An Inventory and Assessment of Invasive Alien Plant Species of Nepal






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AN INVENTORY AND ASSESSMENT OF INVASIVE ALIEN PLANT SPECIES OF NEPAL

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Foreword

Biological diversity faces many threats throughout the world. One of the major threats to native biological diversity is caused by Invasive Alien Species (IAS) which can damage or replace native animal and plant populations, as well as the health of our ecosystems. The impacts of IAS are immense, insidious, and usually irreversible. The scope and cost of biological alien invasions is global and enormous in ecological, environmental and economic terms.

Almost every country is grappling with the problems caused by IAS and Nepal is no exception to this. Addressing the problem is urgent because the rate of invasion is alarmingly rapid in some cases. A comprehensive study to determine the status of IAS in Nepal is still awaited. IUCN Nepal felt the need to undertake a rapid study to preparing an inventory and to assessing the current status of major IAS. Several rounds of consultation meetings and extensive discussions were organised to develop a participatory framework to be used for impact assessment and monitoring of IAS in Nepal.

The book "*An Inventory and Assessment of Invasive Alien Plant Species of Nepal*" is a culmination of 3 years' work by the Ecosystem and Sustainable Livelihoods Group of IUCN Nepal. It represents a collaboration of a wider spectrum of biodiversity experts, ecologists and natural scientists of Nepal including members of IUCN's Species Survival Commission. This publication reaffirms IUCN Nepal's continuing commitment to assist in the efforts of His Majesty's Government as a State Party to follow a path of conservation as directed by the Convention on Biological Diversity (CBD).

This publication comes at a time when the international community has committed itself through passing a resolution in the IUCN 3rd World Conservation Congress (November 2004) to achieving tangible results in the management of IAS.

I am very pleased to make available to the scientific community, researchers and academia, and those actively involved in biodiversity management this document addressing existing legal instruments and identifying selected plant species applicable to IAS in Nepal. It is my hope that this publication will broaden our understanding of the complexity of the issue related to IAS and will also push us towards searching for the remedial measures to be taken. I wish to express my sincere gratitude to all those who have contributed, in one way or another, in the preparation and production of this inventory.

Since the preparation of an inventory is a dynamic and evolving process, any comments or suggestions in further improving it will be highly appreciated.

Sagendra Tiwari
Acting Country Representative
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Preface

A biological species introduced in an ecosystem other than its natural home is called alien or exotic or non native. There exists a long list of alien species throughout the world which make a valuable part of the livelihood and economy of the modern world. If these organisms became aggressive or spread beyond the manageable boundaries and out compete native species in the ecosystem, then these are considered as Invasive Alien Species (IAS). An IAS has the potential to substantially alter the structure and function of natural ecosystems and is likely to cause economic and/or environmental loss and/or harm to human health. IAS can be a plant, an animal, a pest, a disease or any micro-organism. The present inventory encompasses the invasive plant species only.

Nepal's natural resources have been under excessive pressure due to growing population demand and over exploitation for livelihoods and subsistence farming. It is not only agricultural crops but also other unwanted pests and weeds that have been introduced affecting agro-ecosystems as well as forest, fallow land and wetland ecosystems. A number of species is known to prey on, outcompete, hybridize and infect native species thereby causing habitat deterioration, ecosystem disturbance and decline of native species. They are considered as second greatest threat to native species after habitat loss. However, knowledge base on IAS in Nepal is rather meager and limited. There is a great need of comprehensive study and research work revealing the status and impacts of invasive species of Nepal, on the face of some alarming impacts of IAS such as *Eichhornia crassipes* in wetlands of international significance and *Mikania micrantha* in the grasslands of national parks and protected areas.

The World Conservation Union – IUCN Nepal endeavored to make an inventory and assessment of the invasive alien plant species through a prioritization process. The inventory is based on experts' consultation, literature and field studies in collaboration with local partners such as high schools, community forest users' group, community based non governmental organizations, farmers and other stakeholders. The process was initiated in 2001 by developing a background paper and organizing a consultative workshop to draw the attention of scientific community and stakeholders of natural resources and environment conservation.

The cost of negligence and avoidance to control the spread and impact of invasive species grows higher with time and poses serious threat to biosecurity. We have to be more aware of the need to timely respond to the adverse or untoward effects of alien species upon our natural ecosystems. This contribution is intended to attract immediate attention upon some of the alien plant species that pose threats of invasion to natural ecosystems. It is hoped that it will trigger the interest of conservation scientists and ecosystem managers to keep an eye on species that are often neglected as unwanted weeds and wasteland species.

Many individuals and institutions have contributed to undertake this study. We would like to express our sincere gratitude to Dr. Mahesh Banskota, former Country Representative of IUCN Nepal for continued encouragement. We are deeply indebted to Dr. Tirtha B. Shrestha, Life Member of Royal Nepal Academy and Prof. Dr. Ram P. Chaudhary, Member of National Planning Commission for reviewing the document and providing valuable

comments and suggestions to improve it. Sincere thanks are also due to Dr. Pushpa.R. Shakya, Dr. Narendra N. Tiwari, Dr. Purusottam Shrestha, Dr. Keshab Shrestha, Dr. Jagat D. Ranjit, Dr. Dinesh R. Bhuju, Dr. Madhusudan P. Upadhaya, Dr. Bimal K. Baniya, Dr. Keshab R. Rajbhandari, Dr. Nirmal Bhattarai, Dr. Samar.B. Malla, Dr. Bigyan Acharya, Dr. Deep B. Swar, Dr. Surendra Bhandari, Dr. Suresh P. Sharma, Prof. Dr. Krishna K Shrestha, Prof. Dr. Pramod K. Jha, Prof. Karan B. Shah, Mr. Narayan P. Poudel, Mr. Prabhu Budhathoki, Mr. Tulsi B. Prajapati, Mr. Gopal Bhattarai, Mr. Arun Rijal, Ms. Radha Joshi, Mr. Ukesh Bhuju, Mr. Kamal Maden and Mr. Kul P. Limbu for their valuable inputs and insights at the beginning of the study. We are also thankful to Dr. M.K. Adhikari, National Herbarium and Plant Laboratories, Godawari and all the staff for granting permission to study the herbarium specimens. We would also like to acknowledge the active participation of Seti Devi S. School (Talkundechaur, Kathmandu), Bhagawati S. School (Inruwa), Peace Zone Boarding School (Itahari), Dantakali S. School (Dharan), Bhanu Memorial Boarding School (Biratnagar), Gokundeshor S. School (Dhankuta), Department of National Parks and Wildlife Conservation (DNPWC), Koshi Tappu Wildlife Reserve, Royal Chitwan National Park, Langtang National Park, Users' Group of Ghanteswor and Sina Bhawar Rato Mati Community Forests (Doti), Saraswoti Community Forest (Bardia), Kalika Community Forest (Dang), Bhutkhola Soli Ghopte Community Forest (Paplpa), Jhauri Community Forest (Parbat), Humse Dumse Community Forest (Jhapa), project staffs of Garib Kaa Lagi Ban Tatha Batabaran (NGO, Rupendehi), students of Institute of Agriculture and Animal Sciences (Chitwan). Local farmers and inhabitants of Sarlahi and Langtang areas of Rasuwa District deserve special attention for their enthusiastic support to collect information in field.

Contributions from IUCN Nepal field staff in Dharan and Doti as well as the efforts of the Country Office staff is highly appreciated. Special thanks go to Mr. Deependra Joshi, Mr. Kanhaiya Lal Shrestha, Mr. Dwarika Aryal, Ms. Indira Bhurtel and Mr. Naresh Subba for their support in making this publication possible.

-Authors

Acronyms

ADB	Asian Development Bank
C	Central
ca	Circiter; about
CABI	Centre for Agricultural Bioscience International
CBD	Convention on Biological Diversity
CBS	Central Bureau of Statistics
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COP	Conference of Parties
E	East
FAO	Food and Agriculture Organization
FINNIDA	Department of International Development Cooperation
Fl.	Flowering
Fr.	Fruiting
GDP	Gross Domestic Production
GISP	Global Invasive Species Programme
GMO	Genetically Modified Organisms
HMGN	His Majesty's Government of Nepal
IAS	Invasive Alien Species
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
ISSG	Invasive Species Specialist Group
IUCN	The World Conservation Union
KATH	National Herbarium and Plant Laboratories, Godavari
LMO	Living Modified Organism
LRMP	Land Resource Mapping Project
MFSC	Ministry of Forests and Soil Conservation
MoAC	Ministry of Agriculture and Cooperatives
NBCC	National Biodiversity Coordination Committee
NBS	Nepal Biodiversity Strategy
NGO	Non Governmental Organization
PPA	Plant Protection Act
PPD	Plant Protection Directorate
PRA	Participatory Rapid Appraisal
SCOPE	Scientific Committee on Problems of Environment
SP.	Species (singular)
SPP.	Species (plural)
SPS	Sanitary and Phytosanitary Measures
SSC	Species Survival Commission
SSP.	Subspecies
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
VDC	Village Development Committee
W	West
WTO	World Trade Organization

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Mikania Micrantha, Charkoshe Jhadi

CHAPTER ONE

Plant Diversity: At a Glance

Country Description

Nepal occupies about a third (800 km) of its entire length (2,500 km) from the Indus Trench below Nanga Parbat to the Yarlung-Tsangpo-Brahmaputra Gorge below Namche Barwa. It is located at a latitude of 26^{0}02' to 30^{0}27' N and the longitude of 80^{0}04' to 88^{0}22'E between India and China. The country occupies an area of 147,181 sq. km. within which about 86 percent area is covered with hills and mountains and the remaining 14 percent area is flat lowland of the Terai. 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).

Based on altitudinal variations, the country has been classified into seven physiographic zones ranging from low lands (60m) to high Himalayas (8,848m) (Hagen, 1998). The southern lowlands constitute the Terai zone (60 - 300m). It is a part of alluvial Gangetic plain between the Indian border and the outer foothills. The soil in this zone is fertile and is considered as granary of Nepal. The immediate northern belt of the Terai called *Bhabar* zone used to be famous for holding a contiguous belt of forest, locally known as *Char Koshe Jhadi*. Presently, the forest has been fragmented at several places. The north to the *Char Koshe Jhadi* is abruptly raised from 150m to 1,500m. This zone is called as the Siwalik hills, also known as Churiya hills. It is widened in western parts and is narrowed gradually becoming even invisible in some portions of eastern Nepal. There are many gently sloping valleys between Siwaliks and the following Mahabharat Lekh. These are called *Dun* or *Bhitri Madesh*. The Siwalik range has a fragile land system and is composed of sedimentary rocks with big boulders.

The north to the Siwalik zone lies a mountainous range called Mahabharat Lekh. The elevation ranges from 1,500m to 2,700m and it is well developed in eastern and central parts of the country but relatively less developed in the western region. Further north to the Mahabharat Lekh, the middle portion of the country is called Midlands. The altitude of Midlands ranges from 600m to 3,500m. It is an agricultural belt densely populated with some fertile valleys, including Kathmandu, Pokhara, etc.

Further north to the Midlands, the landmass lying above 4,000m, is called Himalayan zone. The lower part of the zone is famous for summer grazing pasture while upper part is covered by alpine scrubs and meadows. The altitude above 5,500m is devoid of vegetation and remains permanently covered with snow. In the area north to the Himalayan zone, there are several trans-Himalayan valleys such as the upper Kali Gandaki, the northern Gorkha and the Bheri. These valleys exhibit desert like climate. The area north to Dhaulagiri and Annapurna Himalaya (Manang, Mustang and part of Dolpa) is arid like Tibetan plateau.

The Master Plan for Forestry Sector in Nepal has divided the country into five physiographic zones (fig.1) based on altitudes (HMGN/ADB/FINNIDA 1988). These are: (i) Terai (below 60-330m); (ii) Siwaliks (120-2000m); (iii) Middle Mountain (200-3,000 m); (iv) High Mountain (3,000-4,000m), and High Himal (above 4,000m).

Vegetation

Vegetation may be varied based on habitats. Broadly, habitats of Nepal can be divided into forestlands, fallowlands, grasslands, croplands, wetlands and snowlands. Based on land use pattern of Nepal, the forest coverage is about 29 percent of the total area. The shrublands and degraded forests comprise 10.6 percent, grassland 12 percent, agricultural land 21 percent and the wetlands is estimated at 5 percent (NBS, 2002). The present study on IAS basically concentrates on forests, croplands, fallow lands and wetlands. The shrub lands and degraded forests have been covered under forest whereas the uncultivated lands and disturbed grasslands have been lumped into fallow lands.

Forest Vegetation

On the basis of climate and altitude, the forest of Nepal can be generally divided into the following five vegetation zones:

1. Tropical Zone (below 1,000m): It extends along Terai, Bhabar and Dun valleys. Dominant forest types are Sal forest (*Shorea robusta*), tropical deciduous riverine forest (*Acacia catechu, Dalbergia sissoo, Bombax ceiba*, etc.) and tropical evergreen forest (*Michelia champaca* association with laurels).
2. Sub-tropical Zone (1,000-2,000m): It lies along outer foothills, lower parts of Mahabharat Lekh and Midlands. The major forest types are Schima-Castanopsis forest (1,000-1,700m) in eastern and central Nepal, Pine (*Pinus roxburghii*) forest (900-2,000m) in western Nepal and patches of Alder (*Alnus nepalensis*) forest along the bank of streams and unstable grounds in the eastern and central Nepal. The west Himalayan alder (*Alnus nitida*) occurs in Mugu and Karnali valley only.
3. Temperate Zone (2,000-3,000m): The Mahabharat Lekh and the southern part of the main Himalayan range come under the influence of temperate bio-climatic zone. Following forest types are pre-dominant in this zone.
   a. Lower temperate mixed broad-leaved forest (1,700-2,200m): This type is dominated by evergreen species of Laurels (*Persea duthiei, P. odoratissima, Phoebe lanceolata, Cinnamomum tamala, Lindera nacusua*, etc.) and occurs in humid habitats of Midlands, such as along the upper Arun and Tamor valleys, and south of the Annapurna and Himalchuli ranges.
   b. Temperate mixed evergreen forest (2,100-2,700m): It is dominated by the association of broad-leaved oaks (*Quercus lamellosa, Q. glauca, Q. semecarpifolia*) all over the eastern and central Nepal, whereas in the western Nepal conifers (*Picea smithiana, Abies pindrow, Cupressus torulosa, Cedrus deodara*) forests take over the temperate zone.
   c. Upper temperate mixed broad-leaved forest (2,400-3,000m): It is characterized by deciduous species of Aesculus-Juglans-Acer association in western Nepal and Magnolia-Acer-Osmanthus association in the central and eastern Nepal.
4. Sub-alpine Zone (3,000-4,100m): It covers the part of the great Himalayan range. The vegetation is dominated by Silver fir (*Abies spectabilis*) forest and Birch-Rhododendron forests.
5. Alpine Zone (above 4,100m): It is an open area lying between the tree line (4000m) and the snowline (5000m), where summer is short and winter is long with severe and heavy snowfall in winter. Vegetation comprises of the association of Juniper-Rhododendron scrubs along the Inner Valley (4,000-4,300m), Caragana-Lonicera scrub along the arid zone, particularly north to the Dhaulagiri-Annapurna massif (4,100-4,800m) and alpine meadow (above 4,800m). The alpine meadow spreads up to 5,200m. The range above this altitude is covered with perpetual snow. Beyond 6,000m, Arctic or Nival zone prevails all along the Himalaya.

Wetland Vegetation

Nepal's wetland habitat is created through varied water bodies that range from permanent flowing rivers to seasonal streams, lowland ox-bow lakes, high altitude glacial lakes, swamps, marshes, paddy fields, reservoirs and ponds. About 25 percent of the total vascular plants are estimated as wetland dependent (Bhandari, 1992). Altogether, 318 wetland dependent plant species have been recorded in Terai's wetlands (IUCN, 2004). Similarly, the eastern plain region of Nepal is reported to have 141 wetland-dependent plant species (Siwakoti and Varma, 1998). On the basis of their general habitat, they may be categorized as:

1. free floating and rooted floating hydrophytes (*Eichhornia crassipes, Pistia stratiotes, Nymphaea nouchali, Nymphoides hydrophyllum*, etc.);

2. suspended and rooted-submerged hydrophytes (*Aponogeton natans, Hydrilla verticillata, Potamogeton crispus, Urticularia aurea*, etc.), and

3. amphibious/emergent hydrophytes (*Alternanthera philoxeroides, Axonopus compressus, Ludwigia octovalvis, Ipomoea carnea* subsp. *fistulosa*, etc.). Many of the wetland species are of alien origin. It is important that wetlands are the most susceptible to IAS and hence, they need to be studied in greater details.

Fallowland Vegetation

Fallowland includes lands along roadsides, uncultivated lands of village surroundings, disturbed grasslands, and waste or marginal lands of forests. Such areas are highly disturbed and hence few scattered trees, hedges and seasonal weeds occur in fallow sites. Since the fallowlands remain highly disturbed, they have become favourable grounds for various alien species which can resist pollution and other disturbances resulting from anthropogenic causes. Many of such alien species seem to have found fairly suitable habitats to mask majority of indigenous species. Common vegetation in the fallowland includes *Ipomoea carnea* subsp. *fistulosa, Parthenium hysterophorus, Lantana camara, Ageratum conyzoides, Chromolaena odorata, Cassia tora, Ageratina adenophora*, etc.

Alternanthera philoxeroides and *Eichhornia crassipes*, Kamalpokhari, Kathmandu

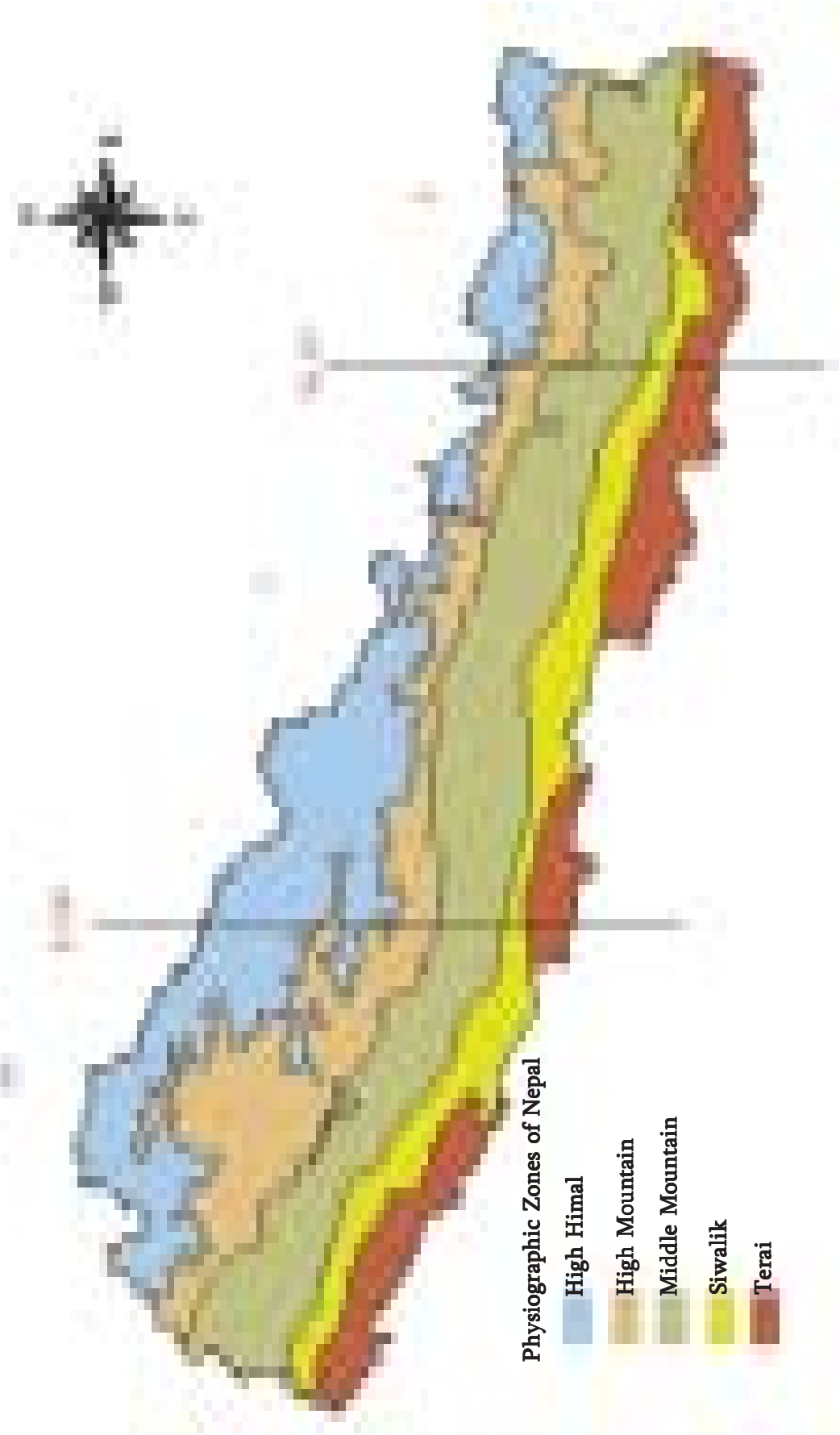

Fig 1: Physiographic Zones of Nepal with Phytogeographic Divisions

Cropland Vegetation

Nepal has a high degree of agro-ecological diversity in response to the varied physiography. The agricultural sector contributes 38 percent in the Gross Domestic Product (GDP) and provides employment to 81 percent of the population of Nepal. Over 500 species of plants are edible in Nepal. Out of these, 200 species of plants are cultivated (NBS, 2002). Rice, maize, wheat, millet and potatoes are principal food crops in Nepal. Above 95 local aromatic and fine rice landraces are grown by Nepalese farmers. The country has numerous native and non-native species of horticultural and vegetables plants. However, their diversity is not properly documented. Different kinds of weeds are undesirable to farmers. They compete with crops for nutrients, sunlight and space. The species composition of weeds varies depending on crops and seasons. Major weeds in rainy season are *Alternanthera sessilis, Amaranthus spinosus, Oxalis latifolia, Mimosa pudica, Crassocephlaum crepidioides, Bidens pilosa, Xanthium strumarium*, etc., whereas in winter season, major weeds are *Argemone mexicana, Cannabis sativa, Lathyrus aphaca, Rorippa indica*, etc.

Floral Species Richness

Nepal is located in the junction of the Palaeo-arctic and the Oriental realms of the earth and in the crossroads of six floristic provinces of Asia. It has a great geographical as well as climatic variation due to mountainous terrain and topography. A wide range of natural attributes in a relatively small area has endowed Nepal with the representation of global ecosystems and habitats. Several classifications have been proposed by different researchers to describe its vegetation.

Stearn (1960) classified Nepal into three regions on the basis of floristic, ecological and climatological data. These are: (i) Western Nepal (Uttar Pradesh border of India to 83^{0}E) just to the west of Dhaulagiri and is dominated by western Himalayan flora such as cedars, cupressus, spruce, etc; (ii) Central Nepal (between 83^{0}E and 86^{0}30' E) just to the west of Mount Everest and represents a zone of merging of western and eastern Himalayan flora; and (iii) Eastern Nepal (east of 86^{0}30' E to Sikkim border) just to the east of Mount Everest and is dominated by eastern Himalayan flora such as oaks, rhododendrons, magnolias and laurels, etc. Stainton (1972) provided the forest classification into following six divisions on the basis of ecological and vegetation composition: (i) Terai, Bhabar, Dun valleys and outer foothills; (ii) the Midlands and southern slopes of the Himalayan ranges; (iii) the Humla-Jumla area in the north-west; (iv) Dry river valleys, (v) the Inner valleys, and (vi) the Arid zone. Based on these divisions, he identified 35 forest types in Nepal.

Dobremez (1972) has proposed four phyto-geographical divisions. These are (i) "*Domaine ouest nepalais*" (from Kumaon frontier to the longitude of Dhaulagiri at about 83^{0}28'E); (ii) "*Domaine nord ouest nepalais*" (the arid north-west region, i.e. north of Dhaulagiri and Annapurna); (iii) "*Domaine centre nepalais*" (from the longitudes of Dhaulagiri to that of Arun Valley at about 87^{0}10'E); and (iv) "*Domaine east nepalais*" (from the Arun Valley to the Sikkim frontier). He also laid down a schematic classification of 118 vegetation types along with 11 bio-climatic zones of Nepal (Shrestha, 1999).

Nepal comprises only 0.09 percent of the total landmass of the globe, but it possesses a disproportionately large diversity of flora and fauna at genetic, species and ecosystem levels (NBS, 2002). The country is yet to prepare any comprehensive Flora of Nepal that could provide detail information about the species. Higher groups of plants, namely, angiosperms and

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gymnosperms, are found to have been studied more in comparison to the lower groups, thallophyta, bryophyte and pteridophyta. A brief overview of floral species richness in Nepal and their share on a global scale has been given in Table 1.

