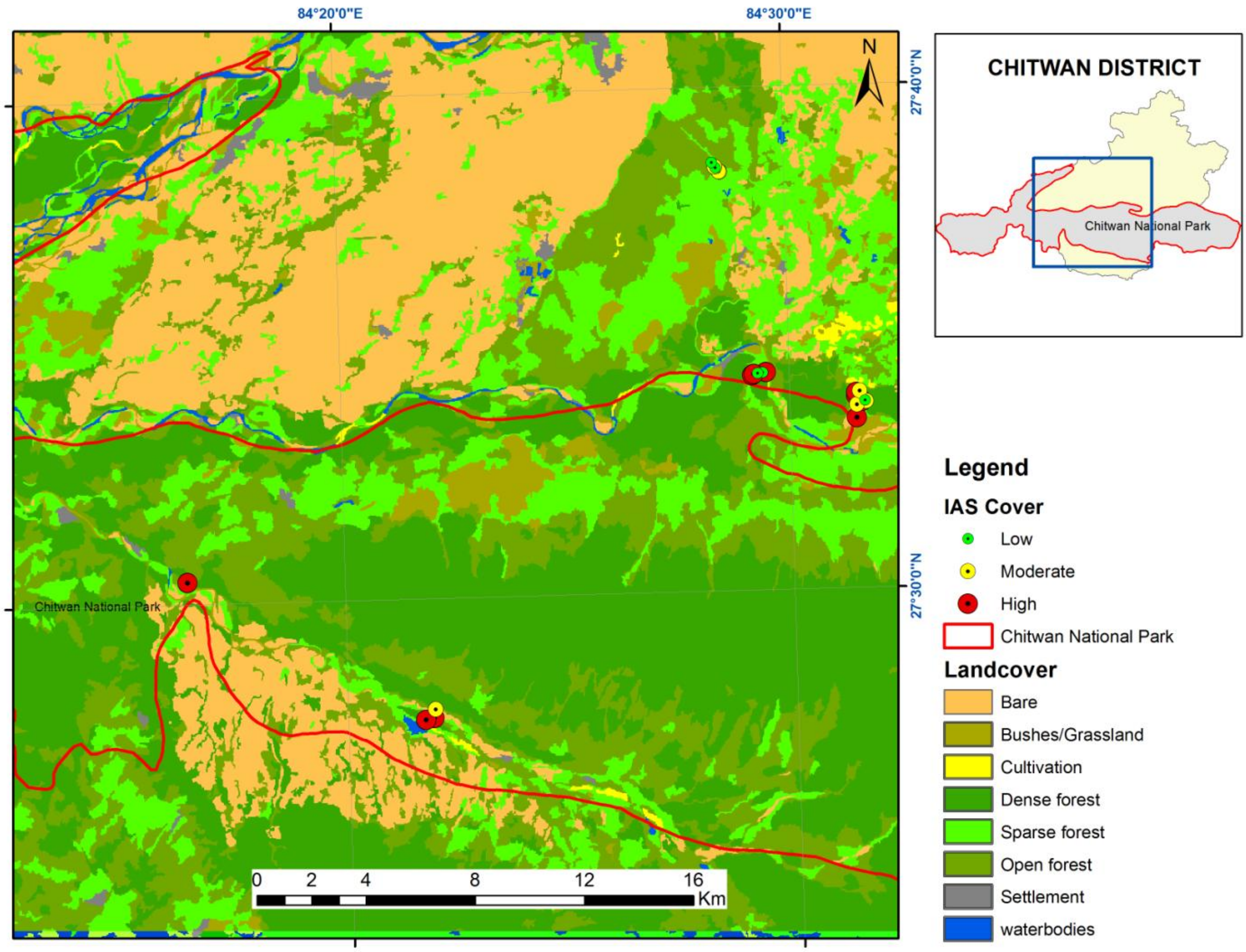

Figure 9: Landcover map of Chitwan NP and study areas with IAS cover

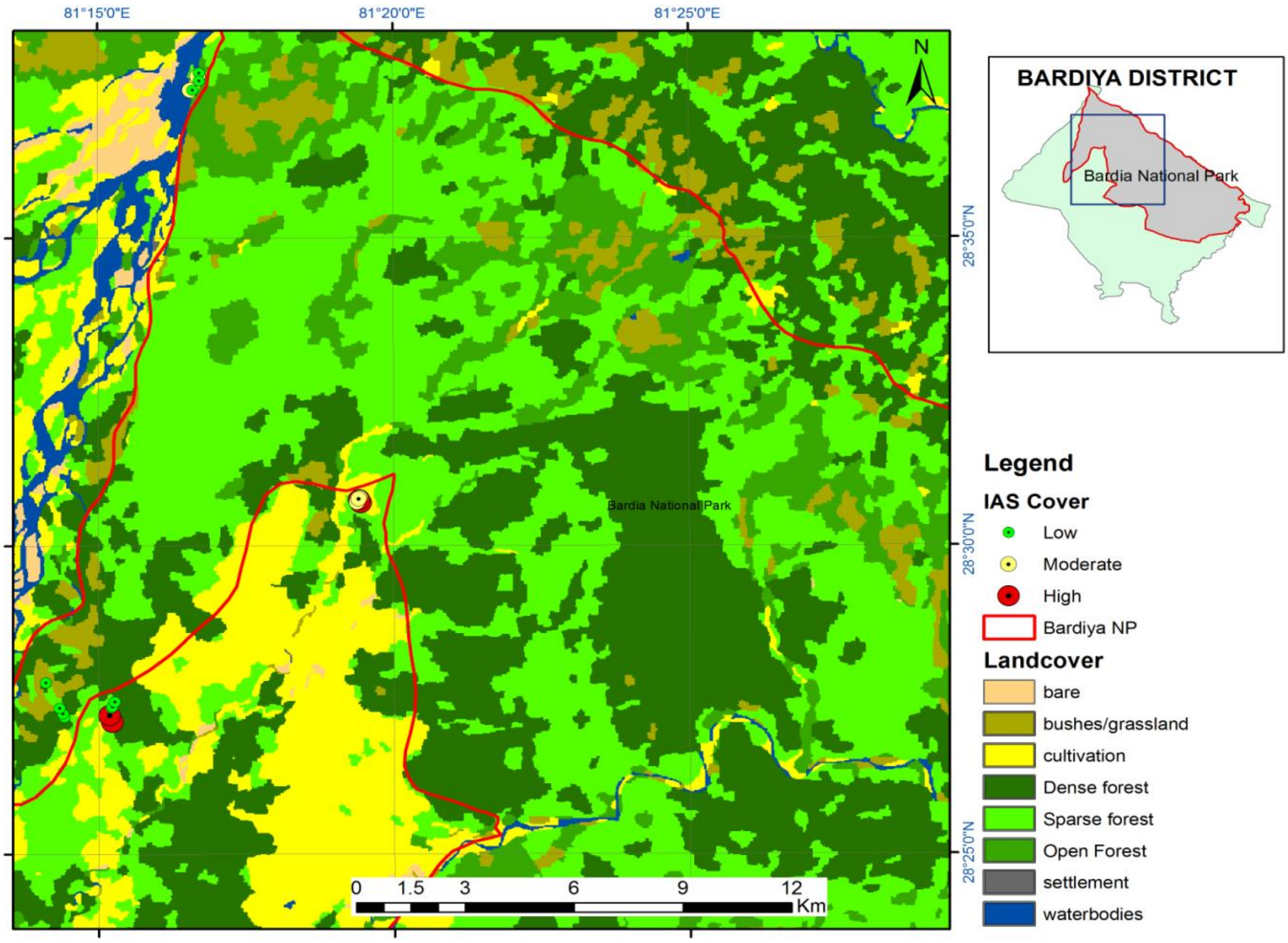

Figure 10: Landcover map of Bardia NP and study areas with IAS cover

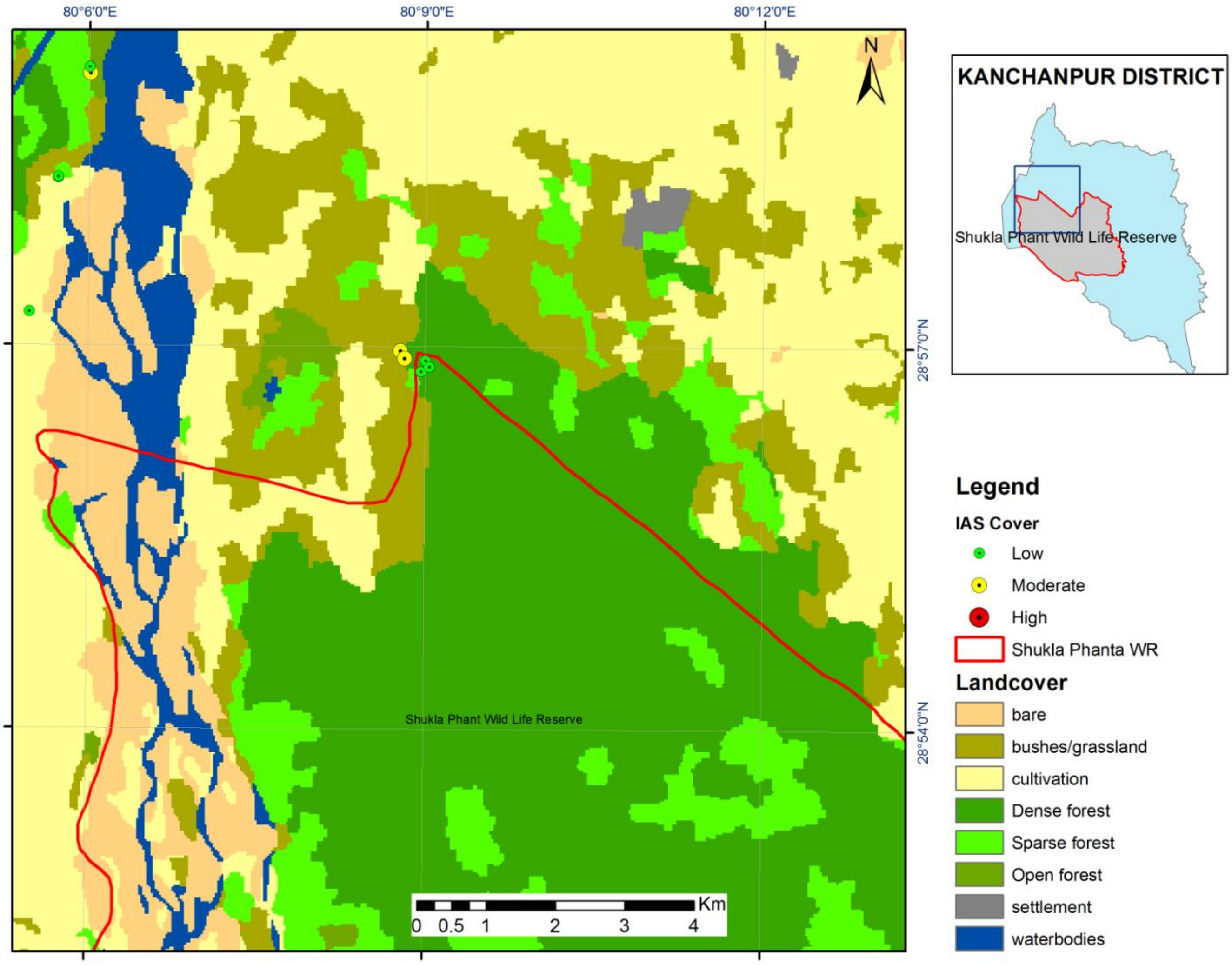

Figure 11: Landcover map of Shukla Phanta WR and study areas with IAS cover

CHAPTER FOUR: CONCLUSIONS AND RECOMMENDATIONS

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Following conclusions have been drawn from the study:

