Draft report on

Analyzing the Status, Distribution, and Impact of Invasive Plant Species in Karnali Province, Nepal.

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Submitted to:

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Abbreviation

BZUG	Buffer Zone User Group
CFUG	Community Forest User Group
DBH	Diameter at Breast Height
DFO	District Forest Office
FGD	Focus Group Discussion
GIS	Geographic Information System
IAPS	Invasive Alien Plant Species
ICIMOD	International Centre for Integrated Mountain Development
INGO	International Non-government Office
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
KII	Key Informant Interview
MoFE	Ministry of Forests and Environment
NARC	Nepal Agricultural Research Council
NGO	Non-government Office
NSF	National Science Foundation
UG	User Group

Table of Contents

List of Annexes

List of Tables

List of Figures

List of Maps

Chapter 1. Introduction

1.1 Background

Ecological perturbations caused by biotic invasion have been identified as a growing threat to global sustainability. Invasive alien plant species (IAPS) are considered to be one of the major drivers of biodiversity loss thereby altering the ecosystem services and socio-economic conditions through different mechanisms. They are amongst the most significant drivers of species extinction and ecosystem degradation, causing negative impacts on ecosystem services and human well-being. These species can interfere with the establishment of native species and consequently affect plant community structure and assembly. IAPS can not only alter natural community assembly but also represent one of the most critical barriers to restoring native ecosystems. The ornamental and multi-purpose IAPS, which were deliberately or accidentally introduced subsequently spread to impose adverse effects on human and ecosystem health.

The history of IAPS in Nepal is also two centuries old as *Chomolaena odorata* was first reported in 1825 (Tiwari et al., 2005). Generally, IAPS is known as Banmara in Nepal (Rai et al., 2012). It is estimated that 179 exotic species have been naturalized in Nepalese forests (Shrestha et al., 2017). The majority of them are native to the Americas (74%) and Europe (8%) (Bhattarai et al., 2014). Nepal is likely to host many exotic species because of its government's priority to promote tourism and increase the volume of trade. In Nepal, 27 species were identified as common IAPS in different ecosystems (Shrestha & Shrestha, 2021). Recently the two species *Sphagneticola trilobata* and *Tithonia diversifolia* are listed as IAPS in Nepal. Out of them *Ageratina adenophora, Chromolaena odorata, Eichhornia crassipes, Ipomoea carnea, Lantana camara*, and *Micania micrant* are considered as high risk posed species (Tiwari et al., 2005). Among them *Chromolaena odorata, Eichhornia crassipers, Lantana camara* and *Mikania micrantha* are listed as the world's 100 worst invasive species (Lowe et al., 2000). Recently, *Parthenium hysterophosus* is problematic in urban areas, grasslands, and croplands (Shrestha et al., 2015). Most of the IAS is reported in the southern lowlands particularly in Terai and Siwaliks, as this is favorable to them which are native to Latin America. Similarly, the majority of the common invasive species are recorded in the mid-hills too, however, only a few including *Ageratina adenophora* and *Galinsoga quadriradiata* are reported in high altitudes (Shrestha, 2016). *Ageratina adenophora*, and *Chromolaena odorata* are the widely distributed IAPS. In addition, the eastern and central regions of Nepal have higher occupancy of IAPS compared to the western Nepal (Bhattarai et al., 2014). This could be mainly due to the entry point of IAPS either in eastern part or Kathmandu.

IAPS are not only linked with the environment, but also, to the human well-being, often in negative and sometimes, positive manner. IAPS management is challenging and a complex task because the invasion processes are dynamic and have multifaceted effects. Controlling invasive plants is then a necessary, yet usually expensive, step towards the restoration of an ecosystem. Responses to invasion include institutional arrangements, policy and governance tools, as well as practical strategies to realize the objectives of the policies (Pandit et al., 2018).

There is no effective control program of IAPS in Nepal. Some organizations have carried out small scale activities to control the invasion. In Nepal, main attention is in the control rather than other measures. In the past, forest users have practiced several strategies to control the spread of invasive in Nepal, but were not succeed (Rai et al., 2012b; Sapkota, 2007). Those efforts were uprooting, manual cutting, firing and ploughing. A study carried out by Rai et al. (2012a) indicates that manual cutting has demonstrated that removal of the vines closes to the ground once a month for three consecutive months in the summer or autumn can eliminate 92 to 98 per cent of Mikania micrantha. This method seems suitable in Nepal, as forest users contribute to forest management activities.

Efforts to address the impact of invasive plants often involve a combination of ecological restoration, public awareness, and strategic management practices to mitigate their negative effects. The study aims to comprehensively investigate the ecological implications of invasive plant species and propose effective management strategies to mitigate their effects.

1.2 Objectives of the study

1.2.1 Assessing Ecological Impact:

i. Evaluate the extent of invasion and distribution patterns of invasive plant species in the target region.

ii. Investigate the impact of invasive plants on native biodiversity, ecosystem structure, and ecosystem services.

1.2.2 Understanding Mechanisms of Invasion:

i. Examine the ecological and physiological mechanisms that enable invasive plants to outcompete native species.

ii. Identify the role of environmental factors and human activities in promoting the spread of invasive plants.

1.2.3 Developing Effective Management Strategies:

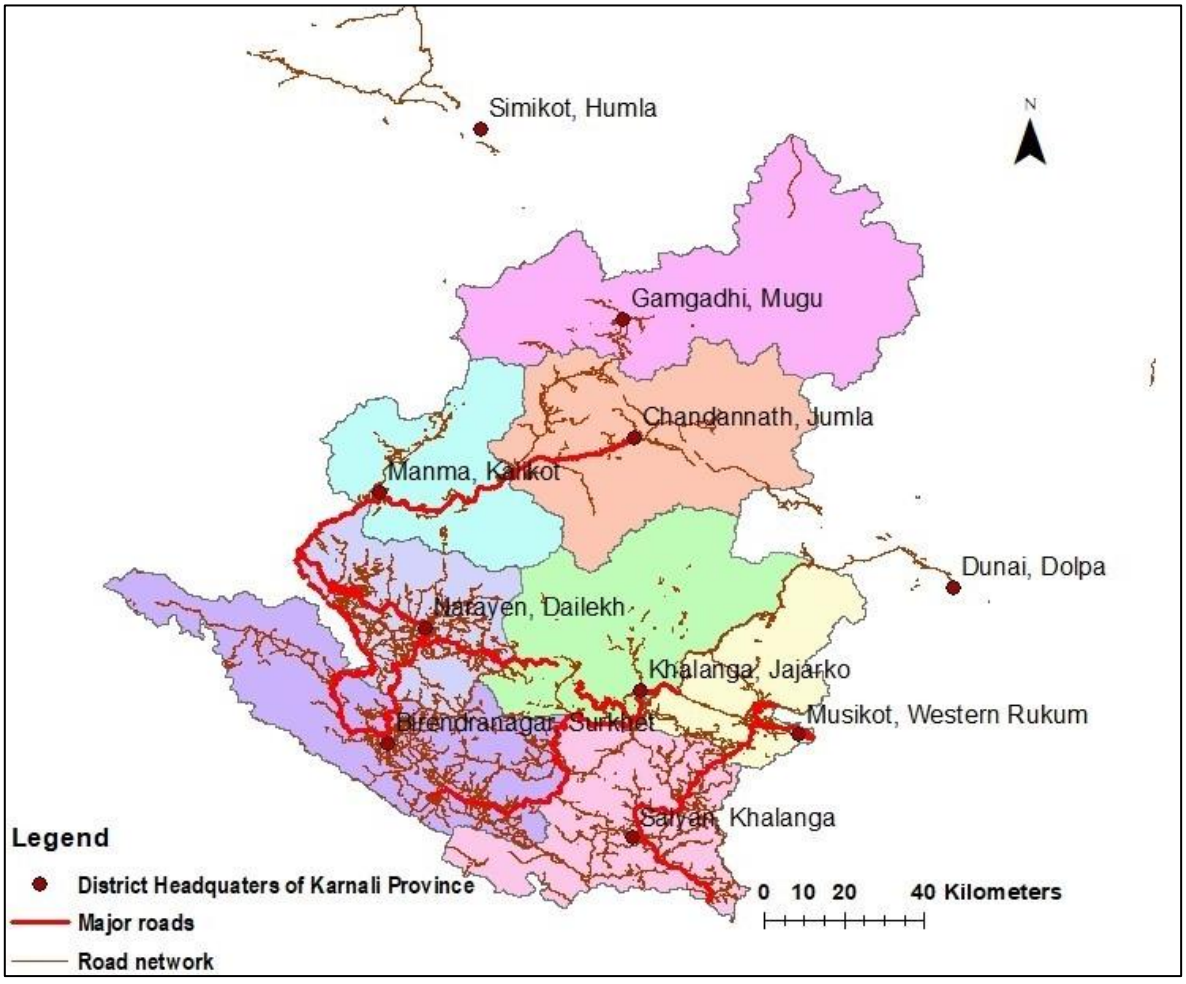
i. Evaluate current management practices and their effectiveness in controlling invasive plant species.

ii. Propose novel management strategies, considering ecological sustainability and long-term efficacy.