Table 1: Floral Species Richness in Nepal

Groups	Species reported from Nepal	Nepal's share in globe (percent)
Lichens	465	2.3
Fungi	1,822	2.4
Algae	687	2.6
Bryophytes	853	5.1
Pteridophytes	380	3.4
Gymnosperms	28	5.2
Angiosperms	5,856	2.7

Source: NBS, 2002.

Endemic Species

A total of 246 flowering plant species have been reported endemic to Nepal (Shrestha and Joshi, 1996). An analysis of the distribution (horizontal and vertical) of endemic species shows that the highest concentration of endemic species (upto 91 percent) occur in sub-alpine zone (3,000-4,000 m), particularly in central Nepal. Protected areas (National Parks, Wildlife Reserves, Hunting Reserve, Conservation Areas and Buffer Zones) cover about 19.42 percent of the total land of Nepal. The protected areas house 140 plant species endemic to Nepal. The remaining 106 species of flowering plants (out of 246) occur outside the protected area system (Shrestha, 1999). The tropical area of Nepal supports very few species of endemic plants. Nepal is also reported to have 39 species of lichens, 16 species of fungi, 3 species of algae, 30 species of bryophytes and 8 species of pteridophytes endemic to Nepal (NBS, 2002).

Alien Species

A biological species introduced in an ecosystem other than its natural home is called alien or exotic species. It is a non-native biological entity, introduced intentionally or unintentionally. The different bioclimatic zones of Nepal favour the introduction of several alien species. Nepal has a long list of alien species introduced for various purposes e.g. cereals (maize), vegetables (potato, tomato, sweet potato), fruits (papaya, guava) and ornamentals (marigold, mirabilis, bougainvillea). These species are cultivated. They never outcompete native species and hence, their control is manageable. On the other hand, many other alien species are known to have become aggressive and rapidly colonized in Nepal, displacing the native species by predation, parasitism or by competition for space and nutrients. They are termed "Invasive Alien Species" (IAS). IAS are capable of altering the habitats and are likely to cause economic and/or environmental loss. They could even harm human health. Some major IAS of Nepal are *Ageratina adenophora, Chromolaena odorata, Lantana camara, Mikania micrantha, Eichhornia crassipes,* etc. It is important, however, to note that alien species are not the only species that could become invasive. There are many examples of native species showing invasive character. Few examples from Nepal include *Rubus ellipticus, Polygonum perfoliatum,* etc.

CHAPTER TWO

Invasive Alien Species

Definition

An alien species has been defined as a species that is non-native, non-indigenous, exotic, and foreign and/or introduced to an ecosystem other than its natural home. Such species may occur in locations beyond its known historical natural ranges. Any species including its seeds, eggs, spores or other living entities through which it is capable of multiplying and propagating in a foreign ecosystem could be an alien species. 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. Native species in an ecosystem thrive in harmony with each other whereby natural succession and biological control mechanisms maintain and sustain a climatic climax of species composition. 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.

The Global Invasive Species Programme has defined 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 systems and/or human health".
Ref.: http://www.gisp.org

Introduction of species to a non-native habitat has been a historical phenomenon both in terms of natural as well as human activities. It was initiated by explorers and colonists. People from all over the globe introduced plants and animal species from one part of the world to other parts in pursuit of fulfilling their social, economic and cultural needs. This has been an ongoing phenomenon, increasing in recent years, either intentionally or unintentionally. Intentionally introduced alien species include agricultural crops; horticultural, medicinal and ornamental plants; farm and pet animals or biological control organisms. Unintentional introduction of species could be through trade commodities, seeds' or organisms' dispersal/dissemination or organisms traveling as stowaway. Unintentional introduction is possible in case of species/ organisms 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 form a part of existing landscapes and ecosystems outcompeting the native species. However, not all alien species are considered as harmful. There exists a long list of alien species throughout the world introduced intentionally and make a valuable part of the livelihoods and economy of the modern world. These species form a basis of our food crops (potato, tomato, maize, etc.) and pose little or no threat to biodiversity, natural ecosystem or economy.

So long as alien species behave just as any other native species allowing them to multiply and sustain as they were doing in the past or could be actively managed, they are not considered as invasive. Many other alien species spread unmanageably, propagate relatively rapidly and outnumber all other native species in their own ecosystems. This is mainly because of their capacity to thrive upon foreign soil and climatic conditions. These species have been termed as invasive alien species (IAS). Sometimes the term noxious weed may be used for invasive species; it is a legal designation used specifically for plant species that have been determined to be major pests of agricultural ecosystems and are subject, by law, to certain restriction (http://www.nps.gov/plants/alien/bkgd.htm). IAS can be distributed everywhere and in all types of ecosystems of the world. Sometimes, alien species introduced deliberately for beneficial purposes could become invasive causing great damage to the livelihoods and environment. IAS is usually problematic in areas that have been disturbed either by anthropogenic activities such as forest clearing, grazing and infrastructure development or by natural causes (floods, landslides, etc.).

Characteristics

Invasive alien species displays strong vegetative growth, abundant seed production capacity, high seed germination rate, long-lived seeds, rapid maturation of a sexually reproductive stage and high ability to establish over large areas. They could exhibit one or many of the following characteristics:

- They grow rapidly and reach maturity early.
- Many species are capable of vegetative reproduction *via* stolons (*Alternanthera philoxeroides*, *Eichhornia crassipes*), rhizomes, bulbs (*Oxalis latifolia*) and rooting at the tips of stem (*Ipomoea carnea*, *Mikania micrantha*) and root fragments (*Ageratina adenophora*).
- They are highly adapted for wind and insect pollinations.
- Their seeds get widely dispersed by winds, water, birds and other means enabling them to colonize in new areas at distances far from their original home.
- They often have a different phenology for leafing to dormant stages that provide better opportunities for taking nutrients from soil.
- They usually are not attacked by parasites, diseases, herbivores, etc. in the newly introduced area.

Impacts

Both positive and negative impacts of IAS have been documented. In many countries and Islands, IAS have contributed to enrich their biodiversity. For example, in Florida, about 25 percent of plant and animal groups are of alien origin. Similarly, in Hawaii Islands, about 45 percent plant and 25 to 100 percent of species in various animal groups are introduced (Schmitz and Simberloff, 1997). Many IAS have been introduced for their economic and ornamental values usually for medicine, food, recreational purposes or industrial purposes including habitat restoration and as biological control organism.

In terms of negative impacts, IAS is considered as one of the greatest threats to natural ecosystems of the earth. IAS are considered as the second biggest threat, after deforestation, to biodiversity conservation. They disrupt the ecology of a natural ecosystem, displace the native plant and animal species as well as degrade the landscape's unique and diverse biological resources. 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). IAS are also considered as biological pollutors (Westbrooks, 1991) and are capable of hybridizing with native plant relatives that result in unnatural changes to a plant's genetic make up. In some cases, IAS have been driving many 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). The introduction of IAS breaks such relationships. Invasive alien plant species serve as host reservoirs for plant pathogens and other organisms that can infect and damage desirable native and ornamental plants.

IAS is also considered as an important source for human health hazard. A number of health related problems due to IAS have been identified. The seed of *Argemone mexicana* resemble mustard seed (*Brassica compestris*) and is used to adulterate mustard seed. *Argemone* seed yields non-edible toxic oil and causes lethal dropsy when the oil is used for cooking. The problem of lethal dropsy due to such adulteration is reported in Nepal. However, in Ayurveda, a number of pharmaceutical properties of this plant have also been documented. Another noxious weed is *Parthenium hysterophorus*, the pollens of which cause allergic types of diseases such as asthma, fever, dermatitis, etc. The ripe fruit of *Lantana camara* are considered edible and are eaten by humans and birds. However, it is reported that unripe *Lantana* fruit is considered highly toxic and may cause death among children in case a considerable quantity of unripe fruit is consumed. Similarly, oil of *Chenopodium ambrosioides* is very toxic. It can cause skin irritation and is dangerous to inhale. The sign of toxicity includes salvation, increased heart beat and respiration rate, changes in blood chemistry, etc. (www.ansci.cornell.edu). The seed of *Cassia occidentalis* is also reported as toxic and causes diarrhoea. Smoke produced by burning the firewood of *Ipomoea carnea* causes throat problem. Further, many IAS (*Ipomoea carnea, Xanthium strumarium, Ageratum houstonianum, Lantana camera,* etc.) are toxic to domestic cattle.

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).

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 become 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).

There are many documented cases of alien species around the world that have turned invasive. One of the examples of deliberate introduction of species which became serious invasive is Rosy wolfsnail (*Euglandina rosea*). It was introduced in Hawaii in 1955 to combat an exotic agricultural pest, the giant African snail (*Achatina fulica*). It has been reported that *E. rosea* is quite effective against A. fulica, but they have not been quantitatively evaluated and there is no report from anywhere that *E. rosea* has completely controlled *A. fulica (*Wittenberg and Cock, 2001). The report also highlights that population of indigenous snails are very much at risk due to the effectiveness of *E. rosea* as snail predator. In Oahu Island, a study has found that the alien snail

Beeshazari Tal, Chitwan

was responsible for the loss of about 15 to 20 endemic species of Achatinella snails. It also resulted in the catapulation of entire genus Achatinella into the USA Endangered List (Wittenberg and Cock, 2001). This is also a good example to warn the possible danger of biological control if such control is initiated without critical evaluation of the risk involved in doing so.

Huge economic loss due to IAS invasion has been estimated/reported from many developed countries. In the United States, a recent estimate indicates that invasive plants and animals entail US$ 20 billion direct economic losses each year affecting food crops, golf courses, the growing turf and ornamentals, industrial sites, forestry, aquatic sites, recreational areas, municipal water supplies, etc. (Gould, 2004). The total damage from the problems of IAS is estimated upto US$ 138 billion per year (http://www.cnie.org/ncseconference/bp/background9.htm). Similarly, African nations alone spend an estimated US$ 60 million annually to control alien water weeds, such as water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia* sp.). Cost of damage to native species and ecosystems further increases the above figures (Gould, 2004).

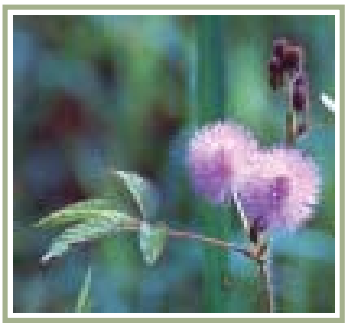
IAS also affect local economies by changing market prices and ecosystem services. Invasion of alien species reduces the productivity and environmental services in both aquatic and terrestrial ecosystems. Following case studies are some examples that illustrate the declination of local economy or impact on livelihood (Ciruna, *et al.*, 2004).

An infestation by the rapid spreading colonies of water hyacinth (*Eichhornia crassipes*) in wetland affects the production of fisheries and other aquacultural products. The prolifically growing plant deprives the life supporting elements (light, air) and reduces the availability of water for drinking, irrigation, navigation and hydropower generation. A study in Benin demonstrated that the impact of the invasion of water hyacinth dropped the annual incomes of local people from US$ 1,984 to US$ 607. Similarly, a golden apple snail (*Pomacea canaliculata*) was deliberately introduced in Asia during 1980 considering as a high protein food source for local consumption and for export. In Asian rice agro-systems, it soon turned out to be invasive spreading through extensive irrigation networks and feeding voraciously on rice seedlings. According to a case study in the Phillipines, actual loss in production amounted to between 70,000 – 100,000 tons of paddy, valued at US$ 12.5 – 17.8 million in 1990. The total cost for rice farmers due to golden apple snail introduction to Phillipines in 1990 was estimated between US$ 28 and 45 million, this included loss of yields and costs for control measures adoption.

Adequate studies about the extent of IAS spread, their impacts to native biodiversity and ecosystems as well as economic losses have yet to be done in Nepal. It is difficult to say how many species are getting extinct or threatened due to the invasion of alien plant species. However, their impact at population level has been realized. Nepal being predominantly an agrarian country, has introduced many alien species. They have been introduced intentionally from neighbouring and other countries to increase the farm and horticultural production. However, many more have been introduced unintentionally owing to the land-linked situation of the country. The environmental impact in different natural ecosystems has already been exhibited by some species, but the economic loss caused by IAS is still unknown. In agro-ecosystems, farmers have experienced remarkable loss in yields and quality of crop due to the invasion of various alien species. The actual losses in monetary terms, however, remain to be assessed.

Xanthium strumarium, in agricultural field, Biratnagar.

CHAPTER THREE



Legislation

The legal and institutional frameworks pertaining to the control and management of invasive alien species is critical for the success of biodiversity conservation initiatives. This chapter highlights major conventions, laws and regulations pertaining to IAS that implies to Nepal. Attempt has also been made to review the institutional framework available in country for the control and management of invasive alien species.

Legal Instruments

Effective legal framework is necessary to regulate, manage and control the introduction of alien species. Many alien species such as water hyacinth (*Eichhornia crassipes*), lantana (*Lantana camara*), myriophyllum (*Myriophyllum aquaticum*), pistia (*Pistia stratiotes*), etc. are considered introduced in the past for ornamental and other purposes. These species could have turned into invasives in foreign soils. However, in the Nepalese context, legal framework alone is not sufficient to control or manage alien species. Many species in Nepal got introduced unintentionally through trade, tourism, transport and air because of its landlockedness nature with India and China. The legal measures could be more effective for controlling intentional or artificial introduction of species.

Nepal has yet to formulate any specific policy and legal instrument to regulate and control the introduction of alien species. However, being a signatory to many global environmental conventions/treaties pertaining to IAS, the country needs to fulfil obligations under these conventions. Besides, the country has developed many biodiversity conservation related and sector specific Acts and Regulations which address IAS to some extent.

International Regulations and Guidelines

Nepal is a signatory to the Convention on Biological Diversity (CBD). Article 8 (h) of the convention calls upon its contracting parties, as far as possible and as appropriate, to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species". Further, CBD Article 8(g) calls parties to establish or maintain means to regulate manage or control the risks associated with the use and release of Living Modified Organisms resulting from biotechnology which are likely to have adverse environmental impacts that could affect the conservation and sustainable use of biological diversity, taking also into account the risk to human health.

The International Plant Protection Convention (IPPC) of Food and Agriculture Organization (FAO) is in existence since 1951 (amended 1987). The convention applies primarily to quarantine pests in international trade. It creates an international regime to prevent spread and introduction of plants and plant products through the use of sanitary and phytosanitary measures

by the contracting parties. Parties establish national plant protection organization and agree to cooperate on information exchange and on the development of International Standards for Phytosanitary Measures which include agreements on definition (terminology) and way of working (procedures). Regional agreements exist for many regions such as Europe and Mediterranean region, the Asia-Pacific, Near East, Pacific, Caribbean, North America, South America and Africa. Nepal has yet to become a party to this convention. However, since 1998, Nepal is trying to enter into this convention. Nepal is a party to the plant protection agreement for the south-east Asia and Pacific Region since 1965. It is a supplementary agreement under Article III of IPPC. The regional agreement pertains to the prevention through concerted action, the introduction into and spread within the Southeast Asia and Pacific region of destructive pests and plant diseases. Article III of the agreement relates to measures regarding the importation of plants from outside the region. Similarly, Article V of the agreement deals with the measures regarding movement of plants within the *Region (*http://sedac.ciesin.org/entri/texts/plant.protection.south-east.asia.pacific.1956.html).

Nepal became a member of World Trade Organization (WTO) in 2004. It is mandatory for the WTO member countries to implement the agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). It is a supplementary agreement to the WTO Agreement and provides uniform interpretation of the measures governing safety of plant and animal health regulations. It is applicable to all sanitary and phytosanitary measures directly or indirectly affecting international trade. Sanitary and phytosanitary measures have been defined as any measure applied to protect animal or plant life or health within the member country's territory from entry, establishment or spread of pests, diseases, organisms carrying diseases, and to prevent or limit other damages within the member country's territory from the entry, establishment or spread of pests, diseases or disease carrying organisms.

Article VI of the SPS Agreement concerning cooperation in the Quarantine of Plants and their protection against pests and diseases also urges the parties to undertake measures to prevent the introduction from one country into another, in exported consignments of goods or by any other means, of quarantinable plant pests and diseases and weeds specified in the lists to be drawn up by agreement between the parties concerned.

The Convention on Wetlands of International Importance especially on Waterfowl Habitat (Ramsar Convention, 1971) recognizes the adverse environmental impacts of IAS on wetlands. The eighth meeting of the Conference of Parties (COP) made a resolution (VIII 18) on invasive species and wetlands. It urges contracting parties to identify the pressure of IAS in Ramsar Sites and other wetlands in their territory. The resolution urges parties to identify threats they pose to the ecological character of those wetlands including the risk of invasions by such species not yet present within each site. It also requires identifying actions underway or planned for their prevention, eradication or control. For Ramsar Sites, the convention requires to report on the above to the the Ramsar Bureau without delay in line with article 3.2 of the convention, so that this information may be included in the Ramsar Sites Database. It further encourages contracting parties in their development and implementation of national strategies and responses to IAS to recognize that terrestrial invasions by alien species can threaten and affect the ecological character of wetlands, including lowering of water tables and alteration of water flow patterns and to ensure that appropriate measures to prevent or control such invasions, are in place.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) intends to prevent or regulate the international trade in species of flora and fauna which are threatened or endangered in exporting countries (Appendices I, II and III). Introduction of IAS can be possible through international trade. Therefore, the convention intends to prevent harm to native biodiversity in exporting countries. However, the convention can be applied when species is endangered in exporting country and considered an invasive in importing

country. It can regulate intentional movements only.

Agenda 21 of the United Nations Conference on Environment and Development (UNCED) calls upon its parties to increase protection of forests from disease and uncontrolled introduction of exotic plant and animal species (11.13g). It acknowledges that inappropriate introduction of foreign plants and animals have contributed to biodiversity loss (15.3). It also urges parties for controlling noxious aquatic species that may destroy other aquatic species (18:40e).

The IUCN Guidelines for Preventing Biodiversity Loss due to IAS (2000) has been designed to increase awareness and understanding of the impact of IAS. It provides guidelines for the prevention of introduction, re-introduction and control as well as eradication of IAS (IUCN, 2000).

National Regulations

Nepal formulated its Nepal Biodiversity Strategy (NBS) in 2002 that shows the commitment of the government and people of Nepal to the protection and wise use of 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 loss of species and genetic resources (NBS, 2002).

A National Wetland Policy has also been approved in 2003. It addresses the need to conserve and manage wetlands and to promote their wise use. One of the objectives of the policy is to eradicate, control and manage IAS in the wetland ecosystems of Nepal. The policy considers all non-native organisms (animals, plants, germs, Living Modified Organism, Genetically Modified Organism) that compete and displace the native species as IAS. The policy guides to restrict the entry of such organisms and strictly control and manage these organisms if they have already been introduced/established. Appropriate legal framework for this to happen, however, is yet to be formulated.

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 programmes to control them.

The Plant Protection Act, 1972, and Plant Protection Rules, 1974, have been enacted with an objective to eradicate and control the accession and extension of destructive germs and diseases likely to affect plants or plant products during export and import. The Act prohibits/regulates the entry of plants or plant products from any country. For the propose of this Act, "plant" has been defined as all living or dead plant or part thereof and it includes stem, branch, corm, bulb, tuber, bark, root, leaf, nursery stock, vegetatively propagated materials, fruit, vegetable and seed. Section 3 of the Act authorizes the government to do any of the following with respect to the importation of plants and plant products into Nepal. A notice should be published in the Nepal Gazette to:

- Prohibit the importation of any suspicious plant or plant product. Permit the importation of any plant or plant product without a license on specific terms and condition and for a specified fee.
- Specify necessary measures and conditions for the transportation of any plant or plant product from one district to another district within Nepal.
- Specify necessary measures and conditions with regard to the means of transport, packaging or godown for the importation of any plant or plant product.
- Establish quarantine stations, check points and laboratories for the inspection and treatment of plants or plant products and prescribe their roles and responsibilities.
- Prohibit the importation of soil attached to a plant or plant product or soil only, or any other medium on which plants can grow or prescribe the treatment required for such soil before importation.
- Specify entry or exist points for the importation and exportation of plants and plant products; and

- Prohibit the entry of organisms, bacteria, spiders and snails or prescribe the planting or keeping plants or plant products in certain places to check over spread.

HMG/N has prohibited the import of 19 plants or plant products from specified countries by exercising the power conferred by section 3 of Plant Protection Act (PPA) to prevent the introduction of various dangerous plant pests or pathogens in the country. If these plants or plant products have been imported from any country other than specified or prohibited, it must be accompanied by an official certificate mentioning that these plants or plant products (seed etc.) are free from prohibited diseases.

Under the PPA, plant quarantine is a technique of plant protection which uses legislative methods to prevent the spread of undesirable organisms. There is a provision of Plant Quarantine Officer to execute the quarantine process. The Plant Quarantine Officer will be ultimately responsible for preventing the introduction and spread of plant pests, pathogens and weeds, and for controlling the movements of other organisms covered by the plant quarantine legislation. The major actions of plant quarantine include (Palikhe *et al.* 2002):

- Issue of importation permit and phyto-sanitary certificate provided by Plant Quarantine Officer;
- Inspect consignments prior to export and, if necessary, fumigation and disinfections for providing phyto-sanitary certificate;
- At the point of entry, inspect imposed consignments along with phyto-sanitary certificate from the country of origin;
- Conduct post-entry quarantine survey of the imposed plants and seeds and allow to grow in specific area for monitoring by plant quarantine staff; and
- Update the list of export and import of plant and plant materials.

The PPA is a pioneer Act promulgated for plant protection in Nepal. However, it is more focused on plant diseases or disease carrying organisms. It fails to adequately address the issues of IAS except for some agricultural weeds that could be both native and non-native. The legislation has only been partially implemented owing to the government's apathy (Belbase, 1999).

List of nineteen plants or plant products prohibited and restricted to import into Nepal from specified countries:
Maize (*Zea may*); Tobacco (*Nicotiana tabaccum*); Sugarcane (*Saccharum officinarum*); Citrus fruit (*Citrus* spp.); Tea (*Thea sinensis*); Cotton (*Gossypium* spp.); Potato (*Solanum tuberosum*); Banana and other plants of family Musaceae (*Musa* spp.); Paddy (*Oryza sativa*); Sweet Potato (*Ipomoea batatas*); Tomato (*Lycopersicon esculentum*); Ground nut (*Arachis hypogea*); Bread fruit (*Artocarpus* spp.); fruits and vegetables; sunflower, lettuce; soil and rooted plants; Wheat (*Triticum* spp.).

The Seed Act, 1988, is adopted with an objective to produce and distribute quality seeds in order to increase the yield of agricultural crops. The Act has provided for the establishment of a National Seed Board headed by the Secretary of the Ministry of Agriculture and Cooperatives to advise the government in the formulation and implementation of a seed policy. The Act has also aimed at promoting grasses/forages. But there are various examples of grasses and fodder such as Ipil Ipil (a fodder tree) turning out to be invasive in foreign soil but the Act does not address this issue. In totality, Nepal's Seed Act is silent about the adverse impacts of IAS. There are some provisions such as prohibition on the sale of seeds that fail to comply with the minimum requirements of germination and purity, but what would be the measuring scale of purity is not described in the Act. Although seed contamination is supposed to be one of the sources of the spread of IAS, the Act remains fairly weak to check the contamination. The Act empowers the government to regulate and control the standard seeds but the institutional arrangements for the implementation of provisions remains insufficient.

The National Parks and Wildlife Conservation Act, 1973, prohibits grazing, cutting, burning or

damaging plants inside the protected areas. Similarly, the clearing of land and cultivating inside the protected area is strictly prohibited for the cause of conservation of ecologically valuable ecosystem and indigenous wildlife. This Act does not have direct provisions to check the invasion of alien plant species. However, such restrictions indirectly help to prevent the introduction of new invasive or reduce the invasion of existing ones.

The Forest Act, 1993, recognizes the importance of forests in maintaining a healthy environment. It has a number of provisions for the conservation of biodiversity though invasive species have not specifically been dealt with. The objective of the leasehold forestry programme for producing forest-based raw materials, however, fails to be conservation-friendly. In order to enable quick income generation by producing raw materials required for forest-based industries, it allows for the production of high yielding exotic, including medicinal plants and improved variety of grasses in up to 40 percent of the leased forest areas (Belbase, 1999). These exotic species could exhibit adverse impact, thus negatively affecting conservation.

The draft Ordinance on Access to Genetic Resources and Benefit Sharing, 2005 consists of a relevant provision dealing with the import of genetic resources. Article 9 outlines that the registration and utilization of the genetic resources and genetic materials that are imported to Nepal from foreign countries would be as prescribed. Though this provision is mainly considered in terms of access to the genetic resources and sharing of the benefits out of their use, this could be useful in controlling IAS to some extent.

Thus, there is a gap in the existing policies and legal instruments for the control and management of IAS. Inadequate provisions to address IAS issues in the existing regulatory frameworks indicate that most of the sectors are yet to be sensitive towards the environmental impacts of IAS. No organization is responsible to lead the management or control of IAS. The Plant Protection Act, 1972, and Plant Protection Rules, 1974, are focussed to control and eradicate the accession and extension of destructive germs and diseases in agricultural crops but do not address adequately the IAS that are in higher groups. Though the introduction of alien species is recognized by Nepal Biodiversity Strategy, 2002, and National Wetland Policy, 2003, as one of the root causes for the species and/or genetic loss in Nepal, formulation of specific Act for IAS is still awaited.