- Among the 13 IAS found in the forests of Terai landscape, *Chromolaena odorata, Mikania micrantha, Lantana camara, Ipomoea carnea* ssp*. fistulosa* and *Parthenium hysterophorus* were the most common and problematic species.
- The central and eastern parts of Nepal seem to have high infestation by IAS with comparison to the western parts.
- Species richness of IAS and their cover declined with increasing canopy cover of the trees
- Most of the sample plots (nearly 2/3rd of the total) had >20% cover of IAS in understory vegetation.
- The results also indicated that the IAS infestation was high in the central and eastern parts of Nepal. Abundance of IAS (species richness and cover) was the highest in buffer zone community forests, followed by the forests in protected areas. However, the difference was only marginal.
- **The IAS are the 'passengers' of deforestation and forest degradation at their early stage of colonization, which later change into 'drivers' by disrupting regeneration process.**
- Community participation can be a key component of IAS management.
- Tree plantation in shrub lands has reduced abundance of IAS.
- IAS has reduced regeneration of tree species; this was evident by low density of tree seedling and sapling in highly infested plots and declining seedling density with increasing cover of IAS.
- The applications of remote sensing have been restricted to those species dominating the canopy of ecosystems.
- Dominant invasive species determine the spectral signature received by the remote sensing scanner and thus allow detection using this spectral signature in a straightforward manner. Many invasive species however, do not dominate the canopy. They are rare or hidden below the ecosystem canopy (Joshi *et. al*., 2003). So, land-cover classification can identify those IAS dominating the canopy.
- IAS cover classified as Low, Moderate and High illustrates status of IAS in various vegetation cover inside or outside boundaries of the protected areas.

4.2 Recommendations

Following recommendations for management have been made based on the above studies:

- Disturbance and removal of trees are the major factors that make the forests highly susceptible to infestation by IAS. Therefore, disturbance should be kept at minimum and sustainable utilization of biological resources by ensured to make the forest communities less susceptible to infestation by IAS.

- In degraded forest where natural re-growth of trees is slow or severely disrupted by IAS, enrichment plantation of native species will be effective to naturally reduce abundance of IAS.

- All stakeholders including local communities should be made aware of the IAS in their localities, mode of dispersal, negative impacts to natural ecosystems, and management option to contain them. A field guide book of IAS with illustrations is desirable for this purpose.

- Detail understanding of the role of IAS on deforestation and forest degradation, and hence on carbon emission is still lacking. Therefore an intensive research in suitable experimental systems (e.g. pair of sites in the same locality, one with high level of IAS infestation and the other conserved forests with no/insignificant infestation) to quantify contribution IAS on carbon emission is suggested.

- This study has made large area coverage in short duration; hence, the GIS could analyze only limited distribution of IAS in the region. More useful results comparing forest degradation and deforestation in those areas with variable status of IAS distribution could be obtained with extended survey period.

- Present study was conducted in pre-monsoon. Further surveys covering post monsoon may give better picture of the IAS occurrence and their distribution to draw general conclusion.

- Land-cover classifications applied in this study should not be considered for other purpose as it is based on samples from IAS study sites only. Also, training sample collection for validation was not feasible due to time limitation.

- Study sites were categorized according to the management regime, but more detailed study with boundaries of various management regimes can incorporate status of IAS in various management regimes.

REFERENCES

Bajracharya, B. and K Uddin. (2010.) Study of Land Cover Dynamics in Sagarmatha National Park and Buffer Zone. International Centre for Integrated Mountain Development (ICIMOD); *10th International Symposium on High Mountain Remote Sensing Cartography*; –Kathmandu Nepal ;pp. 125 - 132).

Basnet B. 2011. *Impact of Mikania micrantha Invasion on Species Richness and Composition: A Case of Chitwan National Park, Nepal* [MSc thesis]. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Chettri MK. 1986. *Effects of herbicides on Eupatorium adenophorum Spreng*. [MSc thesis]. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Davis MA, JP Grime and K Thompson. 2000. Fluctuating resources in plant communities: a general theory of invisibility. *Journal of Ecology* 88: 528-534

DNPWC. 2009. *The Status and Distribution of The Greater One-Horned Rhino in Nepal*. Department of National Parks and Wildlife Conservation (DNPWC), Kathmandu, Nepal.

Dukes JS and HA Mooney. 1999. Does global change increase the success of biological invaders? *TREE* 14: 135-139.

Gurevitch J and DK Padilla. 2004. Are invasive species a major cause of extinctions? *Trends in Ecology and Evolution* 19: 470-474.

Inderjit, TR Seastedt, RM Callaway, JL Pollock and J Kaur. 2008. Allelopathy and plant invasions: traditional, congeneric, and bio-geographical approaches. *Biological Invasions* 10:875–890

Joshi CM, JD Leeuw AK Skidmore, JV Andel, HD Lekhak and IC Duren. 2003. *Remote Sensing and GIS for Mapping and Management of Invasive Shrub Chromolaena odorata in Nepal.* International Institute for Geo-Information Science and Earth Observation (ITC). The Netherlands.

Joshi CM, JD Leeuw, J van Andel, AK Skidmore, HD Lekhak, IC van Duren and N Norbu. 2006. Indirect remote sensing of a cryptic forest understory invasive species. *Forest Ecology and Management* 225:245-256.