Chapter 2. Methods and Materials

2.1 Study Area

This was conducted in Karnali Province (30211 sq. km), the largest province among the provinces of Nepal. It borders the Tibet Autonomous Region of China to the north, Gandaki Province to the east, Sudurpashchim Province to the west, and Lumbini Province to the south. Karnali province consists of 10 districts Humla, Mugu, Kalikot, Jumla, Dolpa, Jajarkot, Dailekh, Surkhet, Salyan, and Rukum West. It is a mountainous and highly heterogeneous province. The elevation range spans from 180 m to 7348 m. More than 40% province area is located at altitudes above 4000 m. The province has a diverse climatic region, ranging from tropical to Alpine. The province experiences a Western Himalayan-type climate, characterized by cool, wet winters and warm and dry summers. The land use cover of the province is forest 30% Shrubland 3% Grassland 18% Agriculture area 14% Barren area 26% Snow/glacier 9% (Udins et al., 2015).



Map 1: Study area with district headquarters and major roads of Karnali Province

2.2 Methods

2.2.1 Literature Review

Firstly, all literature (research articles, guidelines, workbooks) regarding invasive species were collected and reviewed thoroughly. Besides that, existing laws and policy briefs regarding invasive species were studied. While doing so, a comprehensive review of existing literature on invasive plant management in national and international scenarios was reviewed in depth. Studies, reports, and articles based on various management practices of invasive species were reviewed.

2.2.1.1 Global scenario

IAPS poses a significant and growing threat worldwide, impacting ecosystems, biodiversity, and human well-being. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), more than 37,000 established alien species have been introduced by human activities across all regions and biomes of Earth. Based on the negative impact of species more than 3500 species were categorised as invasive alien species. Early et al., 2016 have found that 17% of the global land area (excluding Antarctica and glaciated Greenland) is highly vulnerable to invasion. The threat is high in parts of low-HDI countries in Africa, South America, and Asia.

The increased trade and travel associated with globalization have provided new pathways for IAPS dispersal (Pimentel et al., 2001). The IAPS can collaborate with other elements of global change, including land-use change (Vitousek *et al*., 1996), climate change (Dukes & Mooney, 1999; Simberloff, 2000), increased concentrations of atmospheric carbon dioxide and nitrogen deposition (Dukes & Mooney, 1999; Dukes, 2002). The intensities and global patterns of introduction and disturbance are changing more rapidly today than at any time during human history.

2.2.1.2 National scenario

However, the history of IAPS in Nepal was two centuries old, the *Chomolaena odorata* was first reported in 1825 (Tiwari et al., 2005). The IAPS was identified as a major threat to global biodiversity as early as the 1950s (Elton 1958), and the problem has been recently recognized in Nepal (Tiwari et al. 2005; MFSC 2014; Shrestha 2019). Therefore, Nepal is at the early stage of generating data and knowledge that are essential for the management of IAPS. In 2005, there were only 21 species recognized as IAPS in Nepal (Tiwari et al., 2005), which was continuously increasing (Shrestha, 2016; Shrestha et al., 2017; Shrestha & Shrestha, 2021). Recently, 29 species of IAPS including *Sphagneticola trilobate,* and *Tithonia diversifolia* were

recorded as IAPS in Nepal (ICIMOD, 2021). Out of them *Ageratina adenophora, Chromolaena odorata, Eichhornia crassipes, Ipomoea carnea, Lantana camara, and Micania micrantha* as high-risk posed species (Tiwari et al., 2005). Similarly, IAPS has been identified as one of the nine drivers of deforestation and forest degradation in Nepal.

Studies show a high number of IAPS in the southern part of the country (i.e. Tarai, Siwalik, and Middle Mountains) with a dry tropical to subtropical climate (Shrestha 2016). Only a few species such as *Ageratina adenophora, Bidens pilosa, Galinsoga quadriradiata, and Parthenium hysterophorus* have been reported from the High Mountains (Shrestha et al. 2018) while none of the IAPS has been reported from High Himal. The high number of IAPS in the southern part of the country suggests (i) high propagule pressure of IAPS due to high population density, major border crossings for international trade, and open border with India; (ii) high availability of suitable areas for their establishment due to high anthropogenic disturbances to natural ecosystems; and/or (iii) climatic suitability. In addition, the eastern and central regions of Nepal have higher occupancy of IAPS compared to western Nepal (Bhattarai et al., 2014). This could be mainly due to the entry point of IAPS either in the eastern part or Kathmandu. For instance, *Mikania micrantha* has a westward movement, as it was first recorded in Ilam (Rai et al., 2012b; Tiwari et al., 2005).

2.2.1.3 Policy in Context of Nepal

Nepal is likely to host many exotic species because of its government's priority to promote tourism and increase the volume of trade. In addition, inadequate institutional capacities, such as the absence of policy, quarantine facilities, and researchers of IAPS, are likely to create a favorable environment for the establishment of exotic species

The biological invasion was identified as a one of emerging environmental issue in most of the recent legal documents and strategic plans of forestry and agriculture sectors as well as those which are related to biodiversity conservation and environmental management (Siwakoti and Shrestha 2014; Shrestha 2019a). National Biodiversity and Action Plan, Nepal has developed an action plan for 2014-2020 to assess the nationwide distribution survey of the five most problematic IAPSs, which has developed the map for identification and early detection of IAPS, capacity enhancement of customs and quarantine offices including identification of appropriate biological control agents, public education and community participation (MFSC 2014). Ministry of Forest and Environment (MoFE) Nepal has established a National Invasive Alien Species Coordination Committee to manage the impact of IAPS. The Department of Forest Research and Survey as a focal institute has prepared a draft strategy on

Invasive Alien Species Management (2074). Forest Policy (2075) and Nepal Biodiversity Strategy and Action Plan (2014-2020) have prioritized IAPS and its management. About 20-22 community forests have established control plots under National Science Foundation (NSF) funding (BB Shrestha, CDBTU, personal communication, May 2018). Similarly, NARC has researched the management of *Eichhornia crassipes*; Weevil/beetle has been introduced from India for biological control.

2.2.2 Distribution survey

The road verge is suitable for the colonization of invasive species and the road itself provides the channel to disperse the seeds and propagules of the IAPS. Besides that, the vehicles and transportation system can transport the seeds and propagules long-distance from one place to another. Therefore, the distribution of IAPS in Karnali Province was mapped through a roadside survey. The roadside survey was done through the rapid assessment method. During that survey, IAPS were assessed in 10m × 10m plots in each 10 km interval of major roads, that reached the headquarters of districts of Karnali Province. Meanwhile, the species diversity of IAPS, their percentage of coverage, and average height were recorded including land use type, aspect, elevation, and geographic coordinates. Wherever possible, local people were asked about the period when they first observed the IAPS in the area and their perception of the impact of these plants on their daily lives.

2.2.3 Vegetation Sampling

Vegetation sampling was conducted representing different land use types by quadrat sampling at each interval of 100 m elevation. While doing so, three of the 10 m × 10 m quadrats were laid horizontally at a distance of 20 m (± 10 m) sampled (Figure 1). In each quadrat, the geographic location (aspect, slope, elevation, latitude, and longitude) with other stand characteristics, the IAPS with their cover, and other vascular plant species were recorded. In the case of the forest, the diameter at breast height (DBH, 137 cm) of individual trees and height were measured.

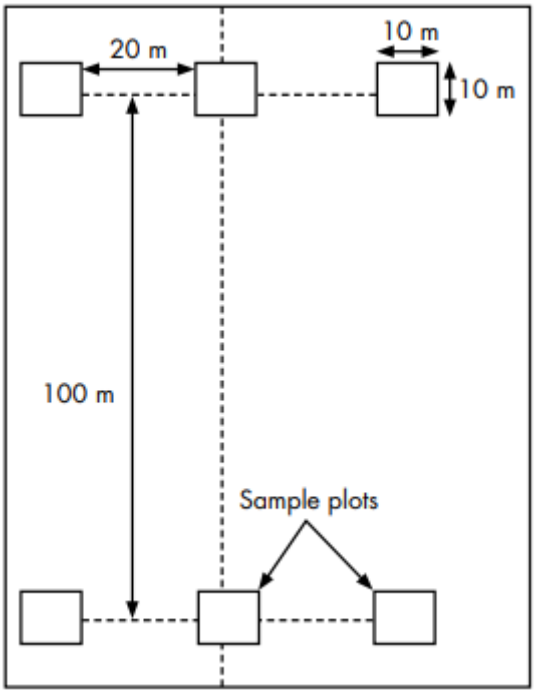


Figure 1: Sampling layout along the transect line

2.2.4 Plant identification

Identification of vascular plants: Plant specimens were identified using an online database such as Plants of the World Online and eflora (Pyšek et al., 2019).