Impacts of IAS are being experienced in different types of ecosystems that fall under the jurisdiction of various government authorities. Therefore, provisions should be made in relevant sectoral Acts and regulations to address the threats of IAS. For this, an integrated effort with

Myriophyllum aquaticum, Taudaha, Kathmandu.

the involvement of all relevant stakeholders including communities is essential. Quarantine regulations that often focus on agricultural aspects only need to be widened to provide protection to native ecosystems/species.

Institutional Arrangements

The increasing volume of global trade and land use changes enhance the opportunity for global spreading of IAS and are likely to become more severe in near future. Yet, both national and multinational leaderships remain under-informed about the scope and gravity of IAS problem. Nevertheless, some useful initiatives are being taken all over the world for their effective management. IAS is now becoming a major focus of international conservation concern and the subject of cooperative efforts (www.issg.org/plantlibary/invasives/invasivenewsfall2000.htm). Some examples of such global initiatives is the Global Invasive Species Programme (GISP). It was established in 1997 and is coordinated by the Scientific Committee on Problems of Environment (SCOPE) in conjunction with Centre for Agricultural Bioscience International (CABI), United Nations Environment Programme (UNEP) and IUCN-The World Conservation Union. GISP is committed to raise awareness on problems of IAS and sharing best practices for their management. Similarly, the Species Survival Commission (SSC) of IUCN has formed the Invasive Species Specialist Group (ISSG) focusing on the problems of invasion all over the globe (www.issg.org).

Nepal so far does not have any specific institution responsible for IAS and it yet remains an overlooked environmental problem. The governmental agencies that are designated as focal points for various global environmental conventions/agreements are mandated to fulfill the IAS related obligations. For example, the Ministry of Forests and Soil Conservation (MFSC) in Nepal as a focal point to implement the Convention on Biological Diversity (CBD) discharges its responsibilities through different departments. The Department of National Parks and Wildlife Conservation (DNPWC) is responsible to conserve the native biodiversity and ecosystem within the protected area systems. This department is also designated as focal point for Ramsar Convention and Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES). The Department of Forests is responsible to manage the national forest ecosystems. More than 13,000 Forest User Groups are involved in the management of community forests under community forestry regulations. The maintenance of a sound forest ecosystem and biodiversity within forest is the key concern of the Forest User Groups in pursuit of forest management and utilization. The Department of Soil Conservation and Watershed Management is responsible for providing technical service for land use planning along the watersheds.

Besides, the Ministry of Agriculture and Cooperatives (MoAC) is responsible for overall agricultural development, including conservation of agro-biodiversity. This ministry is also a focal point for several international agreements and conventions, including Plant Protection Agreement for Southeast Asia and Pacific region; Agreement on the Application of Sanitary and Phytosanitary Measures etc. The Department of Agriculture under the MoAC has created a Plant Protection Directorate (PPD) in 2000. PPD is mandated to implement plant protection programmes in coordination with Plant Quarantine Section. In order to prevent the introduction and spread of pests and diseases, Nepal has established 6 Quarantine Check Posts at different locations adjoining Indian border (Kakarbhitta, Biratnagar, Jaleshwor, Birgunj, Bhairahawa and Nepalgunj) and one at Tribhuvan International Airport, Kathmandu.

Despite various arrangements, nobody is directly responsible for research and management to regulate the introduction of IAS. Even the quarantine office is not much aware or sensitive about the environmental, economic and health impacts of IAS. There is a lack of specific regulations, manual, guidelines, laboratory, taxonomic capacity, etc. for the identification of IAS. The overall institutional facilities and human capacity need to be improved by providing essential technical support, strengthening coordination and sharing IAS information among concerned agencies and stakeholders.

CHAPTER FOUR

Objectives And Scope

Many alien species have been introduced in Nepal from different pathways owing to Nepal's land-linked situation. Some species have already exhibited their invasive character and many more species are leading towards widespread invasion. However, knowledge base on IAS in Nepal is limited. There does not exist any comprehensive study and research work revealing the status and impact of invasion of plants in Nepal. Given the diverse ecological ground that Nepal holds, it has been crucial to develop a knowledge base on the status and impact of alien plant and other species in the country.

IUCN Nepal initiated an inventory and assessment of the alien plant species in Nepal in order to fulfil this knowledge gap. The purpose of this work has been to develop and contribute to a baseline information on the existing state of alien species of invasive character. This is deemed necessary not only for the monitoring and assessment of invasion but also for the control and management of invasive plant species through policy, institutional and programmatic interventions.

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Mikania micrantha, Charkoshe Jhadi.

It is expected that the study results will be beneficial for the policy and decision makers, foresters, agriculturalists, environmentalists, conservationists, students, researchers, academicians and development workers interested in biodiversity conservation.

Objectives

The purpose of this inventory and assessment has been to enumerate the invasive alien plant species in Nepal and undertake an assessment of risk/s posed by them in different ecosystems. The specific objectives are:

- to document and enumerate the non-native plant species of invasive character;
- to generate awareness about the adverse impacts of IAS;
- to assess the impact of major IAS in different ecosystems of Nepal;
- to prioritize IAS in different ranks by evaluating their invasiveness; and
- to prepare "species profiles" of major IAS in Nepal.

Scope and Limitation

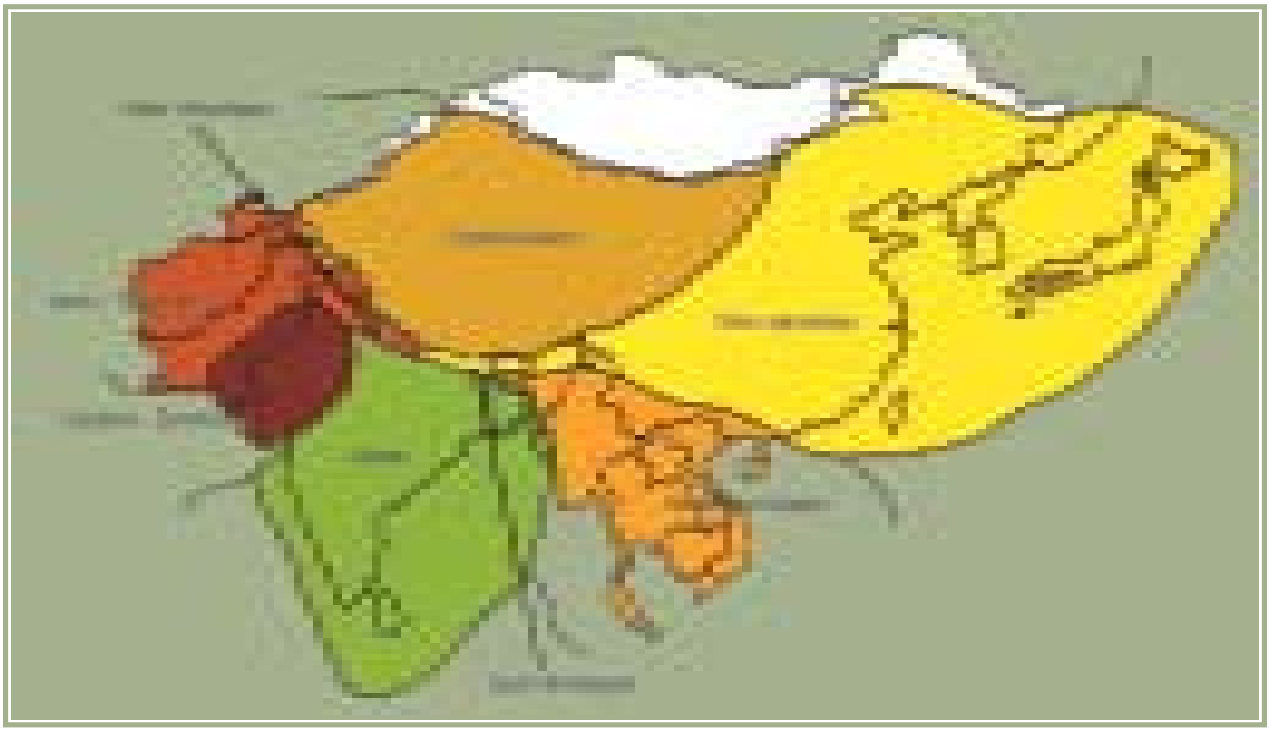
This inventory highlights the current status of invasive alien plant species in Nepal and also serves to describe the general concept on IAS with definition, characteristics, and environmental impacts, legal regulatory mechanisms mandated by global and domestic regulations. It also provides a checklist of non-native species including their place of origin and other relevant information. Although origin of many species presented is subjected to confirmation, detail information on major invasives plant of different ecosystems in Nepal has been presented in the "Species Profiles".

This inventory should be considered a starting point of IAS research. An attempt has been made to cover only the plant species naturalized in certain geographical ranges (Terai to mid-hills) of Nepal. The field survey could be conducted a single time for a particular site. Another limitation was that the field visits to different sites could not be done in the same season. It is important mentioning here that the assessment does not cover species that remained outside the sampling sites, a scope for furthering IAS assessment in future. Besides, researches on IAS invasion have not been done before. Though the analysis of the field observations is based on the standard methods (Zobel *et al.*, 1987), the results form the assessment study could not be compared with findings from other researches. For the sake of convenience, this study considers those plant species as alien that do not fall under the six floristic provinces of Asia (fig. 2).

Six Floristic Provinces of Asia

1. Sino-Japanese (the Himalayan mountain range and its foothills);
2. South-East Asian (Malaysian floristic region to the south-east);
3. Indian (south);
4. African-Asian desert (south-west);
5. Irano-Turranan (north-west); and
6. Central Asiatic provinces (north).

Fig 2: Major Floristic Provinces of Asia



CHAPTER FIVE

Methodology

The inventory and assessment work builds on the expertise of the plant scientists of Nepal. It has adopted participatory tools and techniques and some technical field works in addition to literature review. The steps undertaken to accomplish this work are explained in the following paragraphs.

Expert Consultation

The process was initiated by developing and circulating a background paper to draw the attention of the scientific community and key stakeholders of natural resources and environment. The paper emphasized on the emerging need to develop knowledge base on IAS in Nepal (Tiwari & Siwakoti, 2001). A consultative workshop was held in August 2001 to discuss the emerging need of inventory and assessment of invasive alien plant species in Nepal. Over 20 plant experts representing government and non-governmental organizations participated in the consultation. The experts worked out to define the alien and invasive plant species in the context of Nepal. A format for the collection of different types of information required for the inventory and assessment of alien invasive plants was also worked out. In order to ensure that the inventory could provide an overall status for Nepal, a working modality was discussed that resulted in developing a broad methodology to be adopted for this work.

Formation of Team

A three-member core team was commissioned with the responsibility of coordinating and consulting with experts, stakeholders and partners, conducting orientation training to volunteers and reconnaissance survey, collect information, analyse data and prepare report.

Selection of Site

Information collected from primary and secondary sources show that majority of IAS are tropical in origin. The climatic conditions, particularly, lowlands (Terai, Siwaliks) and mid-hills of Nepal highly favour the growth of IAS. Considering the fact, the study is concentrated on tropical, sub-tropical and lower temperate regions of the country. The study covers forests, fallowlands, croplands and wetlands distributed in 16 districts (extended east to west) of Nepal representing tropical, sub-tropical and temperate regions. The selected sites lie in Jhapa, Morang, Sunsari, Dhankuta, Sarlahi, Chitwan, Rasuwa, Kathmandu, Lalitpur, Bhaktapur, Parbat, Palpa, Rupandehi, Dang, Doti and Kanchanpur districts.

Selection of Partners

Interested partners were selected on each site. They included a total of seven secondary schools, one campus, six community forestry users groups, one Non Governmental Organization (NGO) and

three farmer communities. Altogether, 119 volunteers from these partner institutions were involved in reconnaissance survey on 18 study sites distributed in 16 districts. In each site 5-9 volunteers participated for ecosystems studied and IAS related information collection. A full day intensive training was conducted in each site to acquaint them with the adverse environmental impacts of IAS and to educate the methods for information collection, including ecological survey with a concept of learning by doing. A complete set of questionnaire was also provided to each volunteer to collect information from local community.

Development of Flyers

Some most problematic IAS of Nepal were identified on the basis of literature review and experts' consultation. The selected problematic species were *Ageratina adenophora, Ageratum conyzoides, Alternanthera philoxeroides, Amaranthus spinosus, Argemone mexicana, Bidens pilosa, Cassia occidentalis, Cassia tora, Chromolaena odorata, Eichhornia crassipes, Hyptis suaveoles, Ipomoea carnea* ssp. *fistulosa, Lantana camara, Leersia hexandra, Mikania micrantha, Mimosa pudica, Myriophyllum aquaticum, Oxalis latifolia, Parthenium hysterophorus, Pistia stratiotes and Xanthium strumarium.* The major criteria for the selection of the species included the following:

- rapid growth and maturity;
- high seed production;
- highly successful seed dispersal, germination and colonization;
- rampant vegetative growth;
- ability to outcompete others;
- high cost of removal and control; and
- ability to establish in more than one ecosystem and in vulnerable ecosystems.

A single page flyer furnished with photograph/ sketch, scientific and local names, geographical distribution, taxonomic and ecological characters and uses, if any, was developed in Nepali language for each of the selected IAS. These were distributed to the volunteers from the partner organizations and local communities in each site. The flyer was aimed at educating them on the nature and adverse impacts of IAS.

Development of Data Collection Sheet

A data collection sheet was finalized based on preliminary information sheet designed from the idea of consultative workshop. The information sheet aimed at collecting general, geographical, ecological and economic characteristics and management practices of IAS. Information sheet was pre-tested at Taudaha, Kathmandu (mid-hills). Attention was given to make the sheet simple and reflective of its intended purposes by avoiding redundant and unnecessary information.

Collection of Information

Both secondary and primary information sources were used to collect information. The taxonomic literature mainly related to Nepal (Hara *et al.* 1978, 1982; Hara and Williams, 1979; NBS, 2002; Press *et al.* 2000; Shrestha, 1998; Siwakoti and Varma, 1999) were properly reviewed to know the selected IAS's country of origin, distribution range, current name, first scientific record to Nepal, and other related information. Primary information was collected from the study sites through Participatory Rapid Appraisal (PRA) and survey techniques. The specific tools used to collect information were direct field observation with a group of volunteers, interviews and questionnaires survey with local communities. Field observation as well as specimens housed at National Herbarium Godavari (KATH) was consulted to prepare the distribution map.

Ecological survey was conducted to find out the current status of IAS. The quantitative data of IAS such as density, frequency and coverage were collected by random quadrate sampling method. Different sizes of quadrates were used in different kinds of ecosystems. In each ecosystem, 10-20 quadrates were laid down. The sampling size of quadrate was 20 m x 20m for trees; 5m x 5m for shrubs and 1m x 1m or 50cm x 50cm for herbs.

Quantitative Data Analysis

The ecological data were interpreted using standard methods (Zobel *et al.* 1987).

1. Frequency:

Frequency was calculated separately for individual plant species using the following formula:

Frequency (F) (%) =

$$\frac{\text{No. of plots with individual species}}{\text{Total no. of plots studied}} \times 100$$

2. Density:

Density is the number of individual of a species per unit area or volume. By definition, density requires actual count of individuals in a definite space. It was calculated using the formula:

Density (D) (no. of plants per Hectare)=

$$\frac{\text{Total no. of species in all quadrat}}{\text{Total no. of quadrat studied X area of quadrat}} \text{X10000 m2}$$

3. Coverage:

Cover is defined as the vertical projection of the crown or shoot area of a species to the ground surface. The cover of the ground vegetation was determined by visual estimation.

Assessment of Invasiveness

The prioritized species were evaluated to find out their magnitude of invasiveness. This was assessed by using a modified form of "Invasiveness rank form" developed by Virginia Department of Conservation and Recreation Division of Natural Heritage in June 2001. The invasiveness was categorized into four ranks (high, medium, low and insignificant) based on the following four criteria:

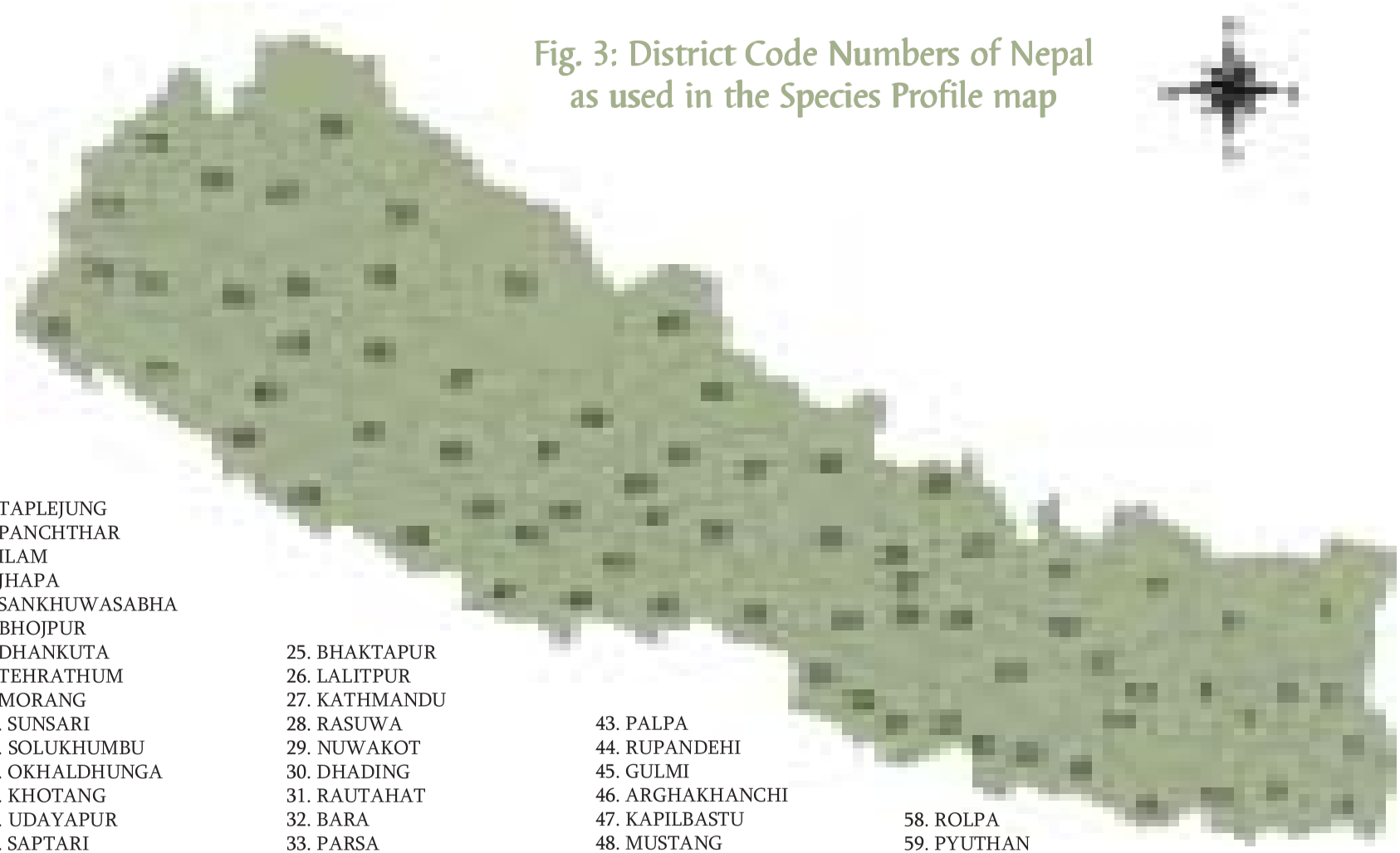
1. Impact on native species, habitats and ecosystems;
2. Biological characteristics and dispersal ability;
3. Distribution and abundance; and
4. Difficulty to control.

Data Presentation

The collected information was properly analyzed and entered into a format. The format developed by Global Invasive Species Programme (GISP) with slight modifications was used (www.gisp.org). On the basis of frequency of distribution and nature of invasiveness, the topmost 21 species were selected for species profile. A checklist of potential IAS was also developed. The inventory excludes the cultivated alien species.

This report provides species profiles of the selected IAS which have been arranged on the basis of invasiveness rank (high, medium, low, insignificant). The "species profiles" includes botanical name of species followed by its synonyms, family, common and local names, if any. A brief diagnostic characteristics of each species follows its habitat, uses, country of origin, distribution range, first reported in Nepal, ecological characters, possible pathways, reproduction mode and dispersal methods. The existing management practices, if any, in Nepal (based on field information) or around the world (secondary sources) is also provided. A brief field note is given as and when appropriate. First Herbarium record of specimen housed at National Herbarium, Godavari (KATH) is also provided, where available.

Fig. 3: District Code Numbers of Nepal as used in the Species Profile map



1. TAPLEJUNG
2. PANCHTHAR
3. ILAM
4. JHAPA
5. SANKHUWASABHA
6. BHOJPUR
7. DHANKUTA
8. TEHRATHUM
9. MORANG
10. SUNSARI
11. SOLUKHUMBU
12. OKHALDHUNGA
13. KHOTANG
14. UDAYAPUR
15. SAPTARI
16. SIRAHA
17. DOLAKHA
18. RAMECHHAP
19. SINDHULI
20. DHANUSA
21. MAHOTTARI
22. SARLAHI
23. SINDHUPALCHOWK
24. KAVRE
25. BHAKTAPUR
26. LALITPUR
27. KATHMANDU
28. RASUWA
29. NUWAKOT
30. DHADING
31. RAUTAHAT
32. BARA
33. PARSA
34. MAKWANPUR
35. CHITWAN
36. GORKHA
37. LAMJUNG
38. TANAHU
39. MANANG
40. KASKI
41. SYANGJA
42. NAWALPARASI
43. PALPA
44. RUPANDEHI
45. GULMI
46. ARGHAKHANCHI
47. KAPILBASTU
48. MUSTANG
49. MYAGDI
50. PARBAT
51. BAGLUNG
52. DOLPA
53. MUGU
54. JUMLA
55. KALIKOT
56. HUMLA
57. RUKUM
58. ROLPA
59. PYUTHAN
60. DANG
61. SALYAN
62. JAJARKOT
63. DAILEKH
64. SURKHET
65. BANKE
66. BARDIYA
67. BAJURA
68. ACHHAM
69. BAJHANG
70. DOTI
71. KAILALI
72. DARCHULA
73. BAITADI
74. DADELDHURA
75. KANCHANPUR

CHAPTER SIX

Profile of Selected Invasive Alien Plant Species

High Risk Posed Invasive Alien Species

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*)

First Herbarium record Manichur forest, 2134 m, 28.03.1961, P.N. Suwal & Party (KATH)

Habitat Open forest margins, grasslands, agricultural lands and fallowlands

Description Perennial, erect or decumbent, foetid subshrub. Stem erect, branched, dark purple or purplish brown glandular-pubescent. Petiole slender, 0.5-3cm long; leaf blade ovate or rhomboid-ovate, 2-6 × 1.5-6cm, base obtuse to cuneate, margin dentate, apex accuminate. Capitula *ca* 50-60 flowered, white, disciform, homogamous, campanulate in dense axillary or terminal glandular hairy peduncled corymbs. Involucres 3 seriate; outer phyllaries few, reduced, inner many, acuminate. Achenes glabrous; pappus bristles, caducous. Seeds numerous.

Fl. & Fr. 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)

Ecological characters The plant grows well in disturbed forest, forest margins, fallowlands, and surroundings of agricultural lands. The plant prefers moist areas but also occurs in open areas. The dense stands of this plant prevent the establishment of other species, both due to competition and allelopathic effects. The plant has unique odour and toxin that makes it unattractive to cattle. It absorbs most of the nourishment of soil to support the rampant expansion of the plant.

Reproductive mode Reproduces sexually by seeds and vegetatively by roots.

Dispersal methods Seed dispersed by wind. Seeds also cling to fur, hair and clothing

Invasion pathways The open and land-linked border with India makes easy to enter this plant in Nepal via India through commercial routes. The numerous light seeds are easily contaminated with agriculture, horticulture, forestry and pasture seeds, or stick to the body of human, livestock and vehicle, etc. or in some adjoining places, seeds are dispersed by air current. It is expected that the first introduction of this plant is in eastern and central Nepal and aggressively naturalized in Siwaliks and mid-hills of entire Nepal.

Management information

Physical In Nepal, people remove plant mechanically by hands at early stages particularly from agricultural land. But if it spreads, it is difficult to remove because the roots form dense mats, hard to remove. In uncultivated habitats, mechanical control is impracticable and expensive.

Chemical Chemical control by using herbicides (e.g. triclopyr) may be effective. But it is impracticable and expensive and may turn counter-productive to the environment.