Joshi RM. 1982. *Role of soil, light and water in the distribution pattern of Eupatorium adenophorum Spreng. (Banmara) in Phulchoki hill of Kathmandu valley* [MSc thesis]. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Joshi S. 2005. *Reproductive efficiency and biomass allocation of invasive weed Parthenium hysterophorus* [MSc thesis]. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Karki D. 2009. *Ecological and socioeconomic impact of Parthenium hysterophorus L. invasion in two urban areas in Nepal.* [MSc thesis]. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

MacDougall AS and R Turkington. 2005. Are invasive species the drivers or passengers of change in degraded ecosystems? *Ecology* 86: 42–55

Maharjan S. 2006. *Phenology, leaf attributes and allelopathic potential of Parthenium hysterophorus L., a highly allergic invasive weed in Kathmandu* [MSc thesis]. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Norbu N. 2004. *Invasion success of Chromolaena odorata in the Terai of Nepal* [MSc thesis]. International Institute for Geo-information Science and Earth Observation, The Netherlands.

Pimentel D, L Lach, R Zuniga and D Morrison. 2000. Environmental and economic costs associated with non-indigenous species in the United States. *BioScience* 50:53-65

Rai RK, H Scarborough, N Subedi and B Lamichhane. 2012. Invasive plants – Do they devastate or diversify rural livelihoods? Rural farmers' perception of three invasive plants in Nepal. *Journal for Nature Conservation* 20:170-176

Reinhard M. 2011. Land cover and land use mapping in the Western Pamirs, Tajikistan As a foundation for an assessment of the Ecosystem Services of the agricultural system. ETH Zürich.

Rogers DA, TP Rooney, D Olson and Waller. 2008. Shifts in southern Wisconsin forest canopy and understory richness, composition, and heterogeneity. *Ecology* 89: 2480–2492.

Russell JC. 2012. Do Invasive Species Cause Damage? Yes. *BioScience* 62:217-217. 2012.

Sapkota L. 2007. Ecology and management issues of *Mikania micrantha* in Chitwan National Park, Nepal. *Banko Janakari* 17:27-39.

Shrestha BB. 2012. *Parthenium* weed in Chitwan National Park, Nepal. *International Parthenium News* 5:6-7

Shrestha, R. 2012. *Impact of Mikania micrantha HBK, an invasive alien species, on native flora of Chitwan National Park and its Buffer Zone, Nepal.* [MSc thesis]. College of Applied Sciences-Nepal, Tribhuvan University, Kathmandu, Nepal.

Siwakoti M. 2007. *Mikania* Weed: A Challenge for Conservationists. *Our Nature* 5:70-74.

Siwakoti M. 2008. A checklist of angiospermic flora in and around the Lumbini Sacred Garden, Nepal. *Journal of Natural History Museum* 23: 27-44.

Timsina B, BB Shrestha, MB Rokaya and Z Munzbergova. 2011. Impact of *Parthenium hysterophorus* L. invasion on plant species composition and soil properties of grassland communities in Nepal. *Flora* 206: 233-240.

Yan G, J-F Mas, BHP Maathuis, Z Xiangmin and PM Van Dijk (2006). Comparison of pixel-based and object-oriented image classification approaches—a case study in a coal fire area, Wuda, Inner Mongolia, China. *International Journal of Remote Sensing* 27:4039-4055.

APPENDIX: I

Appendix I: The number of sample plots inventoried in each study site.

Study site	Management regime	Number of sample plots inventoried
Koshi Tappu WR	Protected area forests	13
	Buffer zone community forests	5
Parsa WR	Protected area forests	10
	Buffer zone community forests	5
	National forest	5
Chitwan NP	Protected area forests	5
	Buffer zone community forests	12
	National forest	5
Bardia NP	Protected area forests	15
	Buffer zone community forests	5
Shuklaphanta WR	Protected area forests	10
	Buffer zone community forests	5
	Community forest	5

APPENDIX: II

Appendix II: Field Data Sheet for forest sampling

Study area: …………… Sampling site:…………, Forest management: PA/BZ/CF/NF/PriF
Transect No: ………… Quadrat No.:…………… Size of quadrat: 20 m × 20 m
Lat:…………………, Long.:…………………, Elevation: ………… Aspect: …………….
Tree canopy cover: …….%, # of stump: ………. Grazing (0-3):……, Trampling (0-3):……
Fodder collection/lopping (0-3): ……………., Exposed soil surface: ………………………%
Other information: ………………………………………………………………………………

SN	Name of IAS	Cover (%)	Max. ht (cm)	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Tree regeneration **Size of sample plot: 5 m × 5 m**

SN	Name of tree species	# of seedlings	# of samplings
1			
2			
3			
4			
5			
6			
7			
8			

APPENDIX: III

Appendix III: Check list of major invasive alien species identified by IUCN Nepal (Tiwari *et al*. 2005).

S.N.	Scientific Name	Local Name
1	*Ageratina adenophora*	Banmara
2	*Chromolaena odorata*	Banmara
3	*Eichhornia crassipes*	Jal kumbhi
4	*Ipomoea carnea* ssp. *fistulosa*	Besaram
5	*Lantana camara*	Banphada
6	*Mikania micrantha*	Lahera banmara
7	*Alternanthera philoxeroides*	Jalajambhu
8	*Myriophyllum aquaticum*	-
9	*Parthenium hysterophorus*	Kanike ghans
10	*Ageratum conyzoides*	Raunne
11	*Amaranthus spinosus*	Kande lude
12	*Argemone mexicana*	Thakal
13	*Cassia tora*	Tapre
14	*Hyptis suaveolens*	Tulsi Jhar
15	*Leersia hexandra*	-
16	*Pistia stratiotes*	Kumbhika
17	*Bidens pilosa*	Kalo kuro
18	*Cassia occidentalis*	Panwar
19	*Mimosa pudica*	Lajjawati
20	*Xanthium strumarium*	Bhede kuro
21	*Oxalis latifolia*	Chariamilo

APPENDIX: IV

Appendix IV: Persons consulted during the study.