Identification of invasive species and species categorization: Invasive plants were identified and specimen categorization was done using a checklist with names and pictures according to the table below. The unknown IAPS will be collected as herbarium specimens. (Singh Yadav et al., 2024)

Table 1: IAPS of Nepal

S.N.	Common name	Local name	Scientific name	Family	Habitat
1	Crofton weed	Kalo Banmara	*Ageratina adenophora* L.	Asteraceae	Woodlands and bushlands
2	Sensitive plant	Lajjawati	*Mimosa pudica* L.	Mimosaceae	Bushlands and woods
3	Siam weed	Seto Banmara	*Chromolaena odorata (L.), R. M. King and H. Roxb.*	Asteraceae	Wooded areas and shrublands

4	Bushmint	Tulsi Jhar	*Hyptis suaveolens (L.)*	Lamiaceae	Shrub lands and forests
5	Bush morning Glory	Besaram	*Ipomoea carnea* ssp. *fistulosa (Mart. ex Choisy) D.F. Austin*	Convolvulaceae	Wetlands
6	Corn spurry	Thangne jhar	*Spergula arvensis* L.	Caryophyllaceae	Agroecosystems
7	Partheniu m	Patijhar	*Parthenium hysterophorous* L.	Asteraceae	Semi-arid meadows that have been damaged and deteriorated
8	Rough cockle Bur	Bhede kuro	*Xanthium strumarium* L.	Asteraceace	Grasslands and populated regions
9	Shaggy Soldier	Jhuse Chitlange	*Galinsoga quadriradiata Ruiz & Pav.*	Asteraceae	Agroecosystem
11	Southern cut grass	Karaute ghans, Navo dhan	*Leersia hexandra Sw.*	Poaceae	Wetlands
12	Alligator weed	Jala jambhu, Patpate	*Alternanthera philoxeroides (Mart.) Griseb.*	Amaranthaceae	Agroecosystems
13	Billygoat	Raunne/Gandhe	*Ageratum conyzoides (L.)*	Asteraceae	agroecosystem
14	Black jack/Hairy beggar-tick	Kalokuro	*Bidens pilosa* L.	Asteraceae	Residential areas and grasslands
15	Lantana	Kirne kanda	*Lantana camara* L.	Verbenaceae	Natural and agricultural ecosystems

16	Mexican poppy	Thakal	*Argemone mexicana* L.	Papaveraceae	Cultivable and deserted field
17	Purple wood sorel	Chari amito	*Oxalis latifoba Kunth*	Oxalidaceae	Agroecosyste m
18	Water hyacinth	Jalkumbhi	*Eichhornia crassipes (Mart.) Solms*	Pontederiaceae	Wetlands
19	Water lettuce	Kumbhika Panibanda	*Pistia stratiotes* L.	Araceae	Wetlands and seas that are abnormally warm
20	Spiny pigweed	Kandelude	*Amaranthus spinosus* L.	Amaranthacea e	Residential neighbourhoo ds and grasslands
21	Parrot's feather	–	*Myriophyllum aquaticum (Vell.) Verdc.*	Holaragaceae	Wetlands
22	Sickle pod senna	Tapre	*Senna tora (L.) Roxb.*	Caesalpiniacea e	Grasslands and populated regions
23	Blue Billygoat weed	Nilogandhe	*Ageratum houstonianum Mill.*	Asteraceae	Fields used for grazing
24	Mile-a-minute weed	Lahare Banmara	*Mikania micrantha Kunth*	Asteraceae	Shrublands and forests
25	Broadleaf bottonwee d	AluPate Jhar	*Spermacoce alata Aubl.*	Verbenaceae	Roadside ditches and vacant fields
26	Karwinsky 's Fleabane	Phule Jhar	*Erigeron karvinskianus DC.*	Asteraceae	Agroecosyste ms

27	Giant sensitive plant	Ara kanda	*Mimosa diplotricha* C. Wright	Fabaceae	Bushlands and woods
28	Coffee senna	Thulo Tapre	*Senna occidentalia* (L). Link	Fabaceae	Grasslands and populated regions

2.2.5 Assessing the Impact of IAPS

The impacts of invasive plant species were identified through key informant interviews and focus group discussions. These interviews and discussions were focused primarily on: 1) the name of the IAPS in their locality, 2) year the IAPS was first sighted, 3) the ecological impact of invasive plants on native plant communities and biodiversity, 4) the cause of spread of invasive plants 5) current management intervention employed to control IAPS (control methods, including mechanical removal, chemical treatments, biological control agents, and integrated pest management.) and its effectiveness, and 6) willingness to participate in future management activities.

2.2.6 Key Informant Interview (KII)

The key informants of the District Forest Officer, Basin Management Center, Local business person, Teachers, and local people were interviewed.

2.2.7 Focus Group Discussion (FGD)

In each district, a focus group discussion was organized to understand and discuss the local knowledge and understanding of IAPS, the impacts of identified IAPS, the year and purpose of their introduction of some problematic IAPS, the uses and benefits of IAPS, and the management efforts carried out by local communities, Rural municipal and municipality.

2.2.8 GIS Mapping

Geographic Information System (GIS) was used as a mapping technique to spatially analyse and visualize the distribution patterns of invasive plant species. This information is valuable for prioritizing areas for management interventions

Chapter 3. Result

3.1 General information

Altogether, 51 quadrat sampling was conducted in each interval of 10km distance at a linear distance to assess the distribution of IAPS. Additionally, the vegetation sampling was conducted in 117 sites in each interval of 100 m elevation change, meanwhile, the three-quadrat sampling was conducted at each band of elevation with a total number of 351 quadrat samples surveyed for the vegetation survey.

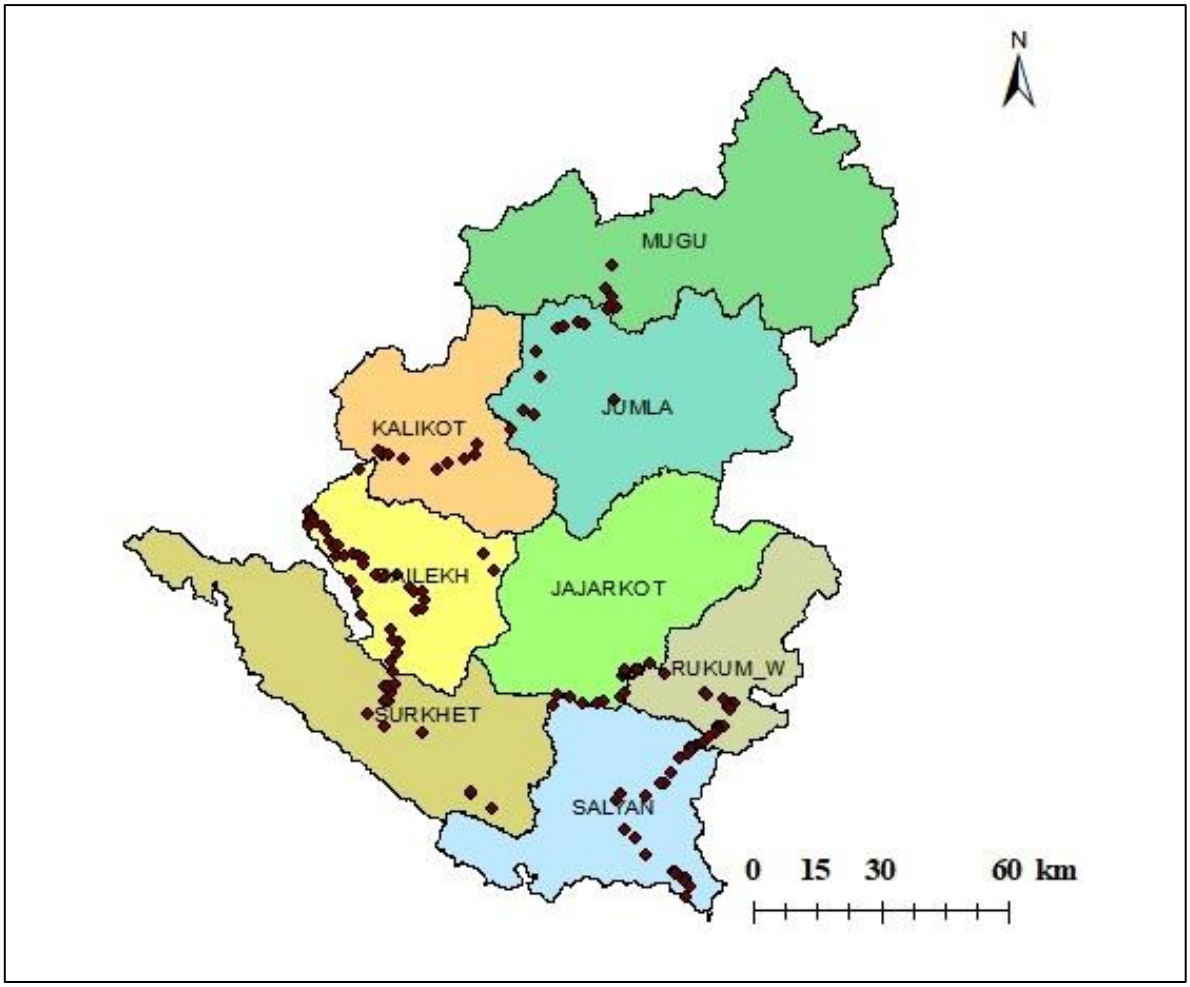
3.2 Consultation meeting

Altogether, 11 FGDs were conducted in different sites of the study area. In the FGD local community, women, and indigenous groups have participated. Besides that, 26 KII were conducted with the key stakeholders including the Warden of Rara National Park and the DFO of Jumla, Local leaders and teachers were interviewed regarding the impacts of IAPS, practices of management, and control measures of IAPS. Furthermore, suggestions were documented for the effective management of IAPS.