Biological In 1984, the Chinese Kunming Institute of Ecology, Academia Sinica found a gall forming tephritid *Procecidochares utilis*, attacking Crofton weed near Chinese/Nepalese border (Wan and Wang, 2001). This Mexican insect had been released in India for the biocontrol of Crofton weed in 1963 (Julien, 1992). The species has caused considerable mortality in pests of Australia, South Africa, New Zealand and India. The parasite larvae live in the stem of the weed, but the weed has not been noticeably suppressed (He *et al.,* 1988).

In 1987, a fungus native to Yunan, *Mycovelosiella* sp. was found to be more effective than stem galling tephritid (Wan and Wang, 2001). Much research has already been done in China but effective control measures have yet to be found.

Field observation In Nepal, most of the disturbed and open landscape (500-2400m) were found to be invaded by the *Ageratina adenophora.* The plant is found to be aggressive in disturbed forests including *Pinus* and *Alnus* forest. The fallowlands and margins of crop fields are also covered by this plant. According to local people, the plant was seen as invasive more than 40 years ago in Dhankuta (eastern Nepal), 6-7 years ago in Langtang region (central Nepal), and 5-6 years ago in Doti (western Nepal). They also informed that after the introduction of the plant, the ground vegetation layer such as *Banso* (*Digitaria* sp., *Eragrostis* sp. etc.), and Siru (*Imperata cylindrica*) etc. have been reduced or have disappeared in some places. It was also believed that people who went to Assam State of India in search of employment brought this plant in Nepal so called *Assame* or it may be introduced through the tea plantation saplings. Many people believe that it decreases the soil fertility by absorbing nutrients from the soil. The cardamom cultivation along the moist hilly areas of eastern Nepal was found to have reduced invasion of this plant to some extent.

Chromolaena odorata (Spreng.) King & Robinson

Synonym *Eupatorium odoratum* Spreng. L.

Family Asteraceae (Compositae)

Common/English name Siam weed; 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)

First Herbarium record Uttarpani, 2000ft, 19.12.1964, M.S. Bista (KATH)

Habitat Edges of forests, fallowlands, shrublands, agricultural lands and grasslands.

Description Perennial herb or sub-shrub up to 2.5m high with long rambling branches; stems terete. Leaves opposite, pubescent; petiole 0.5-1.5cm long; leaf-blade ovate, 3-8 × 2.5-5cm, base cuneate to attenuate, margin coarsely serrate, apex acuminate. Capitula discoid; florets 20-30, more or less all alike, pale purple to white in sub-corymbose axillary and terminal clusters. Involucres 3-4 seriate; phyllaries imbricate, with 3 green ribs on back; style exserted. Achenes linear-oblong, blackish hairy on the ribs.

Fl. & Fr. 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)

Ecological characters The plant grows well in sunny open and well-drained areas such as forest margins, fallowlands and roadsides. It requires disturbances to native vegetation in order to become established. Shoots start rooting once in contact with moist ground. It possesses an underground organ, which ensures the plants survival in case of fire, drought or mechanical damage through coppicing. 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.

Reproductive mode Sexual reproduction starts when the plant is one year old. Seed production is prolific and reported up to 87,000 seeds per mature plant (www.issg.org/database). Seeds germinate readily. Terminal cymes bear around 70 insect pollinated flowers. The small fruit (0.2mm) mature in about a month. The plant resprouts from the root crown following fire or death of old stem.

Dispersal methods Seeds are typically wind dispersed, dry and windy weather is necessary for fruit release. Most seed dispersal is local. However, seeds have small spines and can cling to the fur, feather and clothes which makes possible for long distance dispersal through mammals. Seeds can also travel great distance with contaminated crop plants or vehicles.

Invasive pathways It got introduced in Nepal (most probably first time in the plains of east Nepal) via plains of northeast India through the movement of people for labourers in tea plantations and other activities in West Bengal and Assam. The tiny seed can be contaminated in imported agriculture, forestry and pasture seeds, the barby seeds easily stick to the body of humans, cattle, vehicles, etc. or seeds are easily blown by air current. It is also expected that the initial introduction to southeast Asia probably through Calcutta Botanic Garden, where introduced from Jamaica after Roxburgh's period , 1783-1813 (Sharma and Pandey, 1984).

Management information

Physical In Nepal, people remove it manually by coppicing seasonally if they occur along croplands; but it regenerates rapidly.

Chemical Chemical control using herbicides (triclopyr) applied at the seedling stage or on early regrowth has given encouraging results (www.hear.org./pior/species/chromolaena_odorata.htm). However, it is expensive and non-compatible in many cropping and other environmental situations.

Biological *Chromolaena odorata* is a good candidate for its biological control by the introduction of natural enemies, particularly an arctiid moth, *Pareuchaetes pseudoinsulata*. It effectively defoliates pure stands into Guam, but it is less successful in scattered plants and patches. It was introduced in northern Sumatra of Indonesia where it became effective in reducing density of the weed, but it is not successful in other parts of Indonesia. Another natural enemy, the fly *Cecidochares connexa* has also been successful to control the weed in Indonesia and Philippines (Muniappan and Nandwani, 2002).

Field observation The plant has become well established in disturbed areas such as fallowlands, roadsides, and degraded forests at tropical region of eastern and central parts of Nepal, whereas in western Nepal, it is not observed. The plant invades the interior of the forest if the forest canopy is open. In closed canopy and shaded area, the plant has not succeeded to invade. The plant has become more aggressive since 35-40 years although it was introduced many years ago according to the local people of eastern Nepal. Once established, it is difficult to eradicate because the roots are deep and are difficult to pull out. The thickness (circumference) of the plant is recorded up to 10cm at base According to the local people, some species of grasses (*Imperata sp., Digitaria sp., Eragrostis sp.*) are reduced considerably due to the invasion of *C. odorata*.

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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

First Herbarium record Nepalgunj, 31.10.1972, N.P. Manandhar 9207 (KATH)

Habitat Wetlands such as marshes, lakes/ponds, ditches and slow running water courses.

Description Perennial, stoloniferous herb, floating or rooting in mud; roots feathery. Leaves in basal rosette; petiole long, spongy, lower part becoming inflated; leaf blade rhombic to widely elliptic, 3.6-8.4 × 2.4-4.9cm, base cuneate, apex sub-acute. Inflorescence a terminal spike. Peduncle largely hidden by 2 sheathing membranous spathes; lower spathe bearing small leaf-like blade. Tepals pale mauve or pale voilet to light blue, occasionally white, upper most with yellow spot near base surrounded by darker mauve ring. Capsule 3-locular: many seeded.

Fl. & Fr. 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 have 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)

Ecological characters Water hyacinth is a very fast growing plant with population known to be double in as little as 12 days (IUCN, undated). It grows most prolifically in nutrient-enriched waters and forms small colonies, floating islands or extensive mats completely covering water surface that excludes most light and air for submerged organisms, thus depriving them of essentials for survival. The mats can have serious mechanical impacts on water supply system, drainage, canals as well as on inflow to hydropower generation. It prevents peoples' access to water bodies for collecting water and fishes and provides habitat to disease vectors and vermin. It also increases evapotranspiration causing significant loss of water.

Reproductive mode Water hyacinth reproduces vegetatively by means of stolons; sexually reproduces by seeds.

Dispersal methods Parts of plants (stolons) and seeds are dispersed by water current. Seeds germinate in a few days or remain dormant up to 20 years. (www.ecy.wa.gov/ programs/ wa/plants/mas)

Invasive pathways *Eichhornia crassipes* has been widely distributed throughout the tropics by the beauty of its large, purple to violet flowers which attract the people to cultivate for ornamental purposes. Further, the floating habit of plant makes easy to spread small broken pieces of stolon or whole plant or seeds by water current. Seeds are also dispersed by waterfowls. The plant was introduced as an ornamental plant in the Indian sub-continent in about 1890 from tropical south America, probably via Malaysia or Indonesia (Cook, 1996).

Management information

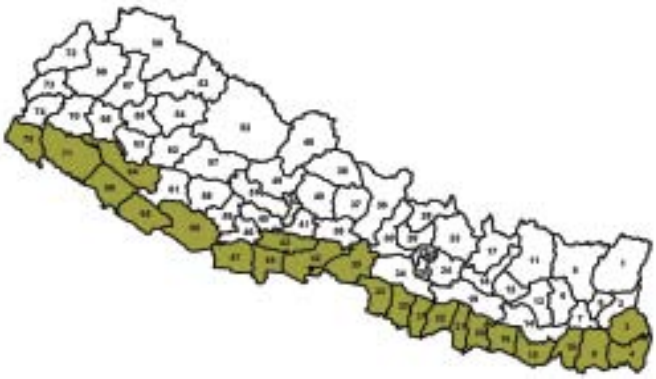
Physical Hand-pulling method is commonly practised in Nepal. Occasionally, water hyacinths are removed from the wetlands, particularly, from some wetlands of Royal Chitwan National Park, Koshi Tappu Wildlife Reserve, and Phewa Lake of Pokhara, etc. but it is very difficult to keep pace with the rapid growth of plant. If it is not removed annually, the growth becomes more prolific and aggressive. It is also very expensive and ineffective for large scale control.

Chemical The most commonly used herbicides are 2,4 -D and glyphosate. Herbicides are effective but has significant risk for other wetland biodiversity.

Biological The most successful biological control agents are two weevil species - *Neachetina bruchi* Hustache and *N. eichhornia* Warner, and a moth *Sameodes albiguttalis*. However, reports state that large scale reduction has not occurred. The insect predation reduces plant height, decreases number of seed production thereby decreasing the seasonal growth of plants.

Field observation *E. crassipes* is found to be dominating in marsh and swamp areas along roadsides, and various types of wetlands in tropical to temperate regions throughout Nepal. People of eastern Nepal use the plant to cover the potato field after plantation and also use as fodder for pig. In Taudaha (Kathmandu), cleaning campaign is done for cleaning of *Eichhornia* and at present this plant is not observed. However, another IAS *Myriophyllum* is dominant. Similarly, in Kamalphokhari (Kathmandu) *Eichhornia* is found to be dominating including other associated invasive species such as *Ageratina adenophora* and *Alternanthera philoxeroides*. The local people particularly in Terai remove water hyacinth annually from various wetland sites to catch fish. The impact of this plant is seen more severe in protected areas in comparison to areas outside the protected areas. A biogas plant was installed in a house of local person at Koshi Tappu Wildlife Reserve buffer zone to promote biogas through the utilization of water hyacinth.

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*)

First Herbarium record Nepalgunj, *ca* 610 m, 25.11.1972, Chandrabali 12498 (KATH)

Habitat Wetlands such as marshes, shallow lakes and ponds, ditches, drainages, etc.

Description Erect or straggling shrub up to 3m high. Stem hollow, woody at base. Leaf blade ovate to deltate or hastate, base shallowly cordate, margin entire, apex acute. Flowers in axillary cymes or panicles, rarely sub-terminal. Peduncles up to 10cm long. Sepals ovate, puberulent. Corolla funnel-shaped, pale pink, lilac or purple, 6-8cm in diameter. Capsule globose with persistent sepals. Seeds ovoid, densely covered with long brownish, woolly hairs.

Fl. & Fr. 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)

Ecological characters Plant grows well in moist habitats usually in lowlands. However, it shows an exceptional ecological tolerance. Often it seems an aggressive invader in disturbed habitats. A piece of stem could stabilize and grow as a fully developed plant. The plants often form tangling cover over ground vegetation or wetland sites.

Reproductive mode Reproduces sexually by seeds as well as the plant spread vegetatively through rooting of stem pieces.

Dispersal methods Due to its fast growing habit, people planted it along irrigation canal to check erosion or fenced around their cultivated

lands. Some people also plant for ornamental purpose due to its large showy flowers. Once established, it spreads quickly through vegetative propagation.

Invasive pathways The actual pathway of invasion is not clear. Perhaps it was introduced as a hedge plant due to its fast growing habit and unpalatable nature to cattle.

Management information

Physical People remove the plant through uprooting it out or cuttings. But it is difficult in established sites.

Chemical It can be controlled by 2,4-D at 3-4 kg/ha; a few weeks after treatment the plant should be burnt to avoid regeneration. Chemical means and methods have not yet been a common practice in Nepal.

Biological Information is not available.

Field observation *Ipomoea carnea* ssp. *fistulosa* found to be dominating in unmanaged or disturbed and shallow wetlands, nearby agricultural canals, moist areas of roadsides. Plants are not eaten by cattle and that favour the spread of plants. In Nepal, the plant has been brought for fencing, probably from neighboring India. However, the plant spreads quickly in unmanaged land as an invasive. Initially, people did not care but now it has become a serious invasive plant in a few years time. The plant has been used for beneficial purposes such as firewood and ecological restoration. For firewood, people remove the bark of the plant to dry it quickly. According to local people, the plant is toxic to goats. A lysosomal storage disease induced by *Ipomoea carnea* was also reported in goats in Mozambique. Affected animals stagger and have head tumors causing eventual death. The latex of the plant causes vomiting and diarrhoea. The plant is quite common along the East-West Highway. Several wetlands of Koshi Tappu Wildlife Reserve and its adjoining areas are covered with this plant and on its way to invade the grasslands. It also creates safe hiding place for snakes. The plant occurs to 1350m as observed in Kirtipur area of Kathmandu Valley.

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.

First Herbarium record Arun Valley, Khadbari, 1219m, 01.01.1956, J.D.A. Stainton 1493 (KATH)

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. Its root system is very stout and gives out a new flush of shoots even after repeated cuttings. Stems roughly hairy. Petiole 1-2cm long, hairy; leaf blade ovate, 4.5-9.0 × 2.5-4.5cm, abaxially scabrous, adaxially stiffy hairy, base attenuate, margin crenate to serrate, apex acute to acuminate. Flowers small, showy, in round flat-topped heads in axils of upper leaves. Calyx 5mm long; lobes 2, triangular. Corolla creamy, yellow, orange, pink or red, tube cylindrical 5-8mm long; lobes 4-5, unequal, rounded. Fruit small, drupaceous, shining, blue black when ripe, with 2-nutlets.

Fl. & Fr. Almost throughout the year.

Uses It grows as hedge plant. Its bark and leaves are used for some medicinal values (cutiginous eruptions, leprous ulcers, swellings and pain of the body). The plant has been reported poisonous to cattle. Young stems are used for 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)

Ecological characters Initially cultivated as an ornamental plant from which it escapes as a weed. The plant forms dense understorey

vegetation in open forests that crowds out and inhibit 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 occurs in pastures, forests and margins of agricultural lands. It changes faunal makeup by providing perch and hide sites.

Reproductive mode Sexual reproduction by seeds, which are about 1.5mm. Vegetatively propagated by regenerating from basal shoots.

Dispersal methods The fruit is dispersed by the frugivorous birds and rodents. Seed germinates easily.

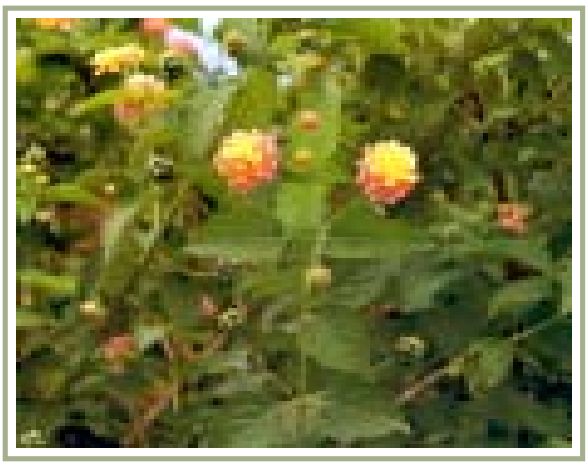
Invasive pathways *Lantana camara* has been established in Nepal via the plains of north-east India. Probably in India it was introduced as a hedge plant because it is quite difficult to penetrate and is very decorative. Local dispersal is possible by garden escape or bird's excreta.

Management information

Physical In Nepal, the management practices done by the people are hand pulling, digging out, coppicing and burning. But burning without follow-up treatment is ineffective and may increase population.

Biological Biological control agents available for this species are not so effective. Following biological agents are released to control *Lantana camara* in Pacific Islands: *Epinotia lantana*, *Lantanaphage pusillidactyla, Diasema tigris, Hypena strigata, Leptobyrsa docora, Octotoma scabripennis, Ophiomyia lanta-nae, Plagiohammum spinipennis, Pseudopyrausta acutangulalis, Salbia haemorrhoidalis, Telionemia scrupulosa, Uropalata givardi* and *Hypene strigata*.

Field observation *Lantana camara* is found in different habitats that ranges from 75 to 1700m. It spreads mostly in fallowlands, scrublands and also in forest margins. According to local people, in Setidevi V.D.C., ward no. 4, Kathmandu *Ageratina adenophora* was dominant 8 years ago, but now a days the area is covered by *Lantana camara*. It also replaces *Artemisia indica* and *Ageratina adenophora* in that area. Lantana is also problematic in agricultural land. Ripe fruits of *Lantana* are eaten by birds. It is also able to establish on decaying trunk of large and old trees (*Ficus religiosa*) as epiphyte after germinating through bird's excreta.



In eastern Nepal, people use the plant for fencing and firewood. Sometimes children also eat the ripe fruits. People believe that the plant is introduced as ornamental due to its showy flowers. It is believed that many native species of grasses have disappeared after the introduction of *Lantana camara*.

Mikania micrantha Kunth

Synonym *M. scandens sensu* F.B.I. non (L.) Willdenow

M. cordata (Burman f.) 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*)

First Herbarium record Illam- Jogmai, Ranga pani, 08.11.1963, H. Hara, H. Kanai, S. Kurosawa, G. Muratta, M. Togashi & T. Tuyama (KATH)

Habitat Fallowlands, croplands, forests, scrubs or shrublands and wetlands.

Description Perennial, scandent or twining herb. Leaves opposite; petiole 1-4cm long; leaf blade, ovate- triangular, 7.5 x 4.5cm, base deeply cordate, margin bluntly dentate, apex acuminate. Capitula small 3-4mm long, 4 flowered, disciform, homogenous, in dense axillary or terminal corymbs. Involucres 1-5mm long, phyllaries oblong. Florets white or greenish white. Achenes *ca* 2mm long. Seeds black, linear-oblong, five-angled. Pappus-hairs silky white.

Fl. & Fr. 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).

Ecological characters The *Mikania micrantha* is a fast growing plant capable of climbing over other plants to gain more sunshine. It is also known as plant killer as it spreads appallingly fast, blocking sun lights for other plants, and strangles many plants, which wither as a result. Although intolerant of heavy shade and water logging condition, it readily colonizes gaps. Its shoot has been reported to grow 27mm a day. It is also reported that a single plant may cover over 25 sq. metres within a few months. It releases the substances that inhibit the growth of other plants.

Reproductive mode Reproduces sexually by seeds and vegetatively by rooting at nodes. A single plant releases over 40,000 viable seeds every year (www.issg.org/plantlibrary/invasives/invasives news fall 2000.htm).

Dispersal methods Seed dispersed by wind and by animals.

Invasive pathways *Mikania micrantha* got introduced in Nepal through north-east India. Further dispersal is possible due to numerous small seeds blown by air or due to humans, livestock and vehicles. Small seeds or stem fragments may easily be contaminated with agriculture, horticulture, forestry and pasture seeds.

Management information

Physical

Farmers dig out the plants, which are tending to invade in their agricultural land.

Manual removal of *Mikania micrantha* is the most feasible method but possible only in early stage. Burning is not viable as it is fairly deep rooted and is almost impossible to burn out the roots to exterminate the plant and prevent it from regenerating. Well established areas pose serious problems because new plants can grow even from the tiniest stem fragments.

Chemical

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).

Biological

An insect *Liothrips mikaniae* appears to be a specific biological control organism though it failed to establish in Solomon Island in 1988 (Swarbrick, 1997). Various researches on classical biological control methods are ongoing; *Puccinia spegazzinii* has been considered as a potential control agent. This rust is under final assessment in quarantine China while the Indian government has approved releasing it to the field. According to CABI Bioscience, the preparation for release is under progress.

Field observation

Mikania micrantha is well established in the tropical part of eastern and central Nepal. It has been causing serious problems in the Koshi Tappu Wildlife Reserve. The plant has seriously invaded the forest in the eastern embankment. The forest trees are totally engulfed by the *Mikania micrantha*. Similarly, many moist parts of Royal Chitwan National Park, including Bhimle Checkpost to Devital are seriously invaded by *Mikania micrantha*. Being a climbing plant, it becomes a nuisance in forest suppressing forest under growth and saplings including those serving as egretories. The ground gets totally covered by *Mikania micrantha*, which prevent the regeneration of other plants. The plant spreads appallingly fast and becomes dense within 8-10 years according to local inhabitants. It tends to invade the agricultural land as well. Farmers have been removing it manually from their croplands.

Attempts have been made at local level to control the invasion of this plant. For example, the District Forest Office of Morang district (Salakpur Range) has initiated manual cleaning of *Mikania* in about ten hectares of forest land two times a year, one before rainy season and the other before flowering time (winter season). The user groups are encouraged to replant native tree saplings in the area. About 3 hectares of another degraded forest marginal lands is also being planted by the user groups after manual cleaning of this plant (per. com. Anirudra Sah, Ranger). Similarly, Koshi Tappu Wildlife Reserve is planning to involve community to clean *Mikania micrantha*. Community is allowed to collect grasses from such areas against their efforts to control *Mikania* (per. com. Lal B. Bhandari, Ranger). However, this method of manual cleaning seems to be impracticable and uneconomic in heavily infected areas like Koshi Tappu. Again, monitroing and regular public involvement is a critical requirement to get good results. In Humsedumse community forest of Jhapa district, the Community Forest User Groups spent Rs. 70,000 in 2002 to clean Mikania.

It has been reported that cattle grazing around *M. micrantha* suffer from liver fluke because a large number of snails are observed near *M. micrantha* and are considered as intermediate host for liver fluke.

Medium Risk Posed Invasive Alien Species

Alternanthera philoxeroides (Mart.) Griseb.

Synonym *Bucholzia philoxeroides* Mart.

Family Amaranthaceae

Common/English name Alligator weed

Local name Jaljamvu

First reported in Nepal Siwakoti & Varma, J. Econ. Taxon. Bot. 18: 495. 1994

Habitat Wetland, particularly shallow water or wet soils, ditches, drainages, marshes, edges of ponds and slow moving water courses.

Description Herbaceous aquatic to terrestrial perennial; stem horizontal to ascending, up to 1m long, rooting at nodes. Leaves opposite; petiole narrowly winged or sessile; leaf blade narrowly lanceolate, 4-11 × 1-3cm, margin entire. Spikes ovoid or globose head-like, 1-2cm in diameter in axillary or terminal peduncles. Flowers and bracts white, glabrous; petals absent.

Fl. & Fr. June-September

Uses The plant is used as pig forage fodder for cattle in Sunsari district. It is considered as excellent pig forage and cultivated in most of southern China (Wan and Wang, 2001). It is also used as green manure as well as medicine. In West Bengal, the plant is sold in market as vegetable (Cook, 1996). The *Musahar* community of eastern Nepal use young parts as green vegetable.

Distribution Native to Central America. Naturalized in other tropical area. Nepal (CE, 80-1350m)

Ecological characters Plants grow best under high nutrient conditions in various types of wetlands. Aquatic form has hollow floating, emergent and submerged stems while terrestrial plant has solid stem. Typically, these plants grow rooted in soil of shallow water and form dense interwoven floating mats that extend over the surface of deep water. Mats can become dense enough to support the weight of a person. The mat disrupts the natural ecology of the wetland site by reducing light penetration and crowding out of native species. Serious infestations can create anoxia, disease and good breeding ground for mosquitoes.

Reproductive mode Reproduces vegetatively from stolons. Each node or fragment with a node is capable of producing a new plant. Plants are highly competitive and have rapid growth rates. Seeds rarely develop, seldom viable.

Dispersal methods Plant parts dispersed by water and various other agents.

Invasive pathways The actual pathways of invasion is not clear. However, it is suspected that it might have been introduced as forage for pig or through contaminated goods of wetland products via India. When a small fragment comes in contact with moist soil, it starts to grow rapidly.

Management information

Physical Removal of dense floating mats manually will only provide temporary control. Care must be taken to prevent the movement and distribution of detached stem parts in the downstream water as it helps in re-establishment of the species at many different places.

Chemical The herbicides used are 2,4-D, glyphosate, dicamba. But there is always risk for other non target plants, both native and agricultural.

Biological The alligator weed flea beetle *Agasicles hygrophilia* causes considerable damage to aquatic mats of *A. philoxeroides*. But it does not affect terrestrial invasion (released in the United States). The alligator weed stem borer *Vogtia malloi* was released in Florida, Georgia, the Carolinas and Alabama from 1971 to 1973. The infested stems rapidly milt and drop.

Amynothrips andersoni attacks and deforms apical leaves of both aquatic and terrestrial plants. Damage, however, is relatively minor.

Field observation *Alternanthera philoxeroides* is found to be dominating in shallow water and marshes along roadsides ditches, drainages, edges of ponds etc. particularly along high nutrient containing wetlands. In Kamalpokhari (Kathmandu), the plant has formed dense mats upon which other invasive species such as *Ageratina adenophora* are also growing. In eastern and central Nepal, this species is more common in marshy areas in comparison to western Nepal. It is suspected that the plant has been introduced nearly a decade ago thereby making it a serious invasive plant in many wetland sites.