SN	Name of the person	Address	Affiliation/Designation
1	Jhamak Karki	CNP	Chief Warden
2	Yubraj Regmi	SWR	Warden
3	Baburam Lamichane	BCC, NTNC	Officer
4	Ramesh Sapkota	KBZCF	Chairman
5	Padam lama	PWR	conservation officer
6	Nuroj Chhetry	PWR	social worker
7	Dirgha Ghimire	PWR	government officer
8	Man Bd. Sth	PWR	forest watcher
9	Pam Pd. Sharma	PWR	Office Secretory, Janahit Cf Simara
10	Bikesk Paudel	CNP	Member of Kumrose BZCF
11	Sandesh Bohara	SWR	BZCF member
12	Bishnu Joshi	BNP	BZCF member
13	Dewaki Pandey	Coordinator	Buffer zone management committee
14	Binay K Jha	ranger	SWR
15	Ashok bhandari	Administrative chief	SWR
16	Lok Bdr Chand	Chairman	Himalayan Consumer Group SWR
17	Dev bdr bista	Chairman	SWR consumer group

APPENDIX: V

Appendix V: Study sites, area, site, IAS cover and GPS Location

SN	Sampling area	Sampling site	No of IAS	IAS cover	Northing	Easting
IAS1	KTWR	PA	5	65	26.65675	87.05991
IAS2	KTWR	PA	3	45	26.65724	87.05961
IAS3	KTWR	PA	4	60	26.65741	87.05918
IAS4	KTWR	PA	4	80	26.65742	87.0591
IAS5	KTWR	PA	6	75	26.65811	87.05845
IAS6	KTWR	BZ/CF	4	85	26.65573	87.05952
IAS7	KTWR	BZ/CF	3	70	26.65521	87.05904
IAS8	KTWR	BZ/CF	4	85	26.65411	87.05829
IAS9	KTWR	BZ/CF	3	60	26.65298	87.05726
IAS10	KTWR	BZ/CF	5	70	26.65205	87.05625
IAS11	KTWR	PA	2	75	26.56872	86.9912
IAS12	KTWR	PA	1	80	26.56543	87.9912
IAS13	KTWR	PA	4	95	26.56964	86.9915
IAS14	KTWR	PA	3	85	26.56969	86.99241
IAS15	KTWR	PA	3	95	26.5703	86.99273
IAS16	KTWR	PA	3	45	26.57097	86.99327
IAS17	KTWR	PA	3	60	26.57167	86.99654
IAS18	KTWR	PA	3	70	26.57164	86.99359
IAS19	PWR	PA	1	10	27.23023	84.9827
IAS20	PWR	PA	1	70	27.23041	84.97965
IAS21	PWR	PA	1	5	27.23054	84.9767
IAS22	PWR	PA	1	5	27.22955	84.97539
IAS23	PWR	PA	1	15	27.23013	84.97463
IAS24	PWR	NF	1	30	27.22889	84.9893
IAS25	PWR	NF	1	10	27.22739	84.98864
IAS26	PWR	NF	1	5	27.22683	84.98853
IAS27	PWR	NF	1	25	27.22659	84.98839
IAS28	PWR	NF	1	35	27.22584	84.9883
IAS29	PWR	BZ/CF	4	30	27.171	84.96865
IAS30	PWR	BZ/CF	4	60	27.17133	84.96822
IAS31	PWR	BZ/CF	1	30	27.17154	84.966762
IAS32	PWR	BZ/CF	2	50	27.17214	84.96641
IAS33	PWR	BZ/CF	1	15	27.17281	84.96609
IAS34	PWR	PA	2	55	27.52204	84.78804
IAS35	PWR	PA	5	65	27.52183	84.78814
IAS36	PWR	PA	2	75	27.52189	84.78862

IAS37	PWR	PA	3	50	27.52153	84.78923
IAS38	PWR	PA	3	50	27.53189	84.78985
IAS39	CNP	BZ/CF	3	35	27.56517	84.52607
IAS40	CNP	BZ/CF	1	5	27.56188	84.52797
IAS41	CNP	BZ/CF	3	85	27.56167	84.527
IAS42	CNP	BZ/CF	3	90	27.556351	84.52474
IAS43	CNP	BZ/CF	4	85	27.5647	84.52471
IAS44	CNP	BZ/CF	4	100	27.56351	84.52474
IAS45	CNP	BZ/CF	4	55	27.56161	84.52842
IAS46	CNP	BZ/CF	5	50	27.56064	84.52486
IAS47	CNP	NF	1	40	27.63875	84.4762
IAS48	CNP	NF	1	40	27.63894	84.47592
IAS49	CNP	NF	1	20	27.64011	84.47478
IAS50	CNP	NF	1	30	27.64052	84.47442
IAS51	CNP	NF	1	10	27.64183	84.47343
IAS52	CNP	PA	3	95	27.57211	84.49142
IAS53	CNP	PA	2	25	27.57196	84.49014
IAS54	CNP	PA		0	27.57174	84.48827
IAS55	CNP	PA	4	70	27.57154	84.48686
IAS56	CNP	PA	3	80	27.57116	84.48632
IAS57	CNP	PA	4	100	27.50741	84.27481
IAS58	CNP	BZ/CF	3	95	27.46004	84.36192
IAS59	CNP	BZ/CF	3	100	27.46066	84.3651
IAS60	CNP	PA	1	60	27.4635	84.36553
IAS61	BNP	PA	0	0	28.45375	81.24033
IAS62	BNP	PA	0	0	28.45467	81.23985
IAS63	BNP	PA	0	0	28.4562	81.23896
IAS64	BNP	PA	0	0	28.46308	81.23507
IAS65	BNP	PA	0	0	28.4562	81.23896
IAS66	BNP	BZ/CF	1	70	28.45231	81.25381
IAS67	BNP	BZ/CF	2	70	28.45418	81.25308
IAS68	BNP	BZ/CF	1	20	28.45625	81.25356
IAS69	BNP	BZ/CF	1	20	28.4566	81.25385
IAS70	BNP	BZ/CF	1	5	28.45787	81.25449
IAS71	BNP	PA	2	10	28.62796	81.27867
IAS72	BNP	PA	0	0	28.62582	81.27868
IAS73	BNP	PA	0	0	28.62335	81.27686
IAS74	BNP	PA	1	40	28.62335	81.27608
IAS75	BNP	PA	1	30	28.62704	81.27836
IAS76	BNP	BZ/CF	1	50	28.51305	81.32379
IAS77	BNP	BZ/CF	1	30	28.51277	81.32345
IAS78	BNP	BZ/CF	1	65	28.5124	81.32355
IAS79	BNP	BZ/CF	1	40	28.5118	81.32301