3.2.1 Assessing Ecological Impact:

3.2.1.1 Evaluate the extent of invasion and distribution patterns of invasive plant species in the target region.

This study was conducted at the roadside, agricultural land, forest, pasture land, river bank, settlement area, and barren land from the elevation of 340 to 3325 m, while traveling the major roads that connected the district headquarters of Karnali Province.



Map 2: Sampling sites

Altogether 18 IAPS were recorded in the Karnali Province among the 29 species of IAPS in Nepal (ICIMOD, 2021). The Kalobanmara *Ageratina adenophora*, Pattijhar *Parathenium hysterophorus*, Kalo kuro *Bidens pilosa*, Thakal *Argemone Mexicana*, Chari amilo *Oxalis latifolia and* Kirne kada *Lantana camera* were the major IAPS in the area

Table 2: Recorded IAPS in the study area

S.N.	Common name	Local name	Scientific name
1	Billygoat	Raunne/ Gandhe	*Ageratum conyzoides*
2	Mexican poppy	Thakal	*Argemone mexicana*
3	Broad leaf botton weed	Alu Pate Jhar	*Spermacoce alata*
4	Bush morning-Glory	Besaram	*Ipomoea carnea*
5	Karwinsky's Fleabane	PhuleJhar	*Erigeron karvinskianus*
6	Crofton weed	Kalo Banmara	*Ageratina adenophora*
7	Lantana	Kirne kanda	*Lantana camara*

8	Parthenium	Patijhar	*Parthenium hysterophorus*
9	Purple wood sorel	Chari amilo	*Oxalis latifolia*
10	Rough cockle-Bur	Bhede kuro	*Xanthium strumarium*
11	Sensitive plant	Lajjawati	*Mimosa pudica*
12	Shaggy Soldier	Jhuse Chitlange	*Galinsoga quadriradiata*
13	Siam weed	Seto Banmara	*Chromolaena odorata*
14	Sickle podsenna	Tapre	*Senna tora*
15	Southern Cutgrass	Karaute ghans,Navo dhan	*Leersia hexandra*
16	Spiny pigweed	Kandelude	*Amaranthus spinosus*
17	Blue BillygoatWeed	Nilogandhe	*Ageratum houstonianum*
18	Black jack/HairyBeggar-tick	Kalokuro	*Bidens pilosa*

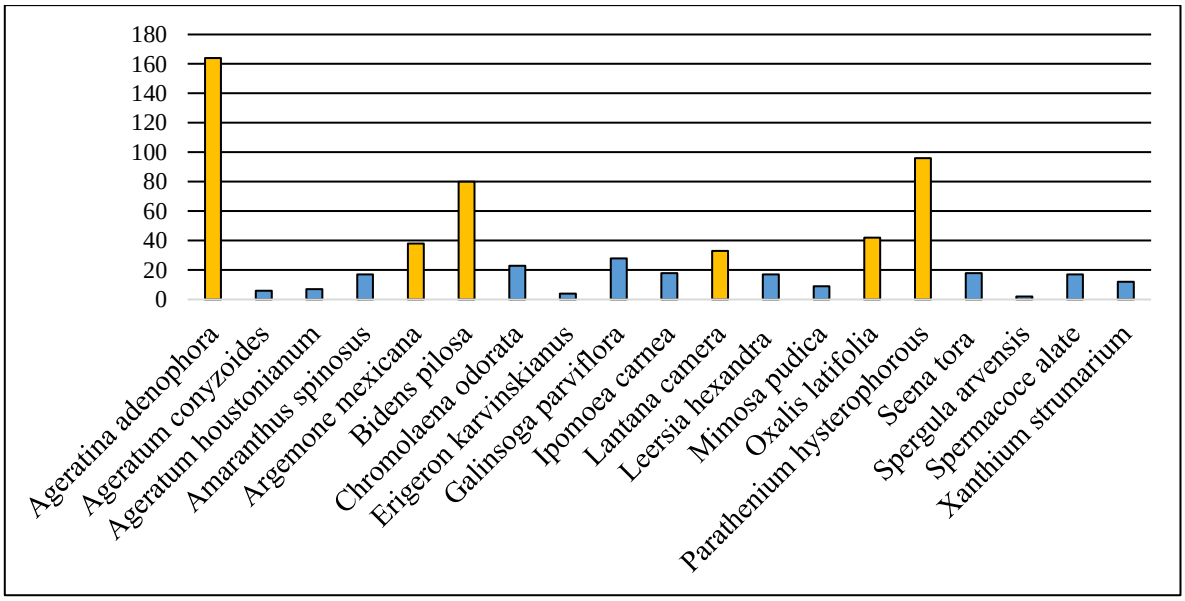


Figure 2: Frequency of IAPS in the study area

3.2.1.1.1 Five major IAPS of Karnali Province

a. Parthenium or 'pati jhar', (*Parthenium hysterophorus* L., Asteraceae)

Invasion of *Parthenium hysterophorus* disturbed agricultural land, road sided including forest. It infests pastures and farmland, causing significant yield losses. In some areas, heavy out brakes in Dailekh, Surkhet, Jumla, and Mugu have affected livestock and crop production.

Previous studies show that the species produces allelopathic chemicals that suppress other plants and allergens that affect humans and livestock. It's even associated with pollen allergies.

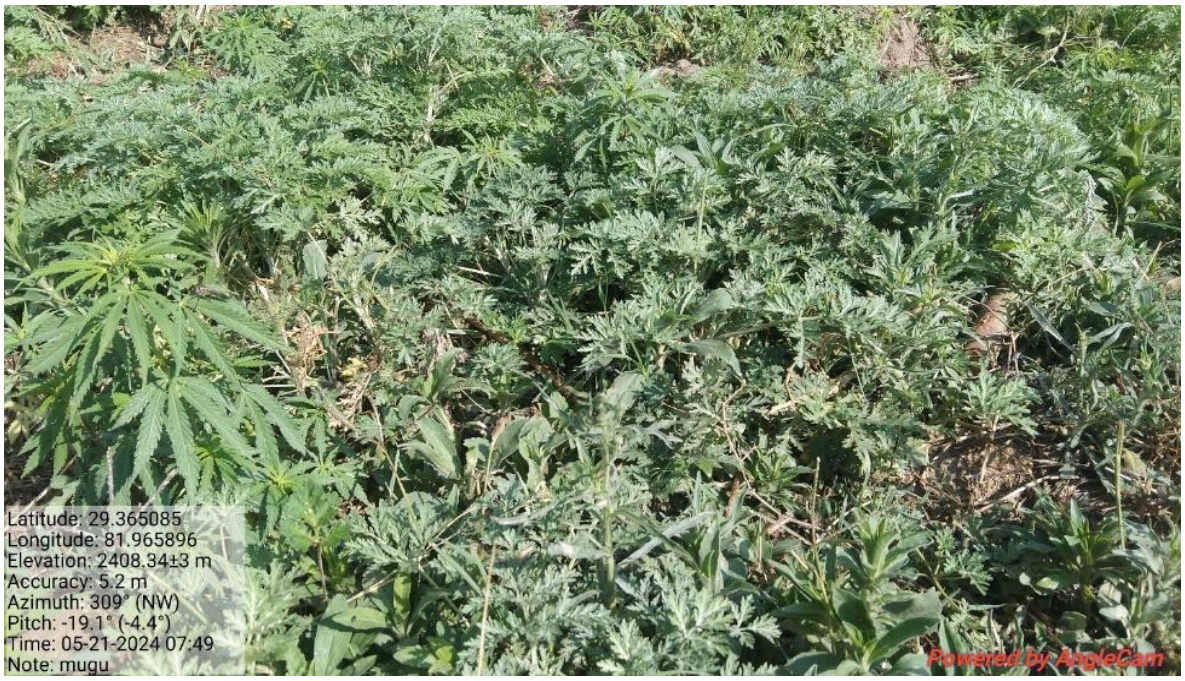
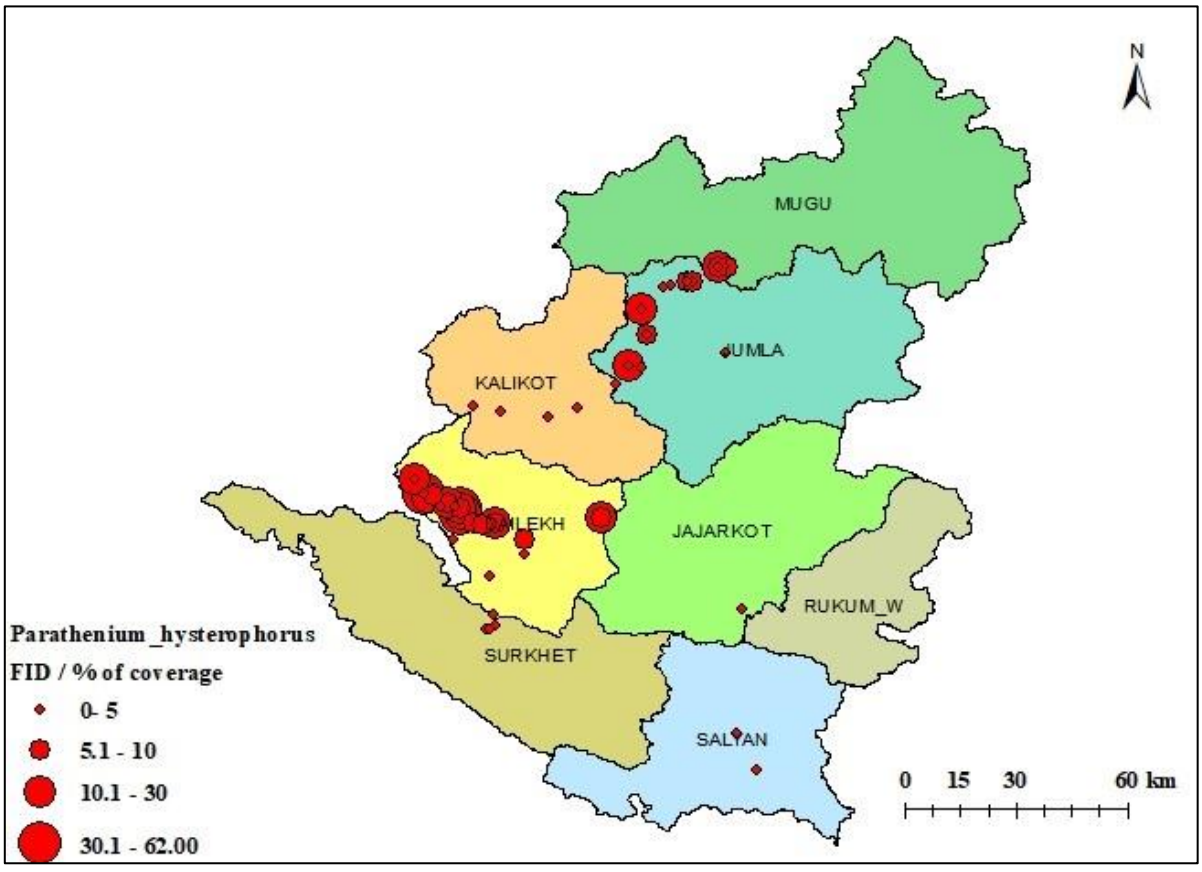