Myriophyllum aquaticum (Vell.) Verdc.

Synonym *Enydria aquatica* Vell.

Family Haloragaceae

Common/English name Parrot's feather

Habitat Nutrient enriched lakes/ ponds, marshes particularly in shallow water up to 2m deep, rooted at mud.

Description Perennial, floating or ascending. The submerged stems form dense interwoven floating mats from which emergent stem arises. Leaves are feather like which are arranged around the stem in whorls of four to six; leaf base somewhat swollen. The submerged leaves are 1.5 to 3.5cm long and have 20 to 30 divisions per leaf. The emergent leaves are 2 to 5cm long, glaucous, light bluish-green and have 6-18 divisions per leaf. Flowers are unisexual (only female), inconspicuous and are borne in the axils of the emergent leaves. Sepals deltate, entire or serrate. Petals reduced or absent.

Uses The plant is used in outdoor and indoor aquarium or as popular aquatic garden plant.

Distribution Native of South America (Amazon river). Naturalized worldwide especially in warmer climates.

Nepal (C, *ca* 1350m)

Invasive pathways *Myriophyllum aquaticum* has been introduced in Nepal recently may be as an aquarium or aquatic garden plant and escaped. It is observed only in Kathmandu Valley being dominant locally; it spreads via fragments.

Ecological characters The plant becomes quite dense in high nutrient environment. It tends to colonize slowly moving on still water rather than in areas with higher flow rates. It grows best when rooted in shallow water, it is known to occur as floating plants in deep water of nutrient enriched lakes, thus blocking water canals. It replaces other aquatic vegetation reducing wetland biodiversity by shading out the algae in the water column that serves as the basis of the aquatic food web. It also provides breeding ground for malaria vecter and other diseases producing organisms.

Reproductive mode It has been reported that, all parrot feather plants are female, male

plants are found only in South America. So, it usually reproduces vegetatively by plant fragments. Rhizomes survive under refrigeration for one year (www.ecy.wa.gov).

Dispersal methods Plant fragments disperse by water current. Humans are also responsible for transfer of plants from one place to another for ornamental purpose.

Management information

Physical Due to its dense, tough and heavy rhizomes, it is very difficult to remove the plant manually. The cut-off rhizomes and stems further increase its spread.

Chemical It is difficult to control completely by using herbicides. The herbicides used are 2, 4-D, diquat, and complexed copper, endothall dipotassium salt and endothall and complexed copper. Fair control was obtained with glyphosate. The control may be achieved with low volatility ester of 2, 4- D at 4.4-8.9 kg/ha sprayed on the emergent foliage.

Biological Potential biological agents are *Lysathia flavipes* a flea beetle found on parrot feather in Argentina, cause moderate damage under field condition. In Argentina, weevil *Listronotus marginicollies* feed only on *Myriophyllum* in its native range. *Argyrotaenia ivana* and *Choristoneura parallela* have also been found in parrot feather in Florida, but their effect is unknown. An isolate of *Pythium carolinianum* collected in California has shown some promise as a potential biocontrol agent.

Field observation *M. aquaticum* was not reported by previous workers (Press *et al.*, 2000), which indicates that the plant was introduced recently in Nepal (may be 10 years ago). It is common in drainages along roadsides in Kathmandu and Lalitpur, particularly along the Ring Road and its adjoining areas. Some patches of this plant is also observed in Dhobikhola (in between Nilopul and Pakkipul) near Kapan, Kathmandu. It has become problematic in Taudaha pond, Kathmandu. The local residents of Taudaha have informed that *M. aquaticum* is invaded after the cleaning of *Eichhornia crassipes* from this wetland. At present, about 30 percent area of Taudaha is covered by the mat of this plant. According to local people, the removal of this plant is much more difficult than *E. crassipes* due to its tough rhizome and is more invasive in nature. Cattle and other grazers, including grass carps do not feed upon the plant due to the presence of high tanin content. If timely and effective measure is not undertaken, it could become a serious weed menace in future.

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.

First Herbarium record Sindhupalchok, Pipaldanda, 1550m, 29.09.1984, N.K. Bhattarai 84/539 (KATH).

Habitat Fallowlands, roadsides, around settlements

Description Perennial, erect or profusely branched herb up to 2 m high. Stem puberulous and ribbed. Leaves white pubescent, pilose on veins; basal leaves long petiolate, leaf blade ovate, 4.5 × 2.5cm, pinnately lobed; lobes irregularly and coarsely rounded or lobulate; upper leaves subsessile, smaller, narrower. Heads white, radiate, heterogamous *ca* 3mm in diam; bracts *ca* 2mm long, biseriate, scarious. Ray flower tube *ca* 0.4 mm long; ligule *ca* 0.7mm long. Corolla of disc flowers *ca* 2.5 mm long. Achene *ca* 2mm long; pappus scales *ca* 0.5mm long. General look of the plant leads to misidentification as *Artemisia spp*.

Fl. & Fr 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).

Ecological characters *Parthenium hysterophorus* aggressively colonises in disturbed sites, particularly along fallowlands and roadsides in tropical and sub-tropical regions. It can colonise degraded natural ecosystems and produce inhibitory effect on surrounding herbaceous vegetation. (Kanchan, 1978, Kanchan and Jayachandra, 1979a, b; Mall and Dagar, 1979; Nath 1981, 1988; Srivastava *et al.* 1985). With good rainfall and warm temperature *Parthenium* seed can germinate and grow at any time of the year. In humans, it causes hay fever, skin problems and asthma (Mc Fad yen 1995; Cheney 1988). The plant can also produce serious allergic

reactions in humans. The plant pollen has parthenin, an incomplete antigen of *Parthenium* which when enters the human skin, combines with albumin in presence of ultraviolet rays and turns into a complete antigen. There will be antigen and antibody reaction thus causing photo phyto dermis (Fisher, 1952). Such reactions will be seen over portions of the body exposed to the sun i.e. over the forehead, molar area, nose and chin, neck, hands and feet. The pollen, when comes in contact with the skin, can cause hypersensitivity reaction leading to oozing, crusting associated with pain and burning sensations. This is called contact irritant dermatitis (Siddiqui *et al.* 1978).

Parthenium is also known for its phytotoxicity towards other plants including aquatic species (Pandey 1996, Batish *et al.* 1997, 2002). However, the phytotoxicity of *Parthenium* could be useful as a natural herbicide for weed management programmes (Batish *et al.* 2002). It is reported that the *Parthenium* affect the germination of *Ageratum conyzoides* but the same concentration has no effect on the germination of wheat (Batish *et al.* 1997).

Reproductive mode Plant reproduced sexually by seeds. A fully grown plant can produce more than 15000 flowers in its lifetime with each flower bearing 4 to 5 seeds.

Dispersal methods Seed is dispersed by wind and water. It is also dispersed by human, animal, and vehicle movements.

Invasive pathways It is suspected that *Parthenium* was introduced in Nepal via India about 2 decades ago and has spread rapidly along roadsides, fallowlands and agricultural lands. Its tiny seeds are contaminated with cereal and other seed items. They can be easily flown by air and water or dispersed by humans, cattle, vehicles, etc. In India, it first appeared accidentally in the Indian Botanical Garden, Calcutta during 1810-1814 (Sharma and Pandey,1984).

Management information

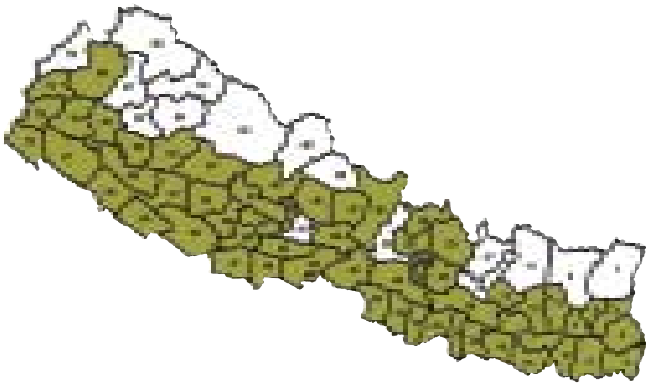
Physical Plants are removed by farmers manually in agricultural fields.

Biological *Zygogramma bicolorata* Pallister is reported as most promising biological agent which causes the defoliation in *Parthenium hysterophorus* (Dhileepan *et al.* 2000). The biological control method was also implemented in Queensland, Australia, and so far 9 species of insect and a rust pathgon have been introduced to control parthenium weed. The combined effects of biological control agents has reduced the density and vigour of parthenium weed and increased grass production (Wittenberg and Cock, 2001).

Field observation Parthenium weed rapidly colonizes arable land, disturbed areas along roadsides and heavily grazed pasture. It is found more profuse in central and western Nepal. It is not so common in Jhapa district of eastern Nepal. People get confused *P. hysterophorus* with *Artemisia* sps. due to morphological resemblance. In Nepal, health hazard caused by the *P. hysterophorus* may have been unnoticed due to the lack of proper identification of the plants. Cattle do not feed upon the plants. According to local people, the plant was seen in Dakshinkali, Kathmandu, about 10 years ago. It was first reported from central Nepal (Press *et al.* 2000).

Low Risk Posed Invasive Alien Species

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

First Herbarium record Nepalgunj, 25.10.1972, N.P, Manandhar 9857 (KATH)

Habitat Crop land, fallowland and forest margins.

Description Annual, aromatic hispid herb 20-60cm high. Stem terete, whitish pubescent. Petiole 1-2cm long; leaf blade ovate, 1.5-6 × 1-13cm, surfaces sparsely pubescent, base truncate or cuneate, margin crenate-serrate, apex sub-acute or obtuse. Heads 3-5mm in diameter, white, sometimes blue or purple, disciform, homogenous arranged in dense terminal corymbs. Involucres linear, eglandular; bracts *ca* 3mm long. Corollas *ca* 2mm long. Styles exerted *ca* 1mm long. Pappus slightly exceeding corolla.

Fl. & Fr. 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)

*A. houstonianum Mill. is also treated as A. conyzoides under the similar local name. The involucres bract of A. houstonianum is glandular that is different from Ageratum conyzoides.

Ecological characters 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.

Reproductive mode Plant reproduces sexually by seeds. Seeds are numerous.

Dispersal methods Seed dispersed by wind or contamination with various biotic and abiotic agents.

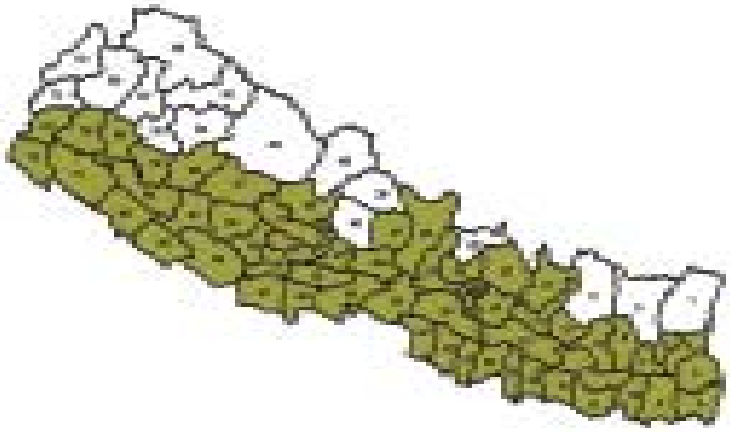
Invasive pathways The plant is introduced in Nepal long time ago via India and is established in warm parts. Local dispersal is made by biotic and abiotic agents.

Management information

Physical The plant is easy to pull out. People simply pull out the plant from the agricultural field.

Field observation Plant is found everywhere. Although it shows some problem in agricultural field, it is well managed by farmers because the cattle feed upon it and it is easily pulled out by hands. *A. houstonianum* which looks similar to *A. conyzoides* causes health impact in cattle. People have informed that sometimes cattle may die after feeding *A. houstonianum* in larger amount.

Amaranthus spinosus L.



Family Amaranthaceae

Common /English name Spiny pigweed

Local name Kande lude, Kande sag, Latte sag, Kande latte, Kantesag, Katari, Genheri sag, Rangnan (Chepang), Katgeri (Danwar), Kataiya (Darai), Chiki (Gurung), Kathgaiyan (Mushahar), Janam-arak (Satar), Bangaidhap (Tamang), Chorai (Tharu)

First reported in Nepal Kitamura in Fau. & Fl. Nepal Himal. 121.1955

First Herbarium record Banke, 181m, 25.10.1972, N.P. Manandhar 9207 (KATH)

Habitat Moist, nutrient-rich fallowland and crop land.

Description Annual erect spinous herb up to 50cm high with pairs of axillary spines of 7-14mm long. Leaves ovate or lanceolate, 1.5-3.5 × 0.7-1.7cm, glabrous above and scurfy beneath, base cuneate, margin sinuate, apex acute or obtuse, spine-tipped. Flowers small, green, monoecious, in dense axillary and terminal spikes of 2-9cm long. Perianth segments 5. Capsules ovoid circumscissile.

Fl. & Fr. Almost round the year.

Uses Young plants are edible as pot herb; also used as medicinal plant.

Distribution Native of Tropical America; Cosmopolitan, warm temperate and tropical weed.

Nepal (WCE, 75-1800m).

Ecological characters The plant is found along wastelands, crop field and pastures. It aggressively grows in nutrient-rich area and replaces the native flora as well as alters the habitat for fauna. It is a common agricultural weed and competes with crops for nutrients.

Reproductive mode Reproduced sexually by seeds.

Dispersal methods Seed dispersed by wind, numerous seeds produced in single plant.

Management information

Physical The mature plant is deep rooted. It is difficult to pull out in hard soil. People dig out the plant from the field.

Chemical 2, 4–D used by people in agricultural field to control the plant.

Field observation The plant is commonly found along roadsides and agricultural fields. People use the plant as vegetables and believe that it contains high amount of vitamins. The plant is found to be somewhat problematic in agricultural field and farmers use 2, 4-D to control the plant in the field or pull out or dig out the plant at young stage.

Argemone mexicana L.

Family Papaveraceae

Common/English name Mexican prickly poppy

Local name Satyanashi, Katar, Jhans, Thakal, Katara (Danwar), Badhebhare kanda (Darai), Palanti Kanth (Mushahar), Dhamoi (Sattar)

First reported in Nepal Burkill in Rec. Bot. Surv. India 4: 98.1910

First Herbarium record Biratnagar, 04.10.1963, H. Hara, H. Kanai, S. Kurosawa, G. Murata, M. Togashi & T. Tuyama (KATH)

Habitat Wasteland and agricultural land.

Description Annual, branched, thistle-like prickly herb 30-60cm with yellow bitter latex. Leaves sessile; leaf blade elliptic-obovate, 5-12 × 3-7cm, pinnatifid to pinnatipartite, base cordate, margin coarsely spinous-dentate. Flowers 2-2.3 cm in diam., bright yellow, solitary, terminal. Sepals elliptic, *ca* 1.5 × 1cm, prickly and with a subterminal spine-tipped horn 5-10mm long. Petals 2-3 × 1.5-2.5cm. Capsules 2.5-3.5 × 1-1.5cm long densely clothed with sharp spines. Seeds globose, brownish black.

Fl. & Fr. December-June

Uses In Nepal, the plant is not used for any purpose. However, according to Ayurveda, the plant is diuretic, purgative and destroys worms. It cures leprosy, skin diseases, inflammations and bilious fever. Roots are anthelmintic. Latex is used to cure opthalmia and opacity of cornea. Seeds are purgative and sedative. Seeds yield non-edible toxic oil and cause lethal dropsy when mixed with mustard oil for cooking. In homoepathic system of medicine, the drug prepared from this herb is used to treat the problem caused by tapeworm. The plant is suitable for reclamation of alkaline soils. Dried and powdered plants are recommended as green manure as it contains sufficient amount of

nitrogen, phosphorus and potassium. Oil cake is used as manure. Seed oil popularly known as "Satyanashi oil" is used as illuminant, lubricant, in soap making, and for protection from termites (Oudhia, 2002)

Distribution It is native of Tropical America; Now a pantropical weed.

Nepal (WCE, 75-1400m)

Ecological characters The plant grows well in wastelands, roadsides, pastures in warm areas. The plant is toxic to animals and cattle avoid grazing this plant. Harmful allelopathic effects of *A. mexicana* on germination and seedling of wheat, mustard, sorghum, finger millet, tomato, cucumber, etc have been reported. The allelochemicals cinnamic and benzoic acid are identified as harmful chemicals responsible for inhibition of germination and seedling vigor.

Reproductive mode Reproduces sexually by seeds.

Dispersal methods Seeds are numerous and are dispersed by wind, water or contaminated mustard seeds.

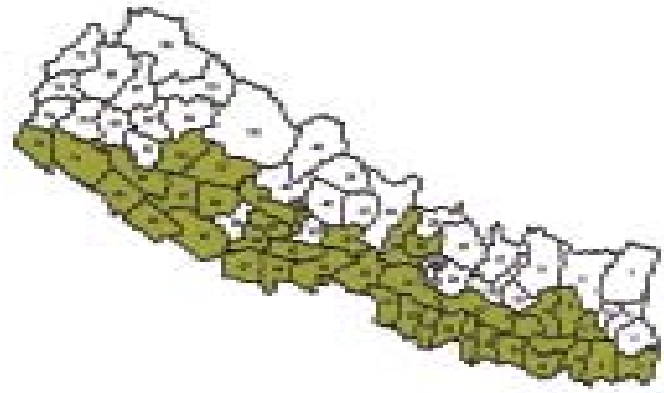
Management information

Physical Dig out manually.

Chemical People of eastern Nepal (Morang) use 2, 4-D herbicide to control the plant in agricultural field.

Field observation In tropical part of Nepal, the plant was seen along roadsides and agricultural field. Cattle do not feed upon the plant. According to local inhabitants, it reduces the soil fertility and oral ingestion of plant also causes paralysis like symptoms. The fruiting time of this plant matches with mustard. So there is a possibility to use the seeds to adulterate mustard seeds.

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

First Herbarium record Karnali, 760m, 24.04.1952, Polunin, Sykes & Williams 1956 (KATH)

Habitat Wasteland, roadsides, forest margins

Description Annual herb, 0.3 - 1m. Stipules linear, *ca* 5mm long. Leaves 5-8cm long; leaflets 2-3 pairs, obovate, 2-6 × 1-2.5cm, base obliquely cuneate, margin entire, apex obtuse or emarginated. Flowers axillary, solitary. Sepals obovate *ca* 5mm long. Petals yellow, obovate. Stamens usually 7, unequal. Pods linear cylindric, 13-15cm.

Fl. & Fr. 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)

Ecological characters The plant is commonly found in dry wastelands, croplands and pastures. It produces large number of seed, which fall after maturation. So it is found in dense thickets. The dense stand of plant replace the native flora.

Reproductive mode Plant reproduces sexually by seeds.

Management information

Physical Hand pulled.

Chemical Farmer of Morang district use 2-4 D to control this weed.

Field observation The plant was found to be less problematic in Nepal. It spreads in forest margins and fallowlands and is more dominant along wastelands of Terai and Dun Valleys. People use the plant as burning materials and also use as medicine.

Hyptis suaveolens (L.) Poit.

Synonym *Ballota suaveolens* L.

Family Lamiaceae (Labiatae)

Common/English name Wild spikenard, Chan

Local name Tulsi Jhar, Gandhe jhar, Silame jhar, Bansilam, Bantulsi, Gankighans

First reported in Nepal Murata in Fl. East. Himal: 275.1966

First Herbarium record Phusri-Sanguribhanjyang, 16.10.1963, H. Hara, H. Kanai, S. Kurosawa, G. Murata, M. Togashi & T. Tuyami (KATH).

Habitat Wasteland, forest margins and crop lands.

Description Annual herb *ca* 1 m. Stem erect, branched, villous. Petiole 0.5-1cm; leaf blade ovate, 2.0-5.0 × 1.0-2.5cm, base rounded, margin serrate or serrulate, apex acute or obtuse. Inflorescence verticillasters with 4-6 flowers. Calyx 4-5mm long, teeth 5; fruiting calyx enlarged 7-8mm long, teeth 3-5mm long. Corolla purple, 3-5mm long. Nutlets compressed, broadly obovoid, emarginated at apex or mucronate, 5mm long.

Fl. & Fr. April - December

Uses Leaves infusion used as medicine in mud infection in foot, cuts and wounds; also used as bedding for cattles.

Distribution Native of Tropical America, Federated states of Micronesia, French, Polynesia, Guam, Hawai, Papua New Guinea, Australia, Indonesia.

Nepal (WCE, 75-1000m)

Ecological characters Plant favours dry open locations. It is a common weed in agricultural fields; also dominates open grassland and fallow lands replacing native flora.

Reproductive mode Reproduces sexually by seeds.

Dispersal methods The spined fruit (bur) catches in fur and clothing; often a contaminant in pasture grass seed.

Management information

Physical Hand pulled and burnt.

Chemical Spraying of ester 2, 4–D. All spray should be applied before flowering begins. Other herbicides such as dicamba, clopyralid and picloram based mixture are also effective but expensive (Parsons and Cuthbertson, 1992)

Field observation Plant is common along roadsides, forest margins, and agricultural land in tropical region. Cattle and goat do not feed upon the plant. Its smell might cause headache. The plant was seen about 40 years ago according to local people in eastern Nepal. It tends to invade agricultural land.

© Colin Pendry

Leersia hexandra Swartz

Family Poaceae

Common/English name Cut grass

Local name Karaute Ghans

First reported in Nepal Hsu in Hara, Fl. East. Himal. 367.1966

First Herbarium record Kathmandu: Godavari, 1600m, 26.6.1977, K.R.Rajbhandari 961 (KATH)

Habitat Marshes, swamps, ditches, streams, ponds, lakes, canals, rice fields.

Description Perennial grass. Culms decument and rooting from lower nodes, branched, nodes hairy. Leaf blades 3.4-11.7 × 0.3-0.5cm. glabrous, linear, acute, becoming in rolled; ligule 1.5-2.7mm, rounded, glabrous. Inflorescence 2.5-11.5cm, triangular in outline, branches single. spikelets deciduous; lemma oblong, abruptly auminate, minutely hispid on veins; palea abruptly acuminate, narrowly oblong, keel ciliate above.

Fl. & Fr. Almost around the year.

Uses Leaves are used as fodder; seed is favourite of many water birds.

Distribution Native of tropical America (www.wes.army.mil).

Nepal (CE,100-300m)

Ecological characters The plant grows well along the marshes, streams, ponds, lakes, swamps, ditches and canals. It forms dense mats in aquatic habitats which hinder recreational activities, sometimes the mats form floating islands. The palnt also can be a weed in rice fields.

Reproductive mode Reproduces sexually by seeds and vegetatively by roots.

Dispersal methods The plant spreads by rhizomes, stolons and seeds.

Management information

Physical People remove plant mechanically by hands from rice fields.

Field observation The plant is problematic in Bishazari lake of Chitwan district, one of the Ramsar sites of Nepal. The plant forms floating island in the lake and make suitable habitat for other terrestrial plants. It also appears as weed in ricefield of terai regions of Nepal.

Pistia stratiotes L.

Family Araceae

Common/English name Water lettuce, tropical duck weed

Local name Kumbhika, Jalkumbhi

First reported in Nepal Hara, Fl. East. Himal: 397.1966

First Herbarium record Kanchanpur, 250m, 9.12.1966, D.H. Nicolson 2876 (KATH)

Habitat Ponds, dams, lakes, rivers and range of permanent and seasonal wetlands.

Description Aquatic herb with a rosettes of pale green leaves and a tuff of long fiberous roots. Leaf blade obovate to obcuneate, 0.6-1.2 × 1-1.5cm, densely pubescent on both surfaces. Inflorescence small, hidden in leaf bases. Spathes 2-4cm long, greenish yellow, hairy, constricted between male and female parts. Spadix almost equaling spathe; lower part consisting of a single ovary, male with single ring of stamens.

Fl. & Fr. August-February

Uses The plant is used as forage for pig and duck.

Distribution Pantropical. (Northern Mariana Islands (Rota), French Polynesia, Gaum, Hawai New Caledonia, Papua, New Guinea, Solomon Islands, Vanuatu, Australia, China, India, Cambodia, Indonesia, New Zealand, Malaysia, Philippines, Thailand, Vietnam, Seychelles)

Nepal (WCE, 75-600m)

Ecological characters It is a common free-floating aquatic weed in dams and lakes which also grows in rice field. Its minimum growth temperature is 15^{0}C. *Pistia stratiotes* mat cloges waterways and irrigation canals causing obstruction in boating, fishing and all other water activities. The mat degrades water quality by blocking the air water interface and greatly reducing oxygen levels for wetland flora and fauna in the water, eliminating under water animals such as fish. Thick and extensive mats can block both sunlight and air from reaching water surface.

Reproductive mode It reproduces vegetatively and sexually; new daughter plants are formed by stolons.

Dispersal methods Dispersed by water; humans are also responsible for dispersal since the plant is attractive to grow in ponds.