IAS80	BNP	BZ/CF	1	90	28.51161	81.324
IAS81	SWR	PA	0	0	28.9295	80.2987
IAS82	SWR	PA	0	0	28.92981	80.2986
IAS83	SWR	PA	0	0	28.92897	80.29858
IAS84	SWR	PA	0	0	28.91844	80.29829
IAS85	SWR	PA	0	0	28.9283	80.29786
IAS86	SWR	PA	2	45	28.94942	80.14803
IAS87	SWR	PA	2	40	28.94843	80.14866
IAS88	SWR	PA	0	0	28.94736	80.15232
IAS89	SWR	PA	1	5	28.94815	80.15174
IAS90	SWR	PA	1	5	28.94672	80.15111
IAS91	SWR	CF	2	60	28.9014	80.29891
IAS92	SWR	CF	2	80	28.90166	80.366
IAS93	SWR	CF	1	20	28.90141	80.3664
IAS94	SWR	CF	1	15	28.90141	80.36671
IAS95	SWR	CF	1	5	28.90126	80.36683
IAS96	SWR	BZ/CF	1	10	28.95433	80.09297
IAS97	SWR	BZ/CF	1	10	28.97194	80.09714
IAS98	SWR	BZ/CF	1	20	28.97187	80.09714
IAS99	SWR	BZ/CF	1	50	28.98553	80.10187
IAS100	SWR	BZ/CF	1	10	28.9863	80.10174

(Abb. KTWR = Koshitappu Wildlife Reserve, PWR= Parsa Wildlife Reserve, CNP= Chitwan National Park, BNP = Bardia National Park, SWR = Shuklaphanta Wildlife Reserve, PA= Protected Area, BZ= Buffer Zone, CF= Community Forest, NF = National Forest)

APPENDIX: VI

Appendix VI: Archives of Invasive Alien Species recorded in the study area.

Ageratina adenophora (L.) King & Robinson

Synonym	*Eupatorium adenophorum* Spreng. *Eupatorium glandulosum* Kunth
Family	Asteraceae (Compositae)
Common/English name	Crofton weed
Local name	Kalo banmara, Kaloharam, Raunne, Hawe, Assame/ Barmeli, Kalo teta, Kalimunte, Mohini (Chepang), Thanga Pa Mraan (Tamang)
First reported in Nepal	Banerji in J. Bomb. Nat. Hist. Soc. 55: 259.1958 (*Eupatorium glandulosum*)
Habitat	Open forest margins, grasslands, agricultural lands and fallowlands
Description	Perennial, erect or decumbent, foetid sub shrub.
Flowering & Fruiting	March-May
Uses	Fresh leaf juice is used to stop bleeding. Plants are collected to make cattle bedding and compost, also used in biogas plant. It is also used as a fodder for goat, but reported as poisonous to domestic animals, specially horses (Wan and Wang, 2001).
Distribution	Native of Central America (Mexico). Pantropical weed. Nepal (WCE, 650-2400m)

Ageratum conyzoides **L.**

Family	Asteraceae (Compositae)
Common/English name	Billy goat weed, chick weed, goat weed, white weed.
Local name	Ilame, Gandhe, Raunne, Hanumane, Ganhiya jhar (Danwar), Phul Gineri, Ganki (Mushahar), Bhagriya, Remai Ganmana ghans, Paino (Gurung), Jhang ninoba (Tamang), Phorijhayang (Tharu)
First reported in Nepal	Burkill in Rec. Bot. Ind. 4:114.1910
Habitat	Crop land, fallowland and forest margins.
Description	Annual, aromatic hispid herb 20-60cm high.
Flowering & Fruiting	June-March (almost round the year).
Uses	Plant is used as fodder for cattle. It is also used as antiseptic to stop bleeding in cuts and wounds, and also to increase appetite. The plant is reported to be used in analgesic, anti-bacterial, anti-inflammatory, emetic, purgative, decoagulant, febrifuge, stimulant, vulnerary (www.raintree-health.co.uk/ plants/ ageratum.html).
Distribution	Native of South America. Pantropical weed. Nepal (WCE, 75-2000m)