Figure 3: Invasion of *Parthenium hysterophorus* in Mugu district

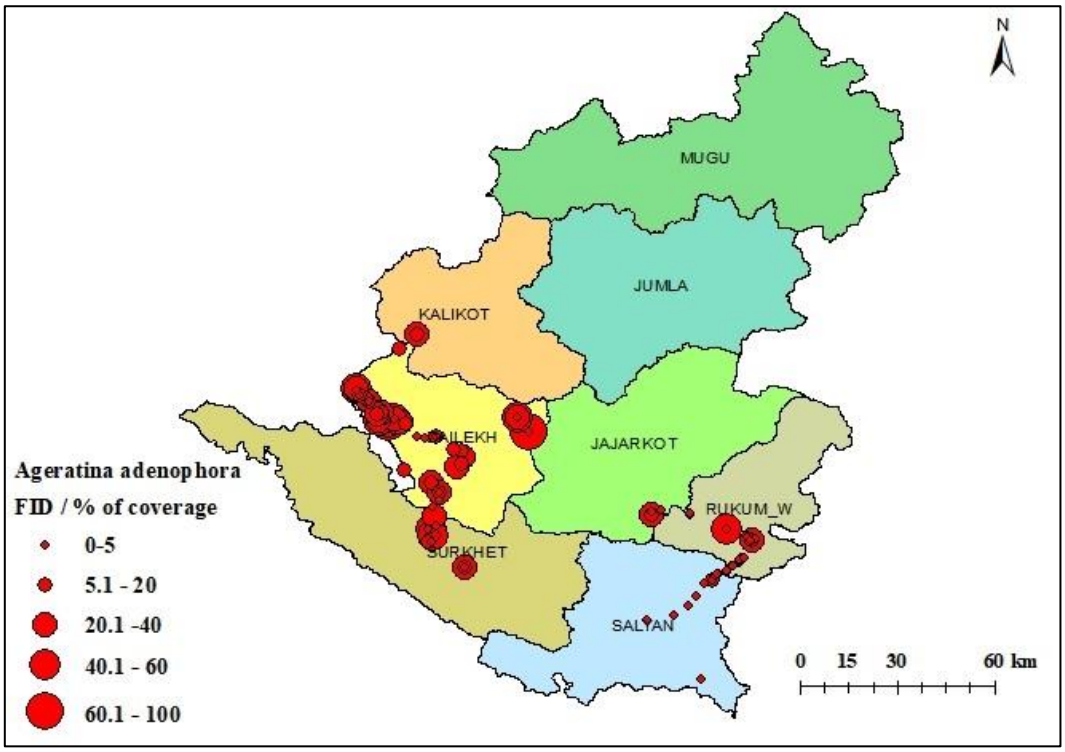


Map 3: Distribution map of *Parthenium hysterophorus*

b. Crofton weed or 'banmara', 'kalo banmara' (*Ageratina adenophora* (Sprenge))

Ageratina adenophora grows in open areas, degraded forests, forest margins, streams, and fallow lands of Surkhet, Jajarkot, Dailekh, Kalikot, Rukum-west and Salyan districts. The study shows that there was an altitudinal variation in the distribution of *Ageratina adenophora*. It forms a dense stand that suppresses the growth of other species through competition and allelopathic (chemical) effects. The species probably entered from eastern Nepal from India.

Figure 4: Invasion of *Ageratina adenophora* in Dailekh district

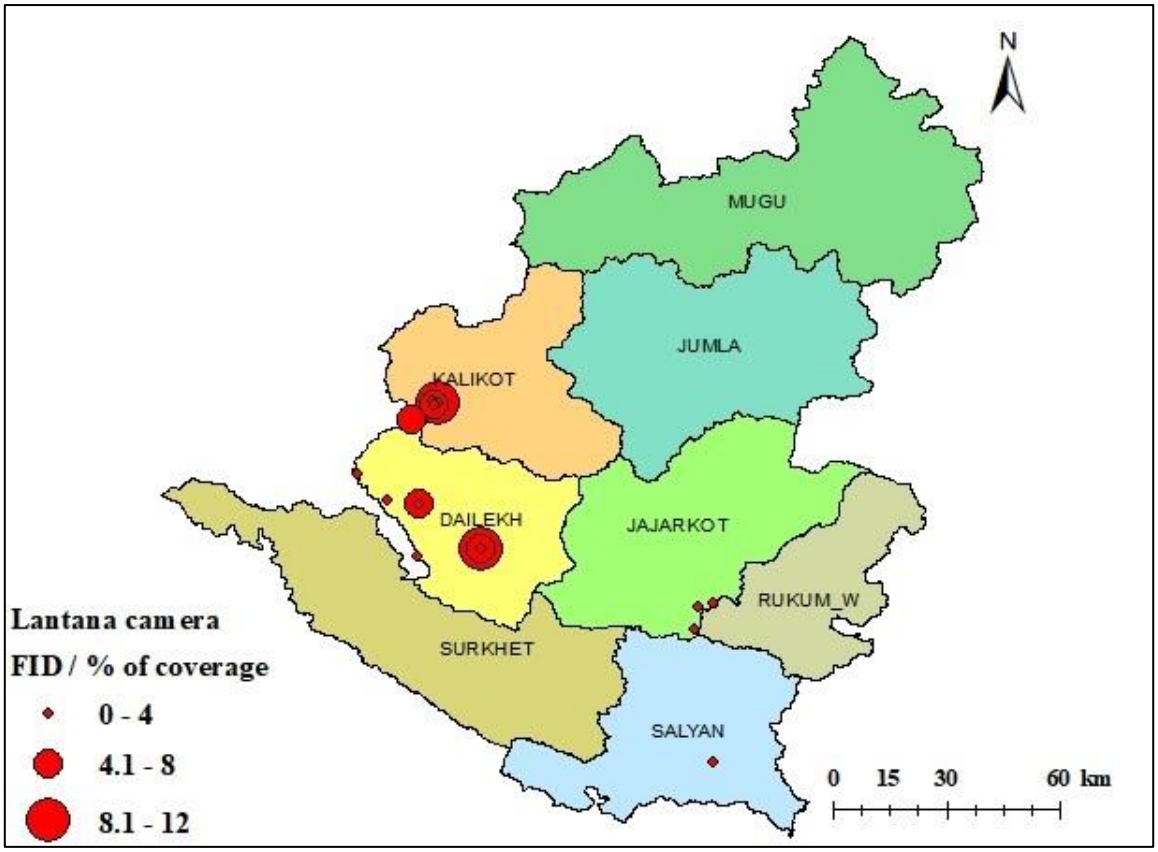


Map 4: Distribution map of *Ageratina adenophora*

c. Lantana or ‘kirne kanda’, ‘ban phanda’, ‘sutkeri kanda’, ‘ban masa’ (*Lantana camara*)

Lantana camara is one of 100 of the world's worst invasive species and was first introduced into the Old World as a garden ornamental. It is now a seriously problematic invasive plant in fallow land, roadsides, and agricultural land of the Dailekh and Kalikot districts of Kalikot in comparison to other districts in Karnali. People have left their field in Rakam, Dailekh due to the invasion of this species. It is mostly spread by its bird-dispersed seeds, but when cut it re-sprouts vigorously, forming dense thickets.