Management information

Physical People simply remove the plants manually from some private ponds. Mechanical harvesters and chopping machines are used to remove water lettuce in U.S.A.

Chemical 2-4 D herbicide is quite effective.

Biological The weevil *Neohydronomous pulchellus*, which was collected in South America substantially reduced the growth of *Pistia stratiotes* in Australia and Zimbabwe. The host specific South American weevil, *Neohydronomus affinis*, has been established readily in six countries and in all, has produced substantial to excellent control. The moth, *Samea multiplicalis*, which attacks *P. stratiotes* and *Salvinia* sp. has been established in Australia but its impact has not been evaluated. In Thailand, mass rearing and release of the native noctuid moth *Spodoptera pectinicornis* has replaced the use of herbicide (Waterhouse, 1994).

Field observation The plant is a potential invasive in Nepal. The plant was seen about 40 years ago in Eastern Nepal according to local people. Cattle do not feed upon the plant. People simply remove the plant by clearing. Single plant is sufficient for its wide spread. The plant is found to be dominating in wetlands where *Eichhornia crassipes* fails to dominate.

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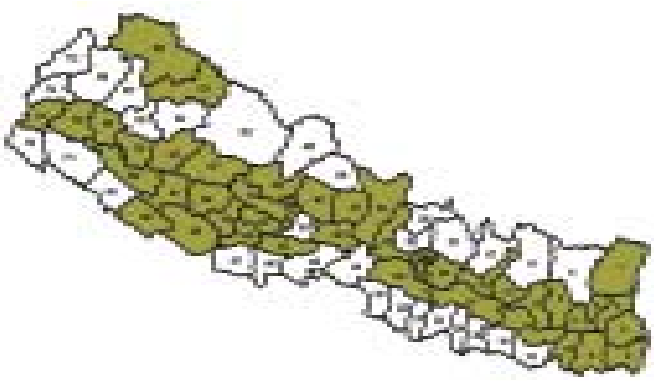
Insignificant Risk Posed Invasive Alien Species

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

First Herbarium record Godavari, *ca* 1524m, 23.05.1962, S.B. Malla & T.B. Shrestha (KATH)

Habitat Fallowlands, agricultural land and forest margins.

Description Annual, erect, thinly hairy herb 20-100cm high Leaves opposite; petiole 1.5cm long; usually trifoliolate; leaflets ovate or elliptic, 0.5-2.5 × 0.4-1.4cm, base obtuse to attenuate, margin serrate, apex acuminate. Heads in peduncled corymbs; involucres 4-8mm in diameter; outer bracts linear, shorter than the acute broadly margined inner ones. Ray florets ligulate, white. Disc florets tubular, yellow. Pappus bristly.

Fl. & Fr. 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)

Ecological characters The plant is common in fallowlands, and agricultural lands. The plant grows freely in open dry area reaching up to 2.5m high. The dense stands of the plant reduce the establishment of other species. Fire hazard may occur in dry season.

Reproductive mode The plant reproduces sexually by seeds.

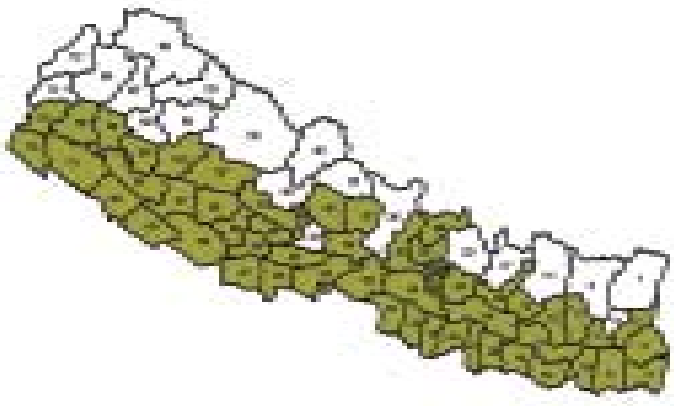
Dispersal methods Seeds are dispersed by wind and animals. Fruit entangled in animal hairs, human clothing etc. facilitates local dispersal.

Management information

Physical The plant is commonly hand pulled and removed from agricultural field. Cattle and goats feed upon the plant.

Field observation The plant is found in agricultural land, wasteland and forest margins. Farmers easily remove the plant by hand pulling. It is common in mid-hills. According to local people, overspreading of plant reduces soil fertility.

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

First Herbarium record Jajorkot, 1219m, 16.10.1952, Polunin, Sykes & Williams 1956 (KATH)

Habitat Fallowlands, roadsides, forest margins, pastures

Description Annual or perennial erect sub-shrub upto 1.5m high. Petiole with ovoid gland at base; leaves 10-12cm long; leaflets 3-5 pairs, base rounded, margin entire, apex acuminate. Flowers axillary, shortly peduncled corymbs; bracts ovate. Sepals 5, obovate. Petals yellow, elliptic to obovate. Stamens unequal, 2 large, 4 medium sized, rest very small. Pods oblong, 9-12 × 0.7-0.9cm, compressed, transversely septate, brown with pale band along both sutures.

Fl. & Fr. 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).

Ecological characters Commonly found in open wastelands, forest margins and pastures. The dense stands reduce the native flora. Seed, roots, leaves fruits are poisonous to human which cause diarrhoea, dark brown urine, etc.

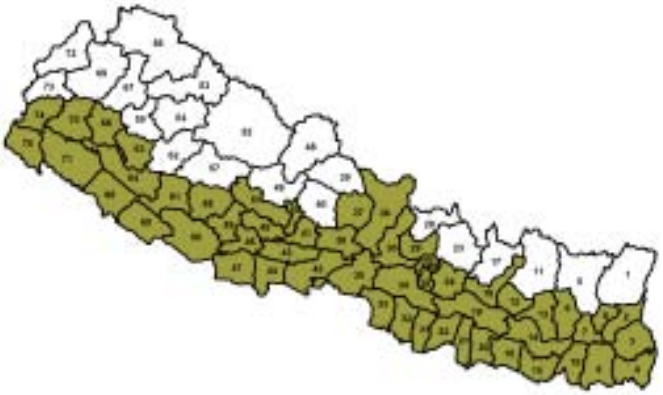
Reproductive mode Reproduces sexually by seeds.

Management information

Physical In Nepal, plants are pulled out by hands to uproot and is burnt.

Field observation In tropical part of eastern Nepal, the plants are found in disturbed forest areas and wastelands. Plants also grow in agricultural field and are removed manually by farmers. The plant is found to be less problematic in comparison to other invasive plants. According to local inhabitants, cattle do not feed upon the plants. The plant reduces the fertility of soil.

Mimosa pudica L.



Family Fabaceae (Leguminosae)

Common/English name Sensitive plant, sleeping grass.

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.

First Herbarium record Sarautikhola, 610m, 12.08.1954, Stainton, Sykes & Williams, 6874 (KATH)

Habitat Moist fallowlands, agricultural lands and forests.

Description Annual, diffuse, subshrub. Stem and branches prickly. Stipules lanceolate, *ca* 1cm long, margin bristly. Petioles 2-7cm long; leaves digitate, immediately folding by pulvini if touched or jarred; pinnae 4; leaflets 10-20 pairs, obliquely narrow-oblong, 8-12 × 2-3mm, base rounded, margin ciliate, apex acute. Flower pink. Stamens 4. Pods compressed, fragmenting into 2-5 rounded segments, suture bearing long bristles.

Fl. & Fr. 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)

Ecological characters The plant is commonly found in moist waste ground, in dry lawn and open plantations. It forms a dense ground cover, preventing dessimination of other species. A fire hazard may occur in dry seasons.

Reproductive mode Plant reproduces sexually by seeds.

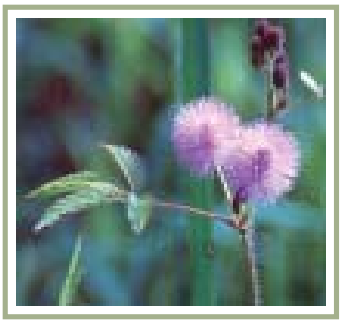
Dispersal methods Seeds are dispersed usually by animals and human; bristles of pod cling to fur and clothes that help seeds dispersal.

Management information

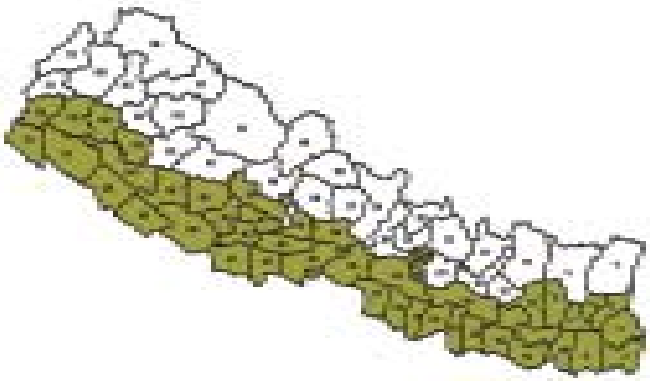
Physical People simply dig out the plants.

Chemical It is susceptible to several herbicides, including dicamba, glyphosate, picloram and triclopyr (Parsons and Cuthberston, 1992).

Field observation *Mimosa pudica* is commonly observed in different habitats of Terai and mid-hill areas of Nepal. When *Mimosa* starts spreading, it totally covers the ground surface, causing threat to ground vegetation.



Oxalis latifolia Humb.



Family	Oxalidaceae
Common/English name	Purple wood sorrel, broadleaf wood sorrel
Local name	Chari amilo
First reported in Nepal	Hara in Fl. East. Himal.168.1966
First Herbarium record	Kathmandu, 1280m, 21.8.1954, Stainton, Sykes & Williams, 6963 (KATH).
Habitat	Agricultural lands, orchard, nursery
Description	Stemless herb with basal bulb consisting of numerous ovoid bulbils. Leaves basal; trifoliate, leaflet triangular, up to 4 x 6cm, apex with broad shallow sinus. Flowers in lax umbels. Sepals with 2 apical glands. Petals reddish pink or purple.
Fl. & Fr.	June - November
Uses	Young leaves are used as pickle for its acidic taste; root is mixed with natural color to make the colors fast (Mananadhar, 2002).
Distribution	Native of Central and South America. Nepal (WCE, 600-2200m)
Ecological characters	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.
Reproductive mode	Reproduces vegetatively by bulbils and sexually by seeds.
Dispersal methods	The plant spreads rapidly in agriculture field such as during ploughing.
Field observation	The plant is growing rapidly in agricultural land throughout the country. Though people remove the plant mechanically by hand, complete removal is impossible because of large number of bulbils produced by a single plant. A single bulbil is capable of producing a mature plant.

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

First Herbarium record Kathmandu, Tripureshwor, 20.09.1970, N.P. Manandhar 16756 (KATH)

Habitat Agricultural fields and Fallowlands.

Description Annual, erect, coarse herb; stem up to 2m high. Leaves alternate, petiole long; leaf blade broadly ovate or ovate-triangular, 5-12 × 5-12cm, 3-5-palmati-lobed or angled at base, deeply cordate, irregularly dentate. Head greenish, monoecious, in dense axillary and terminal racemes. Male capitula 5-7 mm in diameter; phyllaries lanceolate to narrowly obovate, 2-3.5mm long; corolla 2-2.5mm long. Female capitula *ca* 1-2cm long, greenish brown. Burs (fruits) with 2 erect mucronate beaks and densely covered with hooked spines.

Fl. & Fr. 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)

Ecological characters *Xanthium strumarium* is distributed in open and disturbed areas particularly, along roadsides, streams and riverbanks and overgrazed pastures. On nutrient rich soils with abundant moisture, it grows up to 2 m high with pure strands. In dry poor soil, plants may grow to only a few centimeters high. The plant withstands partial submergence for six to eight weeks by forming adventitious roots from the submerged portion of the stem. These roots float in water and often get infested with oxygen-producing green algae (*Dedogonium* sp.) which solves the problem of aeration (Ambasht, undated). It is an extremely competitive weed in agricultural field. Some plants appear to

have allelopathic properties (Cutler, 1983). *X. strumarium* burs contain a highly toxic substance, *Carbo xyatractyloside*, capable of killing cattle, goats, sheep and poultry. It also causes allergic reaction to some people (Parsons, 1973).

Reproductive mode Reproduces sexually by seeds. Seeds are viable for several years. *X. strumarium* is wind pollinated, self compatible and predominately self pollinated. The seeds of this plant are easily spread due to their ability to float and to "hitchhike" on humans and animals. It quickly dominates in an area because of prolific seed production and high germination and survival rates.

Dispersal methods Seeds disperse by wind and animals. One crowded plant reported to have produced 71 to 586 burs (fruits). Burs are buoyant and float for up to 30 days (Kaul 1961), thus being easily dispersed to pastures subject to flooding. The burs are also become entangled in animal hair or human clothing.

Management information

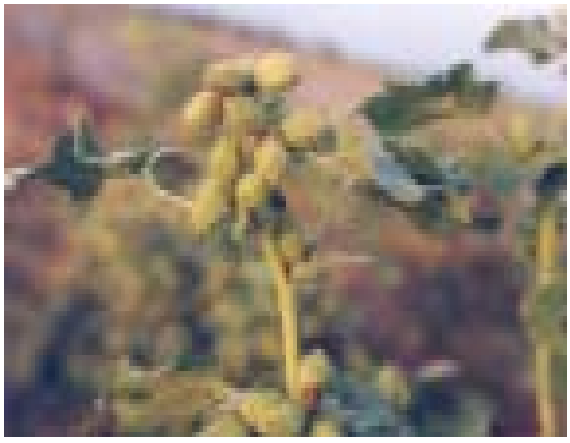
Physical Physical removal of the plants by hand pulling or hoeing is effective, if done prior to flowering. Flowering plants should be carefully removed so as not to dislodge the burs, piled and burned (Parsons, 1973). Burning is an effective mean of destroying the seeds of *X. strumarium*.

Chemical 2, 4-D amine, a phenoxy–type herbicide used for broad leaf weed control, should be applied to plants at the 3 to 5 leaf stage of growth. Dicamba is a broad spectrum herbicide used against perennial broad leaf weeds. Bromoxynil is a contact herbicide, which affects only the plants or portions of a plant actually contacted by the chemical.

Biological The most promising control species introduced in Australia is *Nupserha antennata*, a beetle native to India and Pakistan (Haseler, 1970). *Oedopa* sp. nr. capito (Diptera) is probably the only insect species worthy of study as a potential bio-control agent for *X. strumarium*. (Hilgendrof and Goeden, 1983). Oedopa in restricted to genus *Xanthium* feeding on its roots. The rust *Puccinia xanthii* Schw. is an obligate parasite on species of *Xanthium* and *Ambrosa* (Conners, 1967; Hasan, 1974; Alcorn, 1975; Jadhav and Somani, 1978)

Namatodes reported from *X. strumarium* are *Aphelenchoides ritzema-bosi* Schmidt (Weaver and Lechowicz, 1983) and *Meloidogyne hapla* (Siddique *et al.* 1973). *Cuscuta pentagona* (dodder) is a higher plant parasite that has been found on cocklebur (Munz and Keck, 1973). *Orobanche ramosa* L. (broom rape) is another parasitic plant found on a variety of cultivated and weedy plants, including *Xanthium* (Polunin 1966, Munz and Keck, 1973).

Field observation *Xanthium strumarium* is found to be problematic in Agricultural field. It is a common weed in wheat field. Farmers use 2, 4-D herbicide for the control of the plant in agricultural field. Plant is also found to be dominating in roadsides and open dry pastures. Cattle do not feed upon the plant. People of Morang district informed that the plant has became dominant since last 10 years.



CHAPTER SEVEN

Assessment

A large number of alien species are naturalized in Nepal as permanent denizens of the native flora. Diversity in climate, altitude and edaphic factors of Nepal favour the establishment of IAS from different regions of the world. It may be presumed that majority of IAS have been introduced to Nepal via surrounding countries, particularly India. The natural barrier (Himalayas) of northern region has checked to spread alien species which are mostly neo-tropical in origin.

A rapid inventory of IAS was conducted in forest, cropland, fallowland and wetland ecosystems of Terai, Siwaliks and Mid-hills of Nepal. Attempt has been made to assess the invasion of alien species in different ecosystems.

A. Distribution of Invasive Alien Species in Different Ecosystems

Forests

The disturbed, open and marginalized areas of forests host IAS than undisturbed or close forest. The forests of west Nepal house fewer number of alien species in comparison to central and eastern Nepal. Assessment has been made on the distributional range of alien species occurring in forests of different parts of the country (*Table 2*). *Ageratum conyzoides* and *Chenopodium ambrosioides* are common in the forest of Kanchanpur-Shreepur (290m) of Far-West Nepal. Another site in western Nepal was the forest of Bardia-Rajapur (200m), where invasion is made by *Lantana camara* and *Solanum aculeatissimum*. Similarly, *Chromolaena odorata, Tridax procumbens*, *Cassia tora*, and *Cassia occidentalis* are reported from the forest of Rupandehi district (Tamnagar). The Rampur area of Chitwan (central Nepal) is heavily invaded by *Lantana camara*, *Mikania micrantha*, *Chromolaena odorata*, *Cassia tora* and *Hyptis suaveolens*. It is assumed that the forest of eastern Terai has been deforested or disturbed much earlier than other parts of the country. As a result, the number of IAS is also higher in this area. The forest of Koshi Tappu Wildlife Reserve (eastern embankment) is seriously invaded by *Mikania micrantha, Cassia occidentalis, Chromolaena odorata, Ageratum conyzoides, Lanatana camara, Parthenium hysterophorus, Mimosa pudica, Hyptis suaveolens* and *Amaranthus spinosus*. Similarly, the nearby forest of Tarhara (a portion of *Charkoshe jhadi*) in Sunsari district is invaded by *Chromolaena odorata, Mikania micrantha, Hyptis suaveolens, Lantana camara* and *Ageratum conyzoides*. The forest in Jhapa area (near Damak) is also invaded by *Lantana camara*, *Mikania micrantha*, *Bidens pilosa*, *Chromolaena odorata*, *Tridax procumbens*, *Hyptis suaveolens*, *Cassia tora*, *Cassia occidentalis*, *Ageratum conyzoides*, *Mimosa pudica* and *Leonotis nepetifolia*.

Similarly, the forest ecosystem of mid-hills is also seriously invaded by a large number of IAS. For

Table 2: Forest Ecosystem and Common Alien Species

Forest Site	Location/Altitude	Common Alien Species
Kanchanpur - Shreepur	Western Nepal, 290m	*Ipomoea carnea ssp. fistulosa, Parthenium hysterophorus, Ageratum conyzoides, Xanthium strumarium, Argemone mexicana*
Doti - Ghanteshwor	Western Nepal, 1750m	*Ageratina adenophora, Chromolaena odorata, Ageratum conyzoides*
Bardia - Rajapur	Western Nepal, 200m	*Lantana camara, Solanum aculeatissimum, Urena lobata*
Dang - Tribhuvan nagar	Western Nepal, 250m	*Leucaena leucocephala, Urena lobata, Ageratum conyzoides, Tridax procumbens*
Rupandehi - Tamnagar	Central Nepal, 150m	*Chromolaena odorata, Cassia tora, C. occidentalis, Urena lobata*
Palpa - Dobhan	Central Nepal, 300m	*Leucaena leucocephala, Urena lobata*
Parbat - Khurkot	Central Nepal, 1050m	*Ageratina adenophara, Chromolaena odorata, Ageratum houstonianum, Bidens pilosa.*
Chitwan - Rampur	Central Nepal, 250m	*Lantana camara, Mikania micrantha, Chromolaena odorata, Cassia tora, Hyptis suaveolens, Tridax procumbens, Urena lobata*
Rasuwa - Thulosyabru	Central Nepal, 2100m	*Ageratina adenophora*
Kathmandu - Dakchinkali	Central Nepal, 1300m	*Ageratina adenophora, Ageratum conyzoides, Bidens pilosa, Crassocephalum crepidioides, Urena lobata*
Koshi Tappu	Eastern Nepal, 200m	*Mikania micrantha, Chromolaena odorata, Lantana camara, Parthenium hysterophorus, Cassia occidentalis, Ageratum conyzoidess, Mimosa pudica, Hyptis suaveolens, Amaranthus spinosus*
Sunsari - Tarhara	Eastern Nepal, 225m	*Chromolaena odorata, Mikania micrantha, Lantana camara, Hyptis suaveolens, Ageratum conyzoides*
Sunsari - Bhedetar	Eastern Nepal, 1420m	*Ageratina adenophora, Chromolaena odorata, Ageratum conyzoides, Bidens pilosa*
Dhankuta	Eastern Nepal, 1250m	*Lantana camara, Ageratina adenophora, Chromolaena odorata, Bidens pilosa*
Jhapa - Damak	Eastern Nepal, 200m	*Lantana camara, Mikania micrantha, Chomolaena odorata, Bidens pilosa, Hyptis suaveolens, Cassia tora, C. occidentalis, Ageratum conyzoides, Mimosa pudica, Leonotis nepetifolia, Tridax procumbens, Urena lobata*

Source: IUCN Nepal Field Survey, 2002- 2003.

example, the forest of Doti (Far-West 1750m) is invaded by *Ageratina adenophora* (*Eupatorium adenophora*), *Chromolaena odorata* and *Ageratum conyzoide*s. The *Leucaena leucocephala* (Ipil Ipil), a Mexican and Central American originated plant, was widely promoted in Nepal for agro-forestry and forage production. However, it is found as a potential invasive species along forest margins of Palpa district and some other open semi-natural habitats. The forest of Khurkot area in Parbat district (central 1050m), is seriously invaded by *Ageratina adenophera*, *Chromolaena odorata*, *Bidens* sp., and *Ageratum houstonianum*, whereas the forest of Rasuwa around Thulosyabru (2100m) along Langtang National Park is dominated by *Ageratina adenophora*. The presence of a few number of IAS in Rasuwa district (central Nepal) might be mainly due to the prevalence of cold climate in this high altitude area (above 2100m). Besides, the location of the area seems to have a geographical barrier (although not distinct) due to relatively higher latitudes. Also, the area has poor or relatively less pathways for invasive alien species unintentional introduction due to lack of human migration from lowlands to the area, low transport facility and low demand for unprocessed agricultural goods. The Dakchinkali forest (1300m) in Kathmandu Valley is invaded by *Ageratina adenophora* (distribution is observed up to 2400m), *Bidens pilosa, Ageratum conyzoides* and *Crassocephalum crepidioides.* The degraded forest above Dharan Bazaar (400m) to Bhedetar (1420m) is seriously invaded by *Ageratina adenophora, Chromolaena odorata, Ageratum conyzoides* and *Bidens pilosa,* similarly the forest around Dhankuta Bazaar (1250m) is invaded by *Lantana camara, Ageratina adenophora, Chromolaena odorata* and *Bidens pilosa.*

The *Lantana camara* and *Chromolaena odorata* have been observed in five sites out of total seven study sites in the Terai. The *Lantana camara* has wider extension from Bardia to Jhapa districts whereas *Chromolaena odorata* is extended only from Rupandehi to Jhapa. The other major alien species such as *Mikania micrantha, Hyptis suaveolens* and *Ageratum conyzoides* are observed only in four sites. The distribution of *Ageratum conyzoides* is common all over the Terai whereas the *Mikana micrantha* and *Hyptis suaveolens* are more common from central to eastern Nepal, particularly from Chitwan to Jhapa. The invasion of *Mikania micrantha* is severe in open and moist forests of Royal Chitwan National Park, Tarhara and Koshi Tappu where most of the vegetation, including trees are heavily covered by this vine. Similarly, *Cassia tora* and *Cassia occidentalis* were seen on three sites in central to eastern Terai. *Cassia sophera* is commonly observed along the urban and sub-urban areas of Morang. In terms of IAS distribution in various sites of midhills, *Ageratina adenophora* has occurred in all sites whereas *Lantana camara* is observed mainly in the forests of Kathmandu and Dhankuta. Similarly, *Chromolaena odorata* and *Ageratum conyzoides* have wider horizontal distribution from Doti to Dhankuta.

It is noticed that the warm climate of lower altitude (Terai) houses higher number of alien species (*Chromoloena odorata, Lantana camara, Mikania micrantha, Hyptis suaveolens, Ageratum conyzoides,* etc.) than comparatively cold condition of higher altitudes (mid-hills). In this regard, it is interesting to mention that almost all IAS are neo-tropical in origin.

The average of coverage, density and frequency of common alien species recorded from the forest ecosystem of different study sites are given in *Table 3*.