Chromolaena odordata (Spreng.) King & Robinson

Synonym	*Eupatorium odoratum* Spreng. L.
Family	Asteraceae (Compositae)
Common/English name	Siam weeds; bitter bush, chromolaena
Local name	Aule banmara, Seto banmara, Seto Raunne, Assame/ Barmeli, Teta, Aule jhar, Madhese banmara, Singhar (Chepang), Lohasiya (Danwar), Seto haram (Rai).
First reported in Nepal	D. Don, Prodr. Fl. Nep. 171. 1825 (*Eupatorium acuminatum* D.Don)
Habitat	Edges of forests, fallow lands, shrub lands, agricultural lands and grasslands.
Description	Perennial herb or sub-shrub up to 2.5m high with long rambling branches.
Flowering & Fruiting	December-April
Uses	Juice of leaves are used to control bleeding, young plant used to make compost,mature stem for firewood and fencing. Flowers and young leaves are used as fodder for goats.
Distribution	Native of tropical America, Jamaica, West Indies. It spreads from Western Ghats in India to the Philippines in Asia and the Marainas and Caroline Islands in the Western Pacific. It has become a serious weed in Bhutan, Nepal, China, Bangladesh, Indonesia, Sri Lanka, Nigeria, Malaysia, Mariana Island and Caroline Islands. Nepal (WCE, 75-1540m)


Eichhornia crassipes **(Mart.) Solms.**

Synonym	*Pontederia crassipes* Mart.
Family	Pontederiaceae
Common/English name	Water hyacinth
Local name	Jal Kumbhi, Ghenga, Meteka, Dalkacchu (Tharu), Pindale Jhar, Jalu, Kane, Ghengana.
First reported in Nepal	Hara, Fl. East. Himal: 402. 1966
Habitat	Wetlands such as marshes, lakes/ponds, ditches and slow running water courses.
Description	Perennial, stoloniferous herb, floating or rooting in mud; roots feathery
Flowering & Fruiting	April-November
Uses	Making compost, mulching in the potato field just after the plantation of potato seed to maintain the moisture of soil, fodder for pig, and a source of methane and alcohol. It can be used for biogas plant. The plant obtains its nutrient from the Water and has been used in waste water treatment facilities, but such a practice has not yet been reported in Nepal.
Distribution	Native to the South America introduced and cultivated in most warm countries (naturalized widely in Asiatic tropic). Nepal (WCE, 75-1500 m

 

Ipomoea carnea Jacq. subsp. *fistulosa* (Mart. ex Choisy) D.F. Austin

Synonym	*Ipomoea fistulosa* Mart. ex Choisy
Family	Convolvulaceae
Common/English name	Shrubby morning glory
Local name	Sanai phul, Dhungre phul, Kaudi phul, Dhokre phul, Latkarni (Tharu), Besaram, Karmi, Dhode, Dudhiya, Behaya, Masterphula (Darai)
First reported in Nepal	Yamazaki in Fl. East. Himal: 264.1966 (Ipomoea crassicaulis)
Habitat	Wetlands such as marshes, shallow lakes and ponds, ditches, drainages, etc.
Description	Erect or straggling shrub up to 3m high.
Flowering & Fruiting	April-January or in some places around the year.
Uses	Fencing, firewood, green manure, construction materials for poor people's house. It is often planted for hedging or decoration or in nearby canal to check flooding but it has become a serious weed in some irrigation and drainage channels.
Distribution	Native of South America; Cultivated and naturalized in tropical areas. Nepal (WCE, 75-1350m)

Lantana camara L.

Synonym	*Lantana aculeate* L.
Family	Verbenaceae
Common/English name	Lantana
Local name	Ban phanda, Kirne kanda, Banmakai, Sutkeri kanda, Subandi, Kaligedi, Aankeri kanda, Kharbuja, Kanchi nani, Boksi kanda, Gandhe kanda, Chilaune jhar, Bhakte kanda, Masino kanda, Vanphanda kanda, Ek sanse.
First reported in Nepal	Yamazaki in Fl. East. Himal: 270. 1966.
Habitat	Forest, fallowlands, pastures, roadsides.
Description	Straggling erect or sub-erect shrub, up to 3 m high with stout recurved prickles and a strong odour
Flowering & Fruiting	Almost throughout the year
Uses	It grows as hedge plant. Its bark and leaves are used for some medicinalMvalues (cutiginous eruptions, leprous ulcers, swellings and pain of the body). The plant has been reported poisonous to cattle. Young stems are used form brushing tooth and old ones as firewood.
Distribution	Native to West Indies, distributed in Pacific Islands, Australia, New Zealand, China, Thailand, Cambodia, Vietnam, Malaysia, Indonesia, Philippines and Indian sub-continent. Nepal (WCE, 75-1700 m)


Mikania micrantha Kunth

Synonym	*Mikania scandens* sensu F.B.I. non (L.) Willdenow *M. cordata* (Burmanf.) Robinson var. indica Kitamura
Family	Asteraceae (Compositae)
Common/English name	Mile- a- minute
Local name	Lahare banmara, Bahudale jhar, Bahre mase, Bire lahara, Tite lahara, Bakhre lahara, Pyangri lahara, Pani lahara
First reported in Nepal	Kitamura in Fl. East. Himal: 341. 1966 (Mikania cordata var. indica)
Habitat	Fallowlands, croplands, forests, scrubs or shrublands and wetlands.
Description .	Perennial, scandent or twining herb.
Flowering & Fruiting	November-February
Uses	Sometimes the plant is used as fodder for goat and pigs.
Distribution	Native to Central and South America. It has been reported as a weed in India, Bangladesh, Sri Lanka, Mauritius, Thailand, Philippines, Malaysia, Indonesia, Papua New Guinea and many other Pacific Islands. Nepal (CE, 75-1200m).S


Parthenium hysterophorus L.

Family	Asteraceae (Compositae)
Common/English name	Bitter weed, Carrot grass, false ragweed, Fever few, Parthenium weed,Ragweed parthenium, White top, Santa maria
Local name	Kanike ghans, Bethu ghans, Padke phul.
First reported in Nepal	Hara et al., Enum. Fl. Pl. Nepal 3:35. 1982.
Habitat	Fallowlands, roadsides, around settlements
Description	Perennial, erect or profusely branched herb up to 2 m high.
Flowering & Fruiting	All round the year, particularly March-December.
Uses	The plant has not been used for any purpose in Nepal.
Distribution	Native to Mexico, West Indies, Central and South America. Pantropical weed. Nepal (WCE, 75-1350 m).