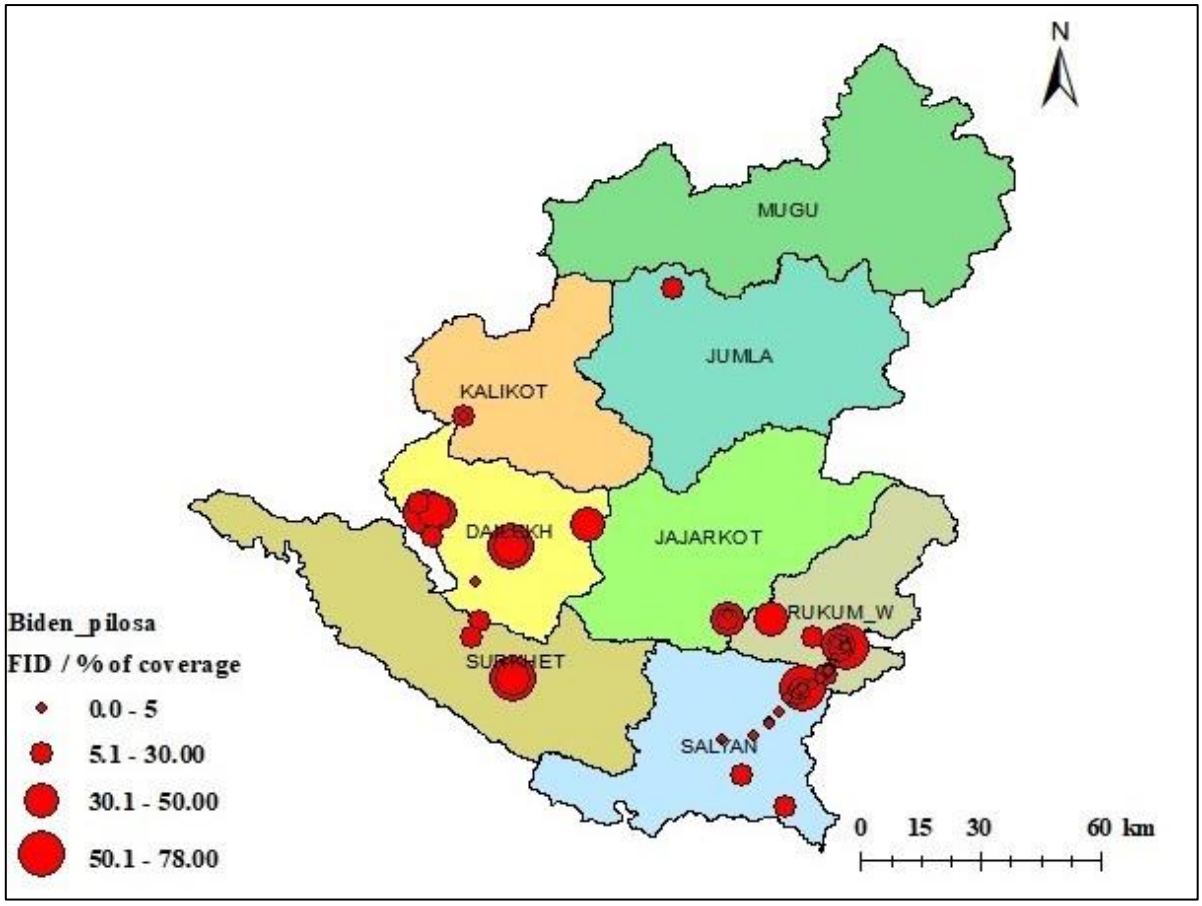
Figure 5: Invasion of *Lantana Camara* in Kalikot



Map 5: Distribution map of *Lantana camara*

d. *Bidens pilosa*

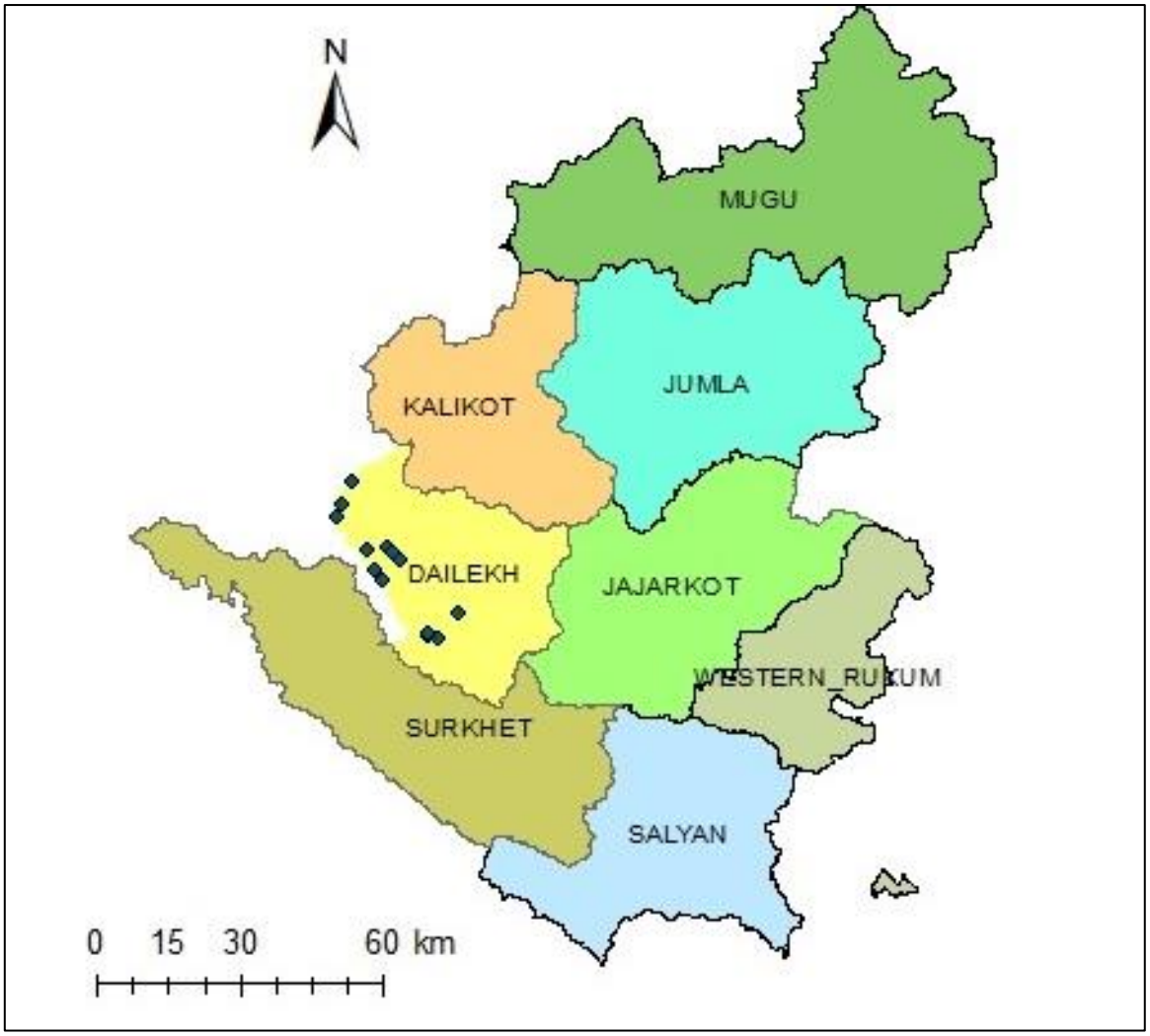
It is a noxious weed that is capable of invading a wide range of habitats such as fallow lands, agricultural lands, disturbed forests, and roadsides in almost all the studied districts except the Mugu.



Map 6: Distribution map of *Bidens pilosa*

e. Bush morning-glory or 'besaram', 'sanai phul' (*Ipomoea carnea* ssp. fistulosa (Mart. ex Choisy) DF Austin; Convolvulaceae)

Figure 6: Invasion of *Ipomoea carnea* in Rakam



Map 7: Distribution map of *Ipomoea carnea*

3.2.1.1.2 Altitudinal variation in species distribution

The number of IAPS declined with increasing the elevation. This study found 17 species of IAPS out of 19 species at 801-100m elevation belt and only three species of IAPS above 2600 m. Among them, patti jhar *Parthenium hysterophorus* was found at almost all the elevation belts of the study area.