Fallowlands

Fallowlands are highly vulnerable to the introduction of alien species and are also considered as an entry point for them. IAS generally invades other ecosystems (forest, wetlands, croplands) only after being established in disturbed areas or fallowland. *Table 4* also shows that fallowlands in Nepal tend to hold highest number of plant invaders. For example, five species of IAS are found in Kanchanpur-Shreepur area of Far-West Nepal: *Ipomoea carnea* ssp. *fistulosa*, *Ageratum conyzoides*, *Xanthium strumarium, Argemone mexicana* and *Parthenium hysterophorus.* In Bardia, nine alien species are invasive. Major ones include *Ipomoea*

Table 3: Common Alien Species Recorded from Forest Ecosystem of Different Study Sites

S.N.	Name of Species	Density (pl/m²)	Frequency (%)	Coverage (%)
1.	*Ageratina adenophora*	0.81	26.66	8.20
2.	*Ageratum conyzoides*	0.73	17.2	1.63
3.	*Amaranthus spinosus*	0.09	0.45	0.28
4.	*Bidens pilosa*	2.65	15.9	1.8
5.	*Cassia occidentalis*	0.08	3.6	0.17
6.	*Cassia tora*	0.16	7.27	0.31
7.	*Chromolaena odorata*	1.01	30.75	12.99
8.	*Hyptis suaveolens*	0.06	3.7	0.42
9.	*Lantana camara*	4.34	26	7
10.	*Leonotis nepetifolia*	0.49	3.8	0.39
11.	*Leucaena leucocephala*	0.23	6.66	0.66
12.	*Mikania micrantha*	1.43	2.67	11.6
13.	*Mimosa pudica*	0.04	2.27	0.06
14.	*Oxalis latifolia*	0.04	0.50	0.11
15.	*Solanum aculeatissimum*	0.08	1.50	0.2
16.	*Tridax procumbens*	0.04	3.03	0.09

Source: IUCN Nepal Field Survey, 2002-2003.

carnea spp. *fistulosa*, *Lantana camara*, *Chenopodium ambrosioides*, *Ageratum conyzoides*, *Xanthium strumarium*, *Alternanthera sessilis*, *Solanum aculeatissimum*, etc. Similarly, the fallowland around Dang-Tribhuvannagar is dominated by *Lantana camara*, *Cassia occidentalis*, *Cassia tora*, *Ageratum conyzoides*, *Solanum aculeatissimum*, *Euphorbia hirta*, *Amaranthus spinosus*, and *Parthenium hysterophorus*, whereas the fallowlands in Rupandehi are invaded by *Ipomoea carnea* ssp. *fistulosa*, *Xanthium strumarium*, *Cassia tora*, *Cassia occidentalis*, *Chromolaena odorata* and *Amaranthus spinosus*.

Similarly, it was observed that the fallowland of Chitwan is invaded by over 13 IAS species. These include *Chromolaena odorata*, *Lantana camara*, *Hyptis suaveolens, Ipomoea carnea* ssp. *fistulosa*, *Cassia tora*, *Ageratum conyzoides*, *Xanthium strumarium*, *Amaranthus spinosus*, *Amaranthus viridis*, *Sida acuta*, *Cassia occidentalis*, *Solanum aculeatissimum*, etc. In Sarlahi, the fallowland is dominated by *Amaranthus spinosus*, *Alternanthera sessilis*, *Chromolaena odorata*, and *Cassia tora*. Over eleven species of IAS are observed in the fallowland around Biratnagar area of Morang district (eastern Nepal). These include *Amaranthus spinosus, Cassia tora, Ipomoea carnea* ssp. *fistulosa, Ageratum conyzoides, Xanthium strumarium,*

Chromolaena odorata, Argemone mexicana, Parthenium hysterophorus, Mikania micrantha, Hyptis suaveolens, Axonopus compressus, Datura metel and *Ricinus communis.*

Following species are found along the fallowland of the Koshi Tappu: *Ipomoea carnea* ssp. *fistulosa, Mikania micrantha, Bidens pilosa, Hyptis suaveolens, Ageratum conyzoides* and *Ageratum houstonianum*. Similarly, P*arthenium hysterophorus, Datura metel, Ageratum conyzoides* and *Hyptis suaveolens* occurs along the fallowland of Tarhara. *Chromoloena odorata, Lantana camara, Mikania micrantha, Xanthium strumarium, Cassia occidentalis, Ageratum conyzoides, Bidens pilosa, Hyptis suaveolens, Parthenium hysterophorus* and *Datura Metel* are major alien species established around the fallowlands of Dharan Bazaar in Sunsari district. The fallowland around Damak municipality of Jhapa district is dominated by *Ipomoea carnea* ssp. *fustulosa*, *Cassia tora*, *Cassia occidentalis*, *Mikania micrantha*, *Mimosa pudica*, *Chromolaena odorata, Ageratum conyzoides, Datura metel* and *Ricinus communis*.

Even the fallowlands in the mid-hills is not spared by IAS. For example, Ghanteshwor area (1750m) of Doti district is invaded by *Ageratina adenophora*, *Solanum aculeatissimum*, *Chenopodium ambrosioides*, *Ageratum conyzoides, Bidens* sp. and *Oenothera rosea*. In Dobhan area (300m) of Palpa district, *Cassia tora*, *Xanthium strumarium*, *Cassia occidentalis*, *Mimosa pudica*, *Ageratum conyzoides*, *Euphorbia hirta*, *Ageratina adenophora*, *Parthenium hysterophorus*, *Chromolaena odorata* and *Ipomoea carnea* ssp. *fistulosa* seriously invade the fallowlands.

Parbat district (Khurkot) is dominated by *Cassia occidentalis*, *Cassia tora*, *Solanum aculeatissimum*, *Ageratina adenophora*, *Chromolaena odorata*, *Ageratum conyzoides*, *Ageratum houstonianum*, *Bidens pilosa* and *Crassocephalum crepidioides*. The fallowlands around Thulosyabru (2100m) of Rasuwa district has more *Xanthium strumarium*, *Bidens* sp. and *Galinsoga parviflora*. Similarly, the fallowland around Kathmandu Valley is invaded by *Ageratina adenophora, Lantana camara, Parthenium hysterophorus, Xanthium strumarium, Bidens pilosa, Ageratum conyzoides, Amaranthus spinosus, Alternanthera philoxeroides, Crassocephalum crepidioides* and *Solanum aculeatissimum*. In Dhankuta, *Ageratina adenophora, Bidens pilosa, Lantana camara, Tithonia diversifolia, Ageratum conyzoides, Chromoloena odorata, Hyptis suaveoles, Xanthium strumarium,* etc. are dominant.

IAS in fallowlands were assessed in altogether 18 sites covering Terai, Siwalik and mid-hills. In Terai and Siwaliks, 12 sites were assessed. The *Ageratum conyzoides* is observed in almost all sites (11 sites) distributed from Kanchanpur to Jhapa districts, followed by *Xanthium strumarium* distributed in eight sites between Kanchanpur and Jhapa. The *Parthenium hysterophorus, Ipomoea carnea* ssp. *fistulosa, Chromoloena odorata* and *Cassia tora* are observed in seven sites. Out of these four species, the distribution range of *Ipomoea carnea* ssp. *fistulosa* is wider (Kanchanpur to Jhapa), followed by *Parthenium hysterophorus* (Kanchanpur-Morang), *Cassia tora* (Dang to Jhapa) and *Chromolaena odorata* (Rupandehi-Jhapa). Similarly, *Lantana camara* (Bardia to Dharan) and *Cassia occidentalis* (Dang to Jhapa) are observed in six sites. *Mikania micrantha* and *Hyptis suaveolens* are observed in five sites. The *Mikania micrantha* is observed along Koshi Tappu to Jhapa whereas the *Hyptis suaveolens* is common from Chitwan to Morang. Similarly, *Solanum aculeatissimum* is common from Bardia to Morang whereas *Amaranthus spinosus* is predominant from Dang to Morang. The other alien species along fallowlands are *Argemone mexicana* (observed in Kanchanapur, Morang and Sunsari districts), *Mimosa pudica, Bidens pilosa, Euphorbia hirta, Leonotis nepetifolia, Chenopodium ambrosioides, Alternathera sessilis,* etc.

Several IAS found in southern flat plains of Terai and Siwaliks are also common in different localities of midhills. Altogether, six sites in different parts of mid-hills were assessed to find out the IAS distributional status along the fallowlands. *Ageratina adenophora, Ageratum conyzoides* and *Bidens pilosa* are distributed in five sites (Doti to Dhankuta). Similarly, *Solanum*

Table 4: Fallowland Ecosystem and Common Alien Species

Fallowland Sites	Location/Altitude	Common IAS
Kanchanpur - Shreepur	Western Nepal, 290m	*Ipomoea carnea ssp. fistulosa, Parthenium hysterophorus, Ageratum conyzoides, Xanthium strumarium, Argemone mexicana*
Doti - Ghanteshwar	Western Nepal, 1750m	*Ageratina adenophora, Solanum aculeatissimum, Chenopodium ambrosioides, Ageratum conyzoides, Bidens sp.*
Bardia - Rajapur	Western Nepal, 200m	*Ipomoea carnea ssp. fistulosa, Lantana camara, Ageratum conyzoides, Chenopodium ambrosoides, Xanthium strumarium, Alternanthera sessilis, Solanum aculeatissimum*
Dang - Tribhuvan nagar	Western Nepal, 250m	*Lantana camara, Parthenium hysterophorus, Cassia occidentalis, C. tora, Ageratum conyzoides, Solanum aculeatissimum, Amaranthus spinosus*
Rupandehi - Tamnagar	Central Nepal, 150m	*Ipomoea carnea ssp. fistulosa, Chromolaena odorata, Xanthium strumarium, Cassia tora. C. occidentalis, Amaranthus spinosus*
Palpa - Dobhan	Central Nepal, 300m	*Ageratina adenophora, Chromolaena odorata, Ipomoea carnea ssp. fistulosa, Parthenium hysterophorus, Cassia tora, C. occidentalis, Xanthium strumarium, Ageratum conyzoides*
Parbat - Khurkot, Kusma	Central Nepal, 1050m	*Ageratina adenophora, Chromolaena odorata, Ageratum conyzoides, A. houstonianum, Cassia tora, C. occidentalis, Solanum aculeatissimum, Bidens pilosa, Crassocephalum crepidioides*
Chitwan - Rampur	Central Nepal, 250m	*Chromolaena odorata, Lantana camara, Ipomoea carnea ssp. fistulosa, Cassia tora, C. occidentails, Ageratum conyzoides, Xanthium strumarium, Amaranthus spinosus, A. viridis, Sida acuta, Solanum aculeatissimum*
Rasuwa - Thulosyabru	Central Nepal, 2100m	*Galinsoga parviflora, Xanthium strumarium ssp.*
Kathamandu	Central Nepal, 1300m	*Ageratina adenophora, Parthenium hysterophorus, Lantana camara, Alternanthera philoxeroides, Xanthium strumarium, Amaranthus spinosus, Crassocephalum crepidioides, Solanum aculeatissimum, Bidens pilosa*
Sarlahi - Malangwa	Eastern Nepal, 200m	*Chromolaena odorata, Amaranthus spinosus, Alternanthera sessilis, Cassia tora*
Koshi Tappu	Eastern Nepal, 200m	*Ipomoea carnea ssp. fistulosa, Mikania micrantha, Bidens pilosa, Hyptis suaveolens, Ageratum conyzoides, A. houstonianum*

Morang - Biratnagar	Eastern Nepal, 80m	*Ipomoea carnea ssp. fistulosa, Chromolaena odorata, Mikania micrantha, Parthenium hysterophorus, Amaranthus spinosus, cassia tora, Ageratum conyzoides, Datura metel, Xanthium strumarium, Hyptis suaveolens, Argemone mexicana, Axonopus compressus, Ricinus communis.*
Sunsari - Tarhara	Eastern Nepal, 225m	*Parthenium hysterophorus, Ageratum conyzoides, Hyptis suaveolens, Datura metel*
Dharan	Eastern Nepal, 400m	*Chromolaena odorata, Lantana camara, Mikania micrantha, Parthenium hysterophorus, Hyptis suaveolens, Xanthium strumarium, Cassia occidentalis, Datura metel*
Dhankuta	Eastern Nepal, 1250m	*Ageratina adenophora, Lantana camara, Tithonia diversifolia, Chromolaena odorata, Bidens pilosa, Ageratum conyzoides, Hyptis suaveolens, Xanthium strumarium*
Jhapa - Damak	Eastern Nepal, 200m	*Ipomoea carnea ssp. fistulosa, Mikania micrantha, Chromolaena odorata, Cassia tora, C. occidentalis, Mimosa pudica, Ageratum conyzoides, Datura metel, Ricinus communis*

Source: IUCN Nepal Field Survey, 2002-2003.

Fallowland Sites	Location/Altitude	Common IAS
Kanchanpur - Shreepur	Western Nepal, 290m	*Ipomoea carnea ssp. fistulosa, Parthenium hysterophorus, Ageratum conyzoides, Xanthium strumarium, Argemone mexicana*
Doti - Ghanteshwar	Western Nepal, 1750m	*Ageratina adenophora, Solanum aculeatissimum, Chenopodium ambrosioides, Ageratum conyzoides, Bidens sp.*
Bardia - Rajapur	Western Nepal, 200m	*Ipomoea carnea ssp. fistulosa, Lantana camara, Ageratum conyzoides, Chenopodium ambrosoides, Xanthium strumarium, Alternanthera sessilis, Solanum aculeatissimum*
Dang - Tribhuvan nagar	Western Nepal, 250m	*Lantana camara, Parthenium hysterophorus, Cassia occidentalis, C. tora, Ageratum conyzoides, Solanum aculeatissimum, Amaranthus spinosus*
Rupandehi - Tamnagar	Central Nepal, 150m	*Ipomoea carnea ssp. fistulosa, Chromolaena odorata, Xanthium strumarium, Cassia tora. C. occidentalis, Amaranthus spinosus*
Palpa - Dobhan	Central Nepal, 300m	*Ageratina adenophora, Chromolaena odorata, Ipomoea carnea ssp. fistulosa, Parthenium hysterophorus, Cassia tora, C. occidentalis, Xanthium strumarium, Ageratum conyzoides*
Parbat - Khurkot, Kusma	Central Nepal, 1050m	*Ageratina adenophora, Chromolaena odorata, Ageratum conyzoides, A. houstonianum, Cassia tora, C. occidentalis, Solanum aculeatissimum, Bidens pilosa, Crassocephalum crepidioides*
Chitwan - Rampur	Central Nepal, 250m	*Chromolaena odorata, Lantana camara,*

Ipomoea carnea subsp. *fistulosa* used as green manure in Agricultural land, Kapilvastu.

aculeatissimum (Doti to Dhankuta) and *Xanthium strumarium* (Palpa to Dhankuta) are recorded in four sites, followed by *Chromolaena odorata* (Palpa to Dhankuta) and *Crassocephalum crepidioides* (Parbat to Dhankuta) in three sites. The invasion of *Lantana camara* (Kathmandu and Dhankuta), *Cassia occidentalis* and *Casia tora* (Palpa and Parbat), *Parthenium hysterophorus* (Palpa, Kathmandu), *Ipomoea carnea* ssp. *fistulosa* (Palpa), *Amaranthus spinosus* (Kathmandu), *Hyptis suaveolens* (Dhankuta), *Tithonia diversifolia* (Palpa and Dhankuta) is observed in two or less than two sites.

The above analysis shows that fallowlands or disturbed habitats favour high introduction of alien species. The overall (vertical and horizontal) distribution of *Ageratum conyzoides* is wider (although its impact is not so high according to local people), followed by *Xanthium strumarium, Cassia tora, Cassia occidentalis, Bidens pilosa, Amaranthus spinosus, Mimosa pudica,* and *Solanum aculeatissimum.* The study shows that serious invasion along fallowland is made by *Lantana camara, Chromolaena odorata, Parthenium hysterophorus, Mikania micrantha, Ipomoea carnea* ssp. *fistulosa* and *Hyptis suaveolens* in Terai/Siwaliks regions. The serious ones in mid-hills are *Ageratina adenophora* and *Lantana camara*.

Table 5: Common Alien Species Recorded in Fallowlands

S.N.	Name of Species	Density (Pl/m^2)	Frequency (%)	Coverage (%)
1.	*Ageratina adenophora*	0.22	19.02	6.44
2.	*Ageratum conyzoides*	2.22	33.56	5.17
3.	*Amaranthus spinosus*	0.43	11.9	0.95
4.	*Argemone mexicana*	0.17	2.69	0.55
5.	*Bidens pilosa*	0.19	12.5	1.56
6.	*Cassia occidentalis*	0.27	13.89	1.38
7.	*Cassia tora*	3.25	40.17	4.12
8.	*Chromolaena odorata*	0.32	19.9	3.37
9.	*Euphorbia hirta*	0.06	2.72	0.57
10.	*Hyptis suaveolens*	0.94	4.07	1.06
11.	*Ipomoea carnea ssp. fistulosa*	0.56	24.10	4.8
12.	*Lantana camara*	0.13	14.33	5.45
13.	*Mikania micrantha*	0.24	5.76	2.93
14.	*Mimosa pudica*	0.12	5.3	0.33
15.	*Parthenium hysterophorus*	0.55	11.12	1.50
16.	*Solanum aculeatissimum*	0.19	11.8	1.14
17.	*Urena lobata*	0.25	13.33	0.9
18.	*Xanthium strumarium*	0.44	14.6	2.72

Source: IUCN Nepal Field Survey, 2002-2003.

The average of density, frequency and coverage of common alien species recorded from fallowland in different study sites (Table 4) are given in Table 5.

Croplands

The invasive species found in agricultural lands are generally called weeds or noxious weeds and are generally herbaceous in nature. Croplands in Nepal have many alien species (*Table 6*). In Kanchanpur-Shreepur area, the major ones along sugarcane fields are *Chenopodium album*, *Solanum nigrum*, *Ageratum conyzoides* and *Physalis angulata* whereas maize field has been invaded by *Cassia tora, Ageratum conyzoides*, and *Paspalum distichum*. Similarly, the sugarcane field of Bardia-Rajapur has been invaded by *Ageratum conyzoides*, *Amaranthus spinosus*, while maize field by *Oxalis latifolia*, *Euphorbia hirta* and *Amaranthus viridis*. The paddy fields around Tribhuvannagar of Dang district has *Ageratum conyzoides*, *Eclipta prostrata* and *Paspalum distichum.* The potato fields in the same stretch has been invaded by *Oxalis latifolia* and *Ageratum conyzoides*. Similarly, *Eichhornia crassipes, Paspalum distichum* and *Alternanthera sessilis* are common invasives in the paddy fields of Rupandehi district. The maize field in Chitwan is occupied by *Amaranthus spinosus*, *Ageratum conyzoides*, and *Solanum nigrum. Ludwigia hyssopifolia*, *Alternanthera sessilis* and *Leersia hexandra* are dominant in paddy fields of Chitwan district.

Paddy fields in Tarhara were visited after harvesting season. The fields were found to be invaded by *Ageratum conyzoides, Parthenium hysterophorus, Amaranthus spinosus, Mimosa pudica, Hyptis suaveolens, Brachiaria mutica, Mikania micrantha* and *Chromolaena odorata*. Similarly, paddy fields in Morang district (Biratnagar) is invaded by *Xanthium strumarium, Chromolaena odorata, Hyptis suaveolens, Mimosa pudica, Cassia tora, Cassia occidentalis, Ageratum conyzoides, Amaranthus spinosus, Alternanthera paronychioides, Solanum nigrum, Conyza bonariensis* and *Crassocephalum crepidioides*, *whereas Mikania micrantha*, *Chromolaena odorata, Physalis peruviana* and *Ageratum conyzoides* are commonly observed around the croplands of Damak.

Many alien species have been successfully established in the agricultural land of mid-hills. For example, croplands in Ghanteshwar (1750m) is invaded by *Galinsoga parviflora*, *Solanum aculeatissimum*, *Bidens pilosa*, *Chenopodium album*, *Ageratum conyzoides* and *Xanthium strumarium*. Similarly, maize field in Palpa (Dobhan) has *Amaranthus spinosus*, *Ageratum conyzoides*, *Euphorbia hirta* and *Crassocephalum crepidioides,* whereas the margins of rice field has *Chromolaena odorata*. In Parbat district (1050m), maize field is invaded by *Ageratum conyzoides*, *Crassocephalum crepidioides*, *Ageratum houstonianum*, *Ageratina adenophora*, *Bidens pilosa*, *Euphorbia heterophylla*, *Cleome spinosa* and *Galinsoga parviflora*. Millet (*Eleusine coracana*) field in Thulosyabru (2100m) is dominated by *Galinsoga parviflora*, *Oxalis latifolia* and *Bidens pilosa*.

Similarly, croplands around Kathmandu Valley are invaded by *Ageratum conyzoides, Axonopus compressus, Galinsoga parviflora, Crassocephalum crepidioides, Bidens pilosa, Ageratina adenophora, Xanthium strumarium,* and *Amaranthus spinosus*. Croplands in Dhankuta are found to have *Ageratum conyzoides, Bidens pilosa, Crassocephalum crepidioides, Galinsoga parviflora,* etc.

Over ten alien species are observed as invasive species along the croplands of Terai and Siwaliks (maize, millet, sugarcane, paddy, etc.). The invasion of *Ageratum conyzoides* is widely extended from Kanchanpur to Jhapa districts. *Ageratum* is followed by C*assia tora, Solanum nigrum and Amaranthus spinosus.* It is found that *Oxalis latifolia* is dominant along the cropfield of western and central Nepal whereas *Mikania micrantha, Mimosa pudica* and *Chromolaena odorata* is dominant in eastern Nepal. Similarly, *Xanthium strumarium, Paspalum distichum, Cassia occidentalis, Hyptis suaveolens, Argemone mexicana, Parthenium hysterophorus* and *Alternanthera sessilis* are also dominant in different croplands of Nepal.

Bidens pilosa, Ageratum conyzoides, Ageratina adenophora, Crassocephalum crepidioides,

Table 6: Cropland Ecosystem and Common Alien Species

Cropland Sites	Location/Altitude	Common IAS
Kanchanpur - Shreepur	Western Nepal, 290m	*Chenpodium album, Solanum nigrum, Ageratum conyzoides, Cassia tora, Paspalum distichum*
Doti - Ghanteshwar, Baglek	Western Nepal, 1750m	*Galinsoga parviflora, Solanum aculeatissimum, Bidens pilosa, Chenopodium album, Ageratum conyzoides, Xanthium strumarium*
Bardia - Rajapur	Western Nepal, 200m	*Ageratum conyzoides, Amaranthus spinosus, A. viridis, Oxalis latifolia*
Dang - Tribhuvannagar	Western Nepal, 250m	*Ageratum conyzoide ,Eclipta prostata, Paspalum distichum*
Rupandehi - Tamnagar	Central Nepal, 150m	*Eichhornia crassipes, Paspalum distichum, Alternanthera sessilis*
Palpa - Dobhan	Central Nepal, 300m	*Amaranthus spinosus, Ageratum conyzoides, Crassocephalum crepidioides, Chromolaena odorata*
Parbat - Khurkot	Central Nepal, 1050m	*Ageratum conyzoides, Crassocephalum crepidioides, Ageratum houstonianum, Ageratina adenophora, Bidens pilosa, Cleome spinosa, Galinsoga parviflora*
Chitwan - Rampur	Central Nepal, 250m	*Amaranthus spinosus, Ageratum conyzoides, Solanum nigrum, Ludwigia hyssopifolia, Alternanthera sessilis, Leersia hexandra*
Rasuwa - Thulosyabru	Central Nepal, 2100m	*Galinsoga parviflora, Oxalis latifolia, Bidens pilosa*
Kathmandu	Central Nepal, 1300m	*Ageratum conyzoides, Axonopus compressus, Galinsoga parviflora, Ageratina adenophora, Bidens pilosa, Xanthium strumarium, Amaranthus spinosus*
Sunsari - Tarhara	Western Nepal, 225m	*Ageratum conyzoides, Parthenium hysterophorus, Amaranthus spinosus, Mimosa pudica, Hyptis suaveolens, Mikania micrantha, Brachiaria mutica, Chromolaena odorata*
Dhankuta	Western Nepal, 1250m	*Ageratum conyzoides, Bidens pilosa, Crassocephalum crepidioides, Galinsoga parviflora*
Morang - Biratnagar	Western Nepal, 80m	*Xanthium strumarium, Hyptis suaveolens, Mimosa pudica, Cassia occidentalis, Alternanthera paronychioides, Solanum nigrum, Conyza bonariensis, Crassocephalum crepidioides, Chromolaena odorata*
Jhapa - Damak	Western Nepal, 200 m	*Mikania micrantha, Physalis peruviana, Ageratum conyzoides, Chromolaena odorata*

Source: IUCN Nepal Field Survey, 2002-2003.

Galinsoga parviflora and *Amaranthus spinosus* are serious IAS along the croplands in mid-hills. These species are distributed from Doti to Dhankuta. This apart, *Xanthium strumarium, Oxalis latifolia, Ageratum houstonianum, Solanum aculeatissimum, Euphorbia hirta,* etc. are also observed as invasives in many cropfields.

It can be inferred that agricultural crops have been adversely impacted by the IAS such as *Ageratum conyzoides, A. houstonianum, Galinsoga parviflora, Oxalis latifolia*, etc. in the form of weed. They can contaminate seed crops, reduce their value and also reduce the fertility of soil. Nepalese farmers are always making hard efforts to control these weeds by mechanical and chemical methods.

The average of density, frequency and coverage of common alien species recorded in agricultural land in different study sites are given in *Table 7*.