Cassia tora L.

Synonym	*Senna tora* (L.) Roxb.
Family	Fabaceae (Leguminosae)
Common name	Sicklesena
Local name	Carkor, Cakramandi, Chakamake, Sarasphul, sanno taapre (Chepang), Taapre (Magar), Chakora (Satar)
First reported in Nepal	Burkill in Rec. Bot. Sur. Ind. 4:106.1910
Habitat	Wasteland, roadsides, forest margins
Description	Annual herb,
Flowering & Fruiting.	July-December
Uses	Plant is used as firewood; seeds are used to cure gastritis. It is used as antipyretic, antibiotic, antihypertensive as well as mild laxative; also has antiparasitical property. The plant is found to reduce cholesterol. The extractions from seeds and leaves are used in skin disease, particularly to treat itching and ringworm (Siwakoti and Varma, 1996). Santar ethnic group uses young leaves as vegetable.
Distribution	Native of South America, Tropical weed. Nepal (WCE, 75-1300m)

Cassia occidentalis L.

Synonyms	*Senna occidentalis* (L.) Roxb.
Family	Fabaceae (Leguminosae)
Common/English name	Coffe senna, coffee weed
Local name	Tapre, Jhing Jhinge, Runche jhar, Tata, Kasaudi, Parwar, Chakaur (Tharu), Panwar, Choklenr (Darai)
First reported in Nepal	Burkill in Rec. Bot. Surv. Ind. 4:106. 1910
Habitat	Fallowlands, roadsides, forest margins, pastures
Description	Annual or perennial erect sub-shrub upto 1.5m high.
.	
Flowering & Fruiting	All round the year.
Uses	Used as fencing and burning materials. Roasted seeds eaten to treat cough and headache. Root bark applied to ringworm infection (Rajbhandari, 2001)
Distribution	Native of tropical America. Nepal (WCE, 75-1400m).

Mimosa pudica L.

Family	Fabaceae (Leguminosae)
Common/English name	Sensitive plant, sleepinggrass.
Local name	Lajjawati, Lajauni, Buhari jhar, Laje jhar, Lajwanti, Lamete jhar, Nidoune ghans, lajkurni Jhyangi (Darai), Jhapani (Satar)
First reported in Nepal	Burkill in Rec. Bot. surv. Ind. 4:106.1910.
Habitat	Moist fallowlands, agricultural lands and forests.
Flowering & Fruiting	August-December
Uses	Roots are used in asthma, fever, dysentery, abdomen pain and for skin diseases. Cattle feed the plants.
Distribution	Native of Tropical America, distributed in Pacific Islands, Indian Ocean islands, Australia, Taiwan, Cambodia, China, Indonesia, Japan, Malaysia, Philippines, Thailand, Vietnam. Nepal (WCE, 75- 1300 m)

Xanthium strumarium L.

Family	Asteraceae (Compositae)
Common/English name	Rough cockle-Bur
Local name	Bheda kuro, Kuro, Aagraha (Tharu), Kastolo, Khanghara
First reported in Nepal	Kitam. in Fau. & Fl. Nepl. Himal: 273.1955
Habitat	Agricultural fields and Fallowlands.
Description	Annual, erect, coarse herb
Flowering & Fruiting	April-July
Uses	The plant is used as green manure in cropland. It is also reported that its fruit is used to dye hair (Munz and Keck, 1973). The mature fruit is burnt and applied in cracks and fissures on human dry skins mixing with mustard and coconut oil (Rajbhandari, 2001).
Distribution	Though the plants were first reported from Europe, it is probably of American origin (Munz and Keck 1973), distributed worldwide. It is a serious weed in Australia, India, South Africa, America and Nepal. Nepal (WCE, 75-2500 m)

***Bidens pilosa* L.**

Family	Asteraceae (Compositae)
Common/English name	Beggar's stick
Local name	Kuro, Kaine Kuro, Kalo kuro, Suere Kuro, Chumra, Nir (Chepang), Tsyathun (Gurung), Katare (Magar).
First reported in Nepal	Burkill in Rec. Bot. Surv. Ind. 4:115.1910
Habitat	Fallowlands, agricultural land and forest margins.
Description	Annual, erect, thinly hairy herb 20-100cm high Leaves
Flowering & Fruiting	May-November
Uses	The whole plant is used to make broom; the plant is also used to cure cuts and wounds as well as fodder for cattle and goat. Tender leaves are cooked as vegetable; stem and leaves are dried and brewed as tea in Morang (Rajbhandari, 2001)
Distribution	Native of tropical America. Pantropical weed. Nepal (WCE, 100-2100m)

APPENDIX: VII TOR

PHOTOGRAPHS


Discussion with local people of BZCF


Coverage of IAS at grassland


Distribution of IAS over wetland


Locating GPS point


Mikania growing over tree


Presence of *Eichhornia*

Presence of *Lantana* in protected area

Mikania in grassland

Map showing BZCF at Madi

Forest fire

Discussion with BZCF management committee

Local people sharing impact of IAS


IAS in protected areas


Mikania climbing the tree


Field sampling


Presence of IAS


FGD with stakeholder of Forest


Eichhornia habitat


Sampling of IAS


Coordination with local for IAS identification


Ageratina adenophora


IAS in sampling plot


People perception on IAS


FGD with tourist guides


Researcher at field


Consulting local people for the presence of IAS


Local people's enthusiasm over IAS discussion


Artistic place for FGD at BNP


Use of *Ipomoea* as hedge plant in agricultural land


Discussion with stakeholders


Beauty at BNP


A large population of *Ipomoea*


Vegetation damaged by forest fire


Consultation with local people


Discussion with stakeholders


Use of *Ipomoea*