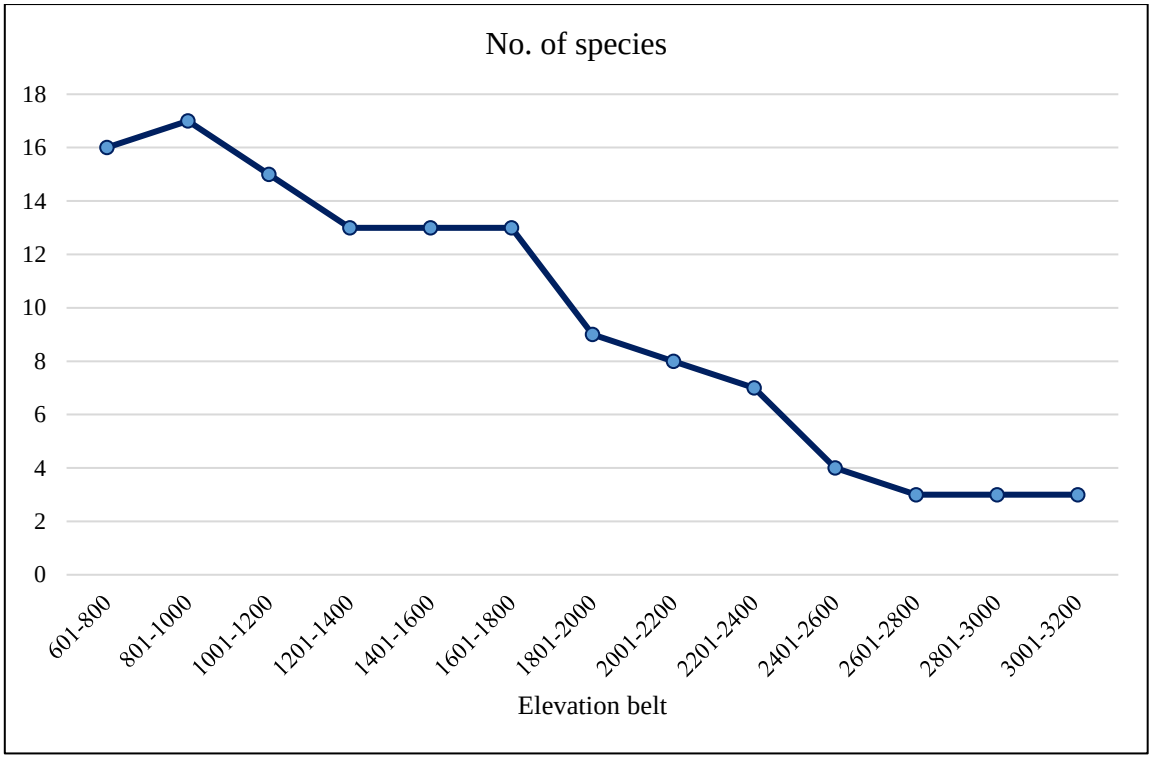


Figure 7: Variation of the number of IAPS along with changes in altitude

3.2.1.2 Investigate the impact of invasive plants on native biodiversity, ecosystem structure, and ecosystem services.

3.2.1.2.1 Variation of IAPS along with the land use

The distribution of IAPS varies with the variation in land use in Karnali. The barren land and roadsides pose more species of IAPS followed by the agricultural land and settlement area.

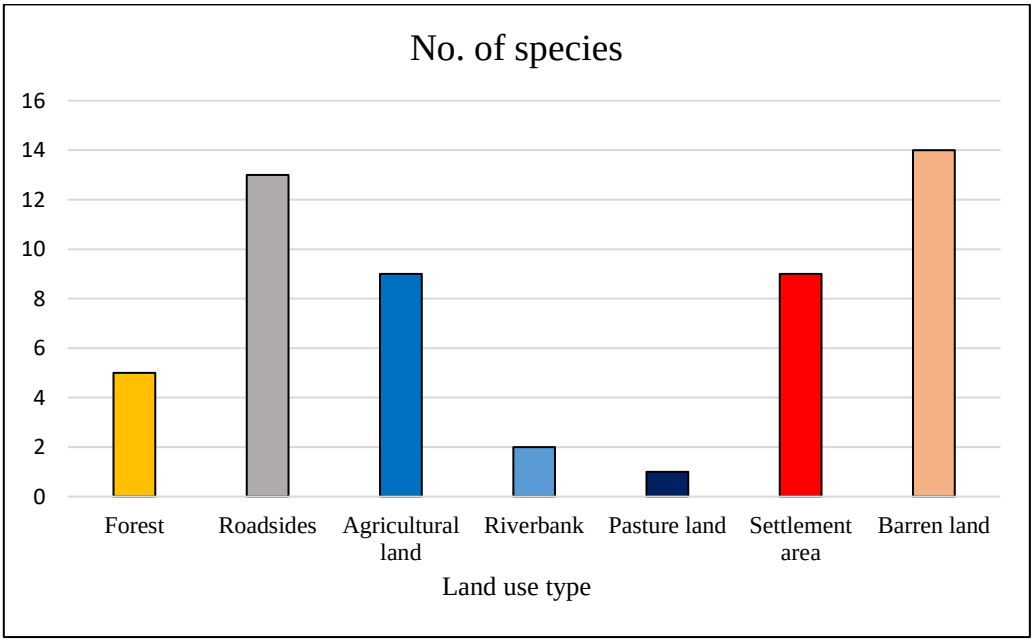


Figure 8: Variation of IAPS along with land use change

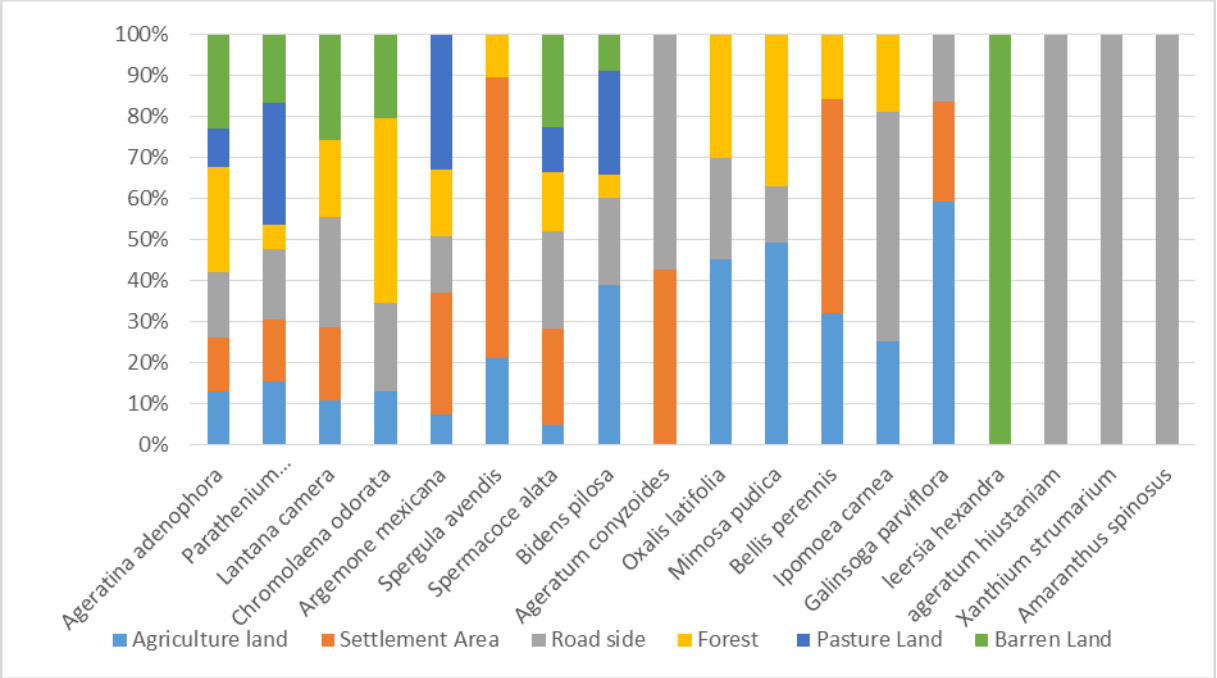


Figure 9: Frequency of IAPS as land use change

Table 3: IAPS as per land use

S.N.	Effected land use	Major IAPS
1	Forest	*Ageratina adenophora, Chromolaena odorata, Mimosa pudica, Ipomoea carnea, Parathenium hysterophorus*
2	Roadside	*Ageratina adenophora, Chromolaena odorata, Parthenium hysterophorus, Argemone Mexicana, Ipomoea carnea, Bidens pilosa, Lantana camara, Xanthium strumarium, Spergula arvensis, Spermacoce alata, Erigeron karvinskianus, Amaranthus spinosus, Galinsoga quadriradiata*
3	Agricultural land	*Ageratum houstonianum, Ageratum conyzoides, Argemone mexicana, Erigeron karvinskianus, Galinsoga quadriradiata, Mimosa pudica, Oxalis latifolia, Parthenium hysterophorus, Spergula arvensis*
4	Riverbank	*Ipomoea carnea, Leersia hexandra,*
5	Pasture land	*Parthenium hysterophorus*

6	Settlement area	*Parthenium hysterophorus,* Ageratum houstonianum, Ageratum conyzoides, Lantana camara, Amaranthus spinosus, Bidens pilosa, Senna tora, Spermacoce alata, Xanthium strumarium
		Leersia hexandra, Ipomoea carnea, Amaranthus spinosus, Ageratina adenophora, Parthenium hysterophorus, Argemone Mexicana, Bidens pilosa*,* Ageratum conyzoides, Erigeron karvinskianus, Ageratum houstonianum, Galinsoga quadriradiata, Amaranthus spinosus, Ipomoea carnea, Oxalis latifolia

3.2.1.2.2 Impact of IAPS in Different land use type

Name of species	Impact of IAPS
Ageratum conyzoides	The species prevent the growth of crops, reducing their productivity. It forms mats in the field that do not allow crop activities.
Argemone mexicana	It has an allelopathic (chemical) that suppresses the germination and growth of crops.
Spermacoce alata	It forms a dense mat and reduces the other plants' activities.
Ipomoea carnea	The latex can cause vomiting and diarrhoea, and it is toxic to goats.
Erigeron karvinskianus	It forms a dense mat with its highly branched stem.
Ageratina adenophora	This suppresses the growth of other species. It is toxic to livestock.
Lantana camara	It is a frequent invader of natural habitats such as open forests and riversides, as well as disturbed cultivated areas, roadsides, pastures, and wastelands. It degrades the soil quality.
Parthenium hysterophorus	It reduces forage production and causes health problems for livestock and people. It also changes the plant and soil chemical composition.
Oxalis latifolia	It grows on a wide range of soil types.
Xanthium strumarium	It is poisonous to livestock but goats feed on this weed, particularly during the dry season

Mimosa pudica	It forms a dense ground cover preventing the growth of other species.
Senna tora	It produces a large number of seeds and is found in dense thickets.
Leersia hexandra	It forms a dense mat, that reduces light penetration, a serious weed of rice.
Amaranthus spinosus	It displaces native plants and alters the habitat of animals.
Ageratum houstonianum	It forms a dense ground cover along forest margins and on agricultural land, limiting the growth of other plants.