Wetlands

Introduction of alien species is one of the major problems for the degradation of Nepal's wetlands. Many native species in wetland sites of Nepal have been threatened by IAS (*Table 8*).

For example, the wetlands of Kanchanpur district are invaded by *Eichhornia crassipes*, whereas the wetland site in Kailali district, particularly Ghodaghodi lake complex (a Ramsar site) is invaded by *Eichornia crassipes* and *Ipomoea carnea* ssp. fistulosa. The largest lake in the

Table 7: Common Alien Species Recorded in Agricultural Land

S.N.	Name of Species	Density (Pl/m^2)	Frequency (%)	Coverage (%)
1.	*Ageratina adenophora*	0.11	3.86	0.38
2.	*Ageratum conyzoides*	3.5	44	6.2
3.	*Alternanthera sessilis*	0.2	6.36	0.28
4.	*Amaranthus spinosus*	0.15	10	1.07
5.	*Amaranthus viridis*	0.18	1.8	0.18
6.	*Bidens pilosa*	0.66	15.8	0.94
7.	*Chromolaena odorata*	0.03	1.53	0.4
8.	*Cleome spinosa*	0.08	3.07	0.23
9.	*Crassocephalum crepidioides*	0.2	6.92	0.35
10.	*Leersia hexandra*	0.3	4.5	0.52
11.	*Mikania micrantha*	0.025	2.5	0.075
12.	*Oxalis latifolia*	6.5	18.3	5.5
13.	*Solanum aculeatissimum*	0.05	4.16	0.20
14.	*Xanthium strumarium*	0.01	0.9	0.04

Source: IUCN Nepal Field Survey, 2002-2003.

Table 8: Wetland Ecosystem and Common Alien Species

Wetland Sites	Location/Altitude	Common IAS
Kanchanpur - Shreepur	Western Nepal, 290m	*Eichhornia crassipes*
Kapilvastu - Jagdishpur	Western Nepal, 190m	*Ipomoea carnea ssp. fistulosa, Paspalum distichum, Eichhornia crassipes*
Rupandehi - Tamnagar	Central Nepal, 150m	*Ipomoea carnea ssp. fistulosa, Eichhornia crassipes, Paspalum distichum*
Chitwan- Bishazari Tal	Central Nepal, 280m	*Eichhornia crassipes, Pistia stratiotes, Leersia hexandra, Alternanthera sessilis, Ipomoea carnea ssp. fistulosa*
Kathmandu	Central Nepal, 1300m	*Alternanthera philoxeroides, Myriophyllum aquaticum, Eichhornia crassipes, Axonopus compressus*
Koshi Tappu	Eastern Nepal, 200m	*Eichhornia crassipes, Ipomoea carnea ssp. fistulosa, Pistia stratiotes Alternanthera, sessilis, A. philoxeroides, Mikania micrantha*

Source: IUCN Nepal Field Survey, 2002- 2003

complex is Ghodaghodi Lake (138ha). It is comparatively less affected by IAS. So, regular monitoring and rapid response to remove the IAS is most urgent to protect the largest natural lake in the Terai. Similarly, Jagdishpur Reservoir (a Ramsar Site) in Kapilvastu district is dominated by *Ipomoea carnea* ssp. *fistulosa*, *Ipomoea aquatica*, *Paspalum distichum*, *Eichhornia crassipes, etc.* The wetlands of Rupandehi district are invaded by *Ipomoea carnea* spp. *fistulosa*, *Eichhornia crassipes* and *Paspalum distichum*. The Beeshazari Tal (another Ramsar Site) of Chitwan district is seriously invaded by *Eichhornia crassipes*, *Pistia stratiotes*, *Leersia hexandra*, *Alternanthera sessilis, Ipomoea aquatica* and *Ipomoea carnea* ssp. *fistulosa*. Furthermore, the wetlands of Koshi Tappu Wildlife Reserve (Nepal's first Ramsar Site) has also been seriously invaded by a number of IAS. Major species are *Eichhornia crassipes, Ipomoea carnea* ssp. *fistulosa, Pistia stratiotes, Alternanthera sessilis, Alternanthera philoxeroides, Mikania micrantha,* etc. Similarly, the wetlands of Kathmandu Valley are invaded by *Eichhornia crassipes, Alternanthera philoxeroides, Myriophyllum aquaticum* and *Axonopus compressus.*

Significant wetlands of Nepal are covered by alien species. *Eichhornia crassipes* is the most problematic species that has invaded most wetlands of the Terai and mid-hills. This species occurs in all study sites extended from Kanchanpur to Jhapa districts in Terai as well as Kathmandu and Pokhara Valleys in mid-hills. Another problematic species is *Ipomoea carnea* ssp.*fistulosa* observed mainly in Terai and Siwaliks along drainages of roadsides, marshes and shallow waters. It has been invading both Terai and mid-hills wetlands. The other important alien species posing a threat to wetlands are *Myriophyllum aquaticum, Paspalum disticuhum, Pistia stratiotes* and *Leersia hexandra.* The *Myriophyllum aquaticum* is observed particularly in Kathmandu Valley (Taudaha, Ring Road sides, etc).

Table 9: Common Alien Species Recorded in Wetland Ecosystem of Nepal

S.N.	Name of Species	Density (Pl/m^2)	Frequency (%)	Coverage (%)
1.	*Alternanthera philoxeroides*	0.12	3.3	1.28
2.	*Eichhornia crassipes*	0.84	83.33	10.42
3.	*Ipomoea aquatica*	0.33	18.81	1.80
4.	*Ipomoea carnea ssp. fistulosa*	0.8	29.95	14
5.	*Leersia hexandra*	0.70	7.14	1.04
6.	*Myriophyllum aquaticum*	0.02	6.2	2.14
7.	*Pistia stratiotes*	0.2	6.33	0.92

Source: IUCN Nepal Field Survey, 2002-2003.

The average density, frequency and coverage of common alien species recorded from wetlands of different sites are given in *Table 9*.

B. Invasive Pathways

The introduction, establishment and spread of IAS in terrestrial and aquatic ecosystems depend on socio-economic, political, cultural and ecological factors. They occur from the source, transport and demand for goods and services, including alteration of habitat. For example, human migration has served as a source of species introduction when people brought familiar plants and animals to their new homes. Along with these species, diseases and pest species were also brought unintentionally. Along with the increase of human population, demands for food sources also increase, and hence the increase in industries for food values. This has resulted in more IAS introduction through horticulture, aquaculture and tourism.

Knowledge on early introduction of alien species in Nepal is poorly documented. It is assumed that some invasive species have been introduced deliberately as ornamentals (*Lantana camara, Eichhornia crassipes, Pistia stratiotes,* etc.) or as plants for soil establishment (*Ipomoea carnea*). Many more have been introduced accidentally. Often agricultural and forestry weeds (*Ageratina adenophora, Ageratum conyzoides, Mikania micrantha, Chromolaena odorata,* etc.) have been introduced as contaminants of imported seeds of crops, forages and nurseries. Similarly, some species are introduced through incoming machinery, equipment, vehicles, etc. which are often shipped from place to place without cleaning. The packaged materials including mail, cargo and tourist luggage are also believed to be the important pathways for IAS introduction. Most of them are introduced in Nepal via India. The land-linked condition, porous border, similarity in culture and ecological conditions with India favour the introduction of IAS through both intentional and unintentional pathways. Nepal's effort has not proved sufficient to stop the introduction. A global, regional or bilateral collaboration, particularly with India is crucial to eradicate/control IAS.

C. Use Value of Invasive Alien Species

Because of high dispersal ability and adaptability to colonize in new habitat, the complete eradication or control of IAS is not easy. An integrated approach is required to reduce their invasion and impacts. The best way is the proper utilization of those species. A cost-benefit analysis should be done before introducing a species

utility purposes if the species is already known as invasive.

Many IAS established /naturalized in Nepal have been used by local people for medicine, firewood, food, fodder, bio-fertilizer, fencing, ornamental and habitat restoration. For example, *Ageratina adenophora, Chromolaena odorata, Eichhornia crassipes, Xanthium strumarium, Hyptis suaveolens* are used for cattle bedding and compost or bio-fertilizer (organic manure). The *Eichhornia crassipes* is also used for mulching in potato crop. Similarly, *Ageratina adenophora, Chromolaena odorata, Mikania micrantha* and *Hyptis suaveolens* are used as fodder for goat, whereas *Ageratum conyzoides, Bidens pilosa, Mimosa pudica, Galinsoga parviflora, Leersia hexandra, Brachiaria mutica, Axonopus compressus, etc.* are used as fodder for cattle. In this way, *Alternanthera philoxeroides, Pistia stratiotes, Eichhornia crassipes* and *Mikania micrantha* are used as pig forage. *Pistia* is also fed for ducklings. Similarly, *Amaranthus spinosus, Rorippa nasturtium-aquaticum, Ipomoea aquatica,* etc. are cooked as green vegetable and *Oxalis latifolia* is used as pickle. Young part of *Alternathera philoxeroides* is used as green vegetable by Mushahar community of Sunsari district. Similarly, tender leaves and twigs of *Bidens pilosa, Galinsoga parviflora,* etc. are used as green vegetable in central Nepal (Rajbhandari, 2001). The *Ageratina adenophora, Chromolaena odorata, Lantana camara, Ageratum conyzoides, Bidens pilosa, Argemone mexicana, Cassia tora* and *Mimosa pudica* are used as medicine by various ethnic communities to cure various ailments (IUCN Nepal, 2004; Manandhar, 2002; Joshi and Joshi, 2001; Siwakoti and Varma, 1996). For example, the root extraction of *Alternanthera sessilis, Amaranthus spinosus, A. viridis, Mimosa pudica, Sida acuta,* etc. are used to relief from fever, cold cough, diarrhoea, dysentery, indigestion and urinary troubles. The leaf extraction of *Ageratina adenophora, Ageratum conyzoides, A. houstonianum, Argemone mexicana, Bidens pilosa, Chromolaena odorata, Galinsoga parviflora, Oxalis latifolia*, *Hyptis sueveolens*, *Tridax procumbens*, etc. are used as antiseptic to treat cuts and wounds. Similarly, the seed extractions of *Cassia occidentalis* and *Cassia tora* are used to cure ringworm and itching and is also applied to forehead to get relief from headache. The dried fruit of *Solanum aculeatissimum* is smoked to get relief from toothache.

Besides, *Lantana camara, Chromolaena odorata, Ipomoea carnea* ssp. *fistulosa, Cassia tora* and *Cassia occidentalis* are used for firewood; sometimes also as construction materials for poor people's hut. Further, *Ipomoea carnea* ssp. *fistulosa*, *Axonopus compressus* and *Brachiaria mutica* are also used in habitat restoration particularly to control soil erosion along the canals and streams banks. The *Eichhornia crassipes* was used in biogas plant near Koshi Tappu Wildlife Reserve. Many IAS such as *Ageratina adenophora, Chromolaena odorata,* etc. are being used for briquette making. The dense under storey of IAS also gives the hiding place for birds, mammals and reptiles.

D. Ecological and Health Impacts of Invasive Alien Species

Invasive Alien Species rapidly colonizes over degraded ecosystems and contributes to enhance the greenery as well as to check soil erosion. The introduction of IAS may also enrich biodiversity by adding species number in total. Nevertheless, IAS is generally considered as great threat to natural ecosystems. They reduce the abundance of native species and may alter the community structure and ecological processes such as nutrient cycling, energy flow or the hydro-dynamic properties of a particular ecosystem. IAS impacts are not only limited to ecosystem degradation. They also affect local economy through reduction of ecosystem services and productivity.

The impacts of IAS have not been studied in Nepal. However, the adverse environmental impacts such as alteration of habitat and species composition have been experienced due to some alien species which are leading towards widespread invasion.

The introduction of *Chromolaena odorata, Ageratina adenophora, Mikania micrantha* etc. suppress the regeneration of tree species by blocking sunlight and releasing inhibitory

chemicals in forest and fallowland ecosystems, also change the floral and faunal composition. Furthermore, the invasion of *Ipomoea carnea* ssp. *fistulosa, Alternanthera philoxeroides, Eichhornia crassipes, Myriophyllum aquaticum* and *Pistia stratiotes* influence the wetland environment by means of reducing dissolved oxygen level and trapping sediments, changes in habitat structure, water quality, food web structure and fish diversity. Similarly, the dense understorey of *Lantana camara* can also change faunal makeup. *Lantana camara* is not only problematic for native species but also to alien species. For example, *Ageratina adenophora* is being replaced by this plant in many localities. *Ageratum conyzoides, Xanthium strumarium, Oxalis latifolia,* etc. outcompete crops for resources thereby leading to the loss of productivity.

Besides, many IAS such as *Ageratina adenophora, Lantana camara, Ageratum conyzoides, Ipomoea carnea* ssp. *fistulosa,* etc. may cause health problems in livestock if they are consumed in large quantity. The oil of *Argemone mexicana* seeds cause lethal dropsy to human who consume adulterated cooking oil; the pollens of *Parthenium hysterophorus* produce allergic reaction in humans. Furthermore, the pungent smoke produced during burning of stems of *Ipomoea carnea* ssp. *fistulosa,* as firewood causes respiratory or throat problems. There may be a long list of IAS likely to cause environmental, economic and health problems but without proper research and study one cannot properly assess their impacts.

E. Management Practices

Different management strategies such as prevention, early detection, eradication and control are recommended to deal with problematic invasive species (Wittenberg and Cock, 2001). Prevention of introduction of invasive species is the first and most cost-effective measure against IAS. Intact ecosystems are the best preventive measure against IAS. Once an IAS has been established, it may be difficult and often impossible to eradicate. Interception, treatment and public education and awareness are the major exclusion measures to prevent the introduction of invasive species. If an IAS has been established or colonized in a new ecosystem, the best course of action is early detection and rapid response. The early detection of alien species is based on regular surveys. However, not all alien species will become invasive. Thus, some surveys will need to focus on specific target species known to be invasive under similar conditions. The early detection of potential IAS is crucial in determining whether eradication of species is feasible or not. When prevention has failed to stop the introduction of IAS, then an eradication programme is a preferred method of action. Eradication can be a successful and cost-effective solution as a rapid response to an early detection of alien species. Successful eradication programme is based on mechanical control, chemical control, bio-pesticides, habitat restoration, etc. However, attention should be given that each single situation needs to be evaluated to find out the best method in that area under prevailing circumstances. For example, plant species can be best eradicated by a combination of mechanical and chemical treatments. When prevention methods have failed and eradication is not feasible, then the last step in the sequence of management strategies is the control of an invasive species. The aim of control will be to reduce the density and abundance of IAS to keep it below an acceptable threshold. In other words, we will have to live with the IAS and can only try to mitigate the negative impacts on native biodiversity and natural ecosystems. All control methods with the exception of classical biological control need long-term funding and commitment. In comparison to other methods, classical biological control is highly cost-effective and self-sustaining when it is successful. Successful control will be achieved through the integrated efforts of various control methods such as mechanical control, chemical control, biological control and habitat restoration. The concept of Integrated Pest Management (IPM) has been adopted widely, particularly in agriculture and forestry sectors in order to control the pest in a sustainable way based on long and bitter experiences of chemical insecticide dependence (Wittenberg and Cock, 2001).

Nepal has not yet made any comprehensive study and research to assess the status and impacts of

IAS. As a result, the country does not have a management strategy to prevent further introduction and spread of IAS. Quarantine offices have been established under the Plant Protection Act that works for the control and eradication of agricultural germs, pests and weeds. Furthermore, some crop specific herbicides are recommended to control the agricultural weeds that may be native and non native. Some examples are Butachor for rice; Lasso 50 EC for soyabean, groundnut and maize, 2,4-D Na Sat 80 WP for wheat; Moloran 50 WP for lentil. The quarantine investigation and herbicides are focussed mainly on agricultural weeds or pests and diseases. However, cautions should be taken while using herbicides. They would be toxic to humans and wildlife. For example, picloram, glyphosphate, triclopyr, paraquet, endothall, diquat, bromacil, dicamba, dalapon, etc. cause irritation to skin, eye and respiratory systems of humans. They are also harmful to wildlife and fish (Watterson, 1988). Similarly, 2-4, D and 2,4,5 – T (dioxin – a contaminant of 2,4,5 – T) are known to be a potent carcinogen (Cronk and Fuller, 1995). More than ten countries have banned the use of these herbicides (Martlew and Silver, 1991). Integrated pest management is also adopted in Nepal that is gaining popularity among farmers through farmer schools. These efforts, however, are not directly related to prevent the introduction and spread of IAS.

The manual method traditionally practised by farmers is the most common to control and eradicate the weeds in Nepal. It includes hand weeding, ploughing, control grazing, hoening, digging, mowing, burning, flooding, etc. However, it is expensive and impractical in large areas. In order to develop effective management strategy, proper coordiantion among different concerned agencies as well as proper development/sharing of information and regular monitoring are essential.

F. Ranking Invasive Alien Species

There are 21 IAS prioritized on the basis of experts consultation, literature review and field survey. These species were evaluated by using Invasiveness Rank Form developed by Virginia Department of Conservation and Recreation 2001. Invasiveness was determined by assessing each species which were identified or prioritized for Species Profiles. Invasiveness Rank Form consists of a series of multiple questions under

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Fishing in fallowland invaded by *Eichhornia crassipes*, Koshi Tappu .

four components or criteria. Answers to questions were converted into weighted score to tally sub-ranks for each area. The sub-ranks were converted to weighted scores to tally an overall rank for the species called plant species invasiveness rank. Score are weighted with greater emphasis on those criteria that most strongly reflect species impact on native plant and animal habitat and biological characteristics common to invasive plants. Compartively, less emphasis is placed on distribution, abundance, and difficulty to control. Species were ranked in one of four categories of invasiveness: High, Medium, Low, and Insignificant.

Criteria for Ranking

Following four criteria were used for ranking invasiveness of each species:

1. Impact on native species, habitats and ecosystems;
2. Biological characteristics and dispersal ability;
3. Distribution and abundance in Nepal; and
4. Difficulty to control.

The first component examines the impact of a species over native plants, habitats, and ecosystems, which include inter-specific competition for limiting resources such as light, water or nutrients. Biological characteristics help to predict whether a species might become invasive. Rapid growth to reproductive maturity, rapid vegetative spread, prolific seed production free from insects or diseases, opportunistic growth habit are the traits that show the competitiveness of species over native species. Distribution and abundance indicates presence of a species in a given landscape and suggests potential for that species to disperse to new sites. Similarly, difficulty to control indicates what resources are required to control an invasive species. Feasibility of control and degree of impact were two primary factors used to prioritize invasive plant population for management action. Each criteria was furnished with multiple sets of questions. Based on the questions, each selected species was assessed. On the basis of weighted score, an overall invasiveness ranking was made. The scoring and ranking system considered is as follows:

Weighted average/point system

I. Impact:

High = 4, Medium = 3, Low = 2, Insignificant = 0

II. Biology and ecology:

High = 3, Medium = 2, Low = 1, Insignificant =0

III. Distribution:

High = 1, Medium = 0, Low = 0, Iow = 0

IV. Management (difficulty to control):

High = 2, Medium = 1, Low = 0, Iow = 0

Overall ranking scale:

Insignificant (I): total score = 0-3

Species represent an insignificant threat to natural communities

Low (L): total score = 4-6

Species represent low threat to natural communities

Medium (M): total score = 7-8

Species represent moderate threat to natural communities

High (H): total score = 9-10

Species represent high threat to natural communities

Result of the Ranking Process

Altogether, 21 species are prioritized for assessment of invasiveness character (*Table 10*). Among them, six species are considered as high threat to the native species habitats and ecosystems. These species include *Ageratina adenophora*, *Chromolaena odorata*, *Lantana camara*, *Mikania micrantha*, *Eichhornia crassipes* and *Ipomoea carnea* ssp.*fistulosa*. Following three species are recorded as medium threat: *Alternanthera philoxeroides*, *Myriophyllum aquaticum* and *Parthenium hysterophorus*. Similarly, low threat causing species are *Ageratum conyzoides*, *Amaranthus spinosus*, *Argemone mexicana*, *Cassia tora*, *Hyptis suaveolens*, *Pistia stratiotes* and *Leersia hexandra*. There are five species with insignificant threats, which include *Bidens pilosa*, *Xanthium strumarium*, *Cassia occidentalis*, *Oxalis latifolia* and *Mimosa pudica*.

Table 10: Ranking Criteria Score for 21 Species Under Study

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

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

CHAPTER EIGHT

Conclusion and Recommendations

Alien species, when they become invasive, create great threats to natural ecosystems and native biodiversity. Rapidly accelerating international trade, tourism, transport and travel over the past century have dramatically enhanced the spread of invasive species and caused adverse impacts on agriculture, forestry, fisheries and other human enterprises, including health. Even the protected areas have been affected by alien plant invaders.

Many alien species are introduced deliberately for intended purposes. Nevertheless, a lot of risk is associated with the introduction of new species. Introduction of *Lantana camara, Ipomoea carnea* ssp. *fistulosa* and *Eichhornia crassipes* have now become problematic due to their invasion on natural areas and wetlands. Similarly, *Leucaena leucocephala* that was introduced into Nepal for agro-forestry has now turned invasive in Palpa district. Even biological control should be undertaken only after critical evaluation of the risks involved.

Majority of IAS in Nepal are of neo-tropical origin (South America) and have been introduced in Nepal by numerous pathways. The knowledge base on IAS control options is limited. This has resulted into numerous problems experienced only after alien species invasion, which do not seem to have easy solutions.

Twenty one invasive plant species, identified as problematic, were considered for field assessment and study. Out of these, the plant species found to be highly invasive included *Ageratina adenophora, Chromolaena odorata, Eichhornia crassipes, Ipomoea carnea ssp. fistulosa, Lantana camara* and *Mikania micrantha.* Similarly, *Alternanthera philoxeroides, Myriophyllum aquaticum* and *Parthenium hysterophorus* are found to have medium threats. On the other hand, *Ageratum conyzoides, Amaranthus spinosus, Argemone mexicana, Cassia tora, Hyptis suaveolens, Leersia hexandra* and *Pistia stratiotes* have been assessed to have comparatively low threats. The threat from *Bidens pilosa, Cassia occidentalis, Mimosa pudica, Xanthium strumarium* and *Oxalis latifolia* is not significant.

Control of invasive species runs into serious problems if early steps are not taken to resolve the problem. Study team commissioned by IUCN Nepal has come up with the following set of recommendations to deal with alien species that are invasive:

1. Institutional arrangement

It is important that a high level body at national level take care of the issues related to alien species undertaking programmatic interventions for their control and management. The "Biosecurity" sub-committee that has been constituted under the National Biodiversity Coordination Committee (NBCC) of NBS, 2002, should prioritize actions for programmatic interventions on IAS issues. A multi-sectoral IAS experts' group needs to be formed under this sub-committee to

provide technical inputs. Experts from the relevant fields such as horticulture, weed science, ecology, conservation biology, botanical gardens and researchers should be included in the group in addition to other stakeholders.

2. Legal and policy framework

Alien species and their invasion intersect multiple sectors. Therefore, the existing laws, policies and regulations in sectors such as agriculture, forestry (including protected areas), wetland, trade and tourism should be reviewed to address alien species related issues.

3.Research and monitoring

Establishment of baseline data and regular monitoring of alien species dynamics are essential to fully understand the IAS problems and their impacts. Therefore, extensive and intensive research should be promoted. In-depth studies of high risk IAS including their ecology, morphology, phenology, reproductive biology, physiology and phytochemistry should be conducted to understand the ecological and economic problems. Risk assessment should be done for all alien species already naturalized in the country as well as for new and proposed intentional introductions. Researches and results from biological control programme implemented in other countries should be carefully studied for their replicability in Nepal, mainly for the species that have been highly problematic to natural ecosystems.

A functionable system should be developed for regular assessment and monitoring of IAS. District-wise reporting system of new invaders is essential for regular monitoring. Mechanisms and approaches to quickly identify new IAS should be established. A database should be prepared and used for research and monitoring purpose.

4. Awareness campaign

Public awareness campaigns must be organized to involve the public at all stages to undertake concerted actions for the prevention of alien species invasion. Local and national media are quite effective for generating awareness. Awareness raising materials should be developed in local languages. Working with community based organizations and schools throughout the country should be considered for creating awareness on IAS and undertaking their management. Involvement of local and indigenous communities and other relevant stakeholders should be done at all levels for the identification, prevention and control of IAS in various ecosystems.

5. Management and control

Plantation of native plants species available in the country should be encouraged. Until there is any firm conclusion to indicate otherwise, plantation of non-native and invasive species should be discouraged. For the alien species that have already naturalized in the country, maximum utilization of the species should be promoted. Quarantine checks should be made mandatory for introduction of any new species.

Volunteer group should be developed and motivated for cleaning invasive plants from protected areas, public lands, forests and wetlands. It is important to identify the preferred management and control options for various invasive species. Control strategy at initial phase should target the species considered at high risk.

6. International collaboration/ networking

International networking is essential for the control and management of IAS. An integrated management approach and policy framework should be developed in collaboration with neighbouring countries in the region. Such collaboration should also extend to development of monitoring frameworks including sharing information and technical capacity building.

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