3.2.2 Understanding Mechanisms of Invasion:

3.2.2.1 Examine the ecological and physiological mechanisms that enable invasive plants to outcompete native species.

The rate of invasion of IAPS significantly increases within half a decade in comparison to the previous decades. The *Parthenium hysterophorus*, *Amaranthus spinosus*, *Ageratina adenophora*, and *Lantana camara* were excessively increasing in the Karnali Province. Altogether, 69% of respondents had responded that the invasion of IAPS has increased in the last half a decade, 24% had responded as fair change and 7% had responded as no change.

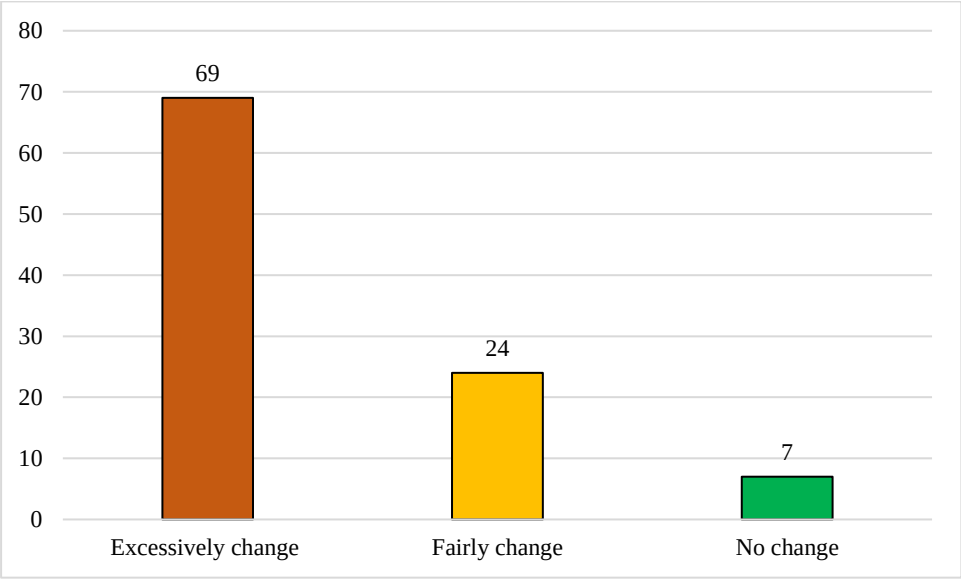


Figure 10: Rate of invasion of IAPS

The IAPSs were invaded more in monsoon in comparison to other seasons of winter. Altogether, 79% responded that the invasion of IAPS was more in monsoon, 17% percentage in winter, and a4 % responded in all seasons. Nobody else responded to that invasion of IAPSs in the summer.

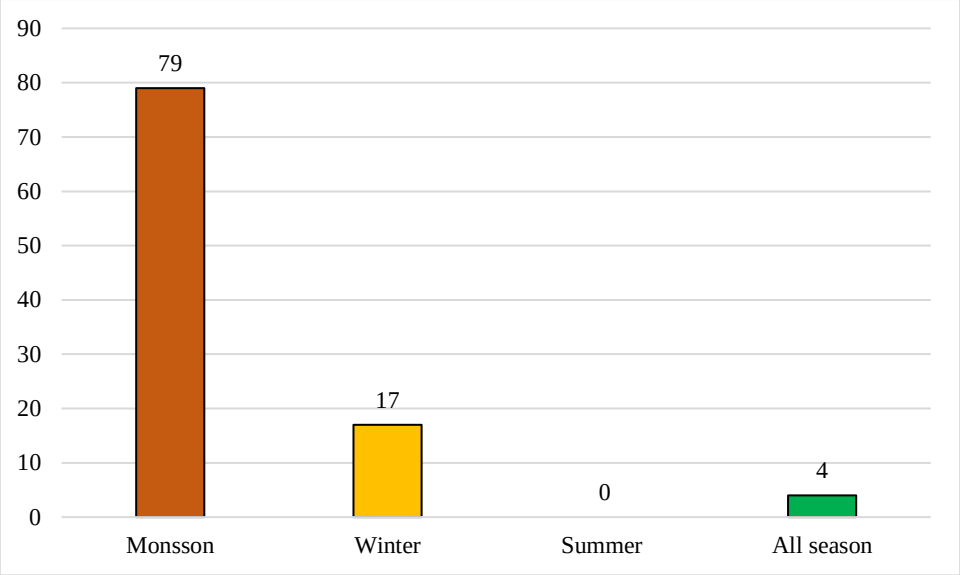


Figure 11: Invasion of IAPS as per season

The invasion of IAPSs has affected various ecosystem services like soil, water, fodder, and medicinal plants including other sectors. Altogether, 29% of respondent had responded that IAPSs have decreased the fodder for their livestock. Similarly, 26 % of respondents said that soil quality has been degraded due to the invasion of IAPSs (Fig).

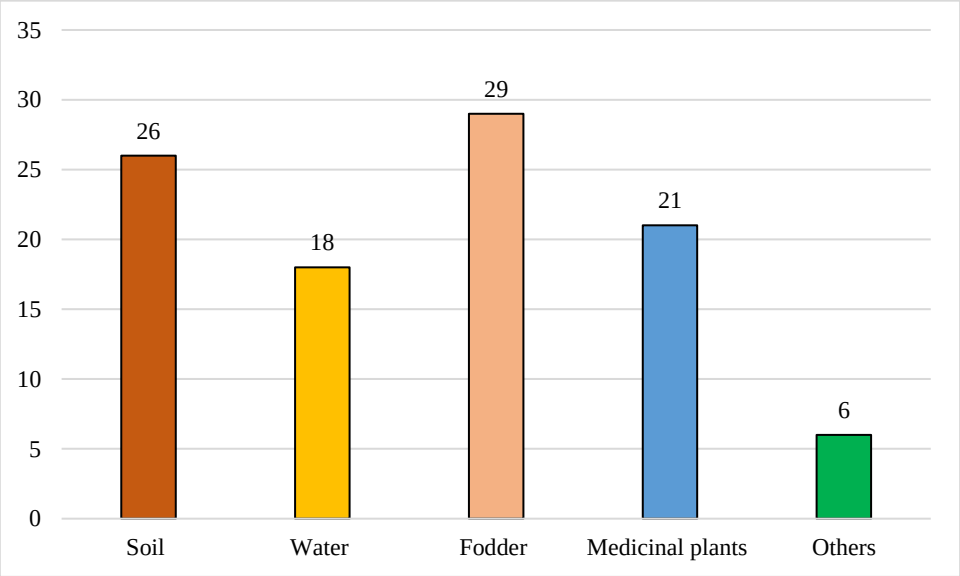


Figure 12: Impact of IAPS in different ecosystem services

3.2.2.2 Identify the role of environmental factors and human activities in promoting the spread of invasive plants

Name of species	Problems	Promoting factors	
		Ecological	Human activities
Ageratum conyzoides	This species prevents the growth of crops, reducing their productivity.	A single mature plant can produce up to 40,000 seeds which are easily dispersed by wind and water (Adhikari et al., 2022).	The livestock, and wild animals, as well as clothes and agricultural machinery.
Argemone mexicana	It that suppresses the germination and growth of crops. Manual removal is difficult because of its prickly nature.	A single plant can produce up to 4000 small seeds (Adhikari et al., 2022).	It can spread through contamination of other seeds.
Spermacoce alata	It forms a dense mat and reduces the other plants' activities.	It reproduces by seeds, as well as through its spreading shoots.	
Ipomoea carnea	The latex can cause vomiting and diarrhoea, and it is toxic to goats.	It spreads rapidly from seeds and stem fragments, invading unmanaged land and blocking out native plants	Plantation of the irrigation canals.
Erigeron karvinskianus	It forms a dense mat with its highly branched stem.	It can produce huge number of light seeds that are dispersed long distances by wind.	
Ageratina adenophora	The allelopathic (chemical) suppresses the growth of other species. It is toxic to livestock.	A single plant can produce several thousand seeds which are easily dispersed by the wind and water.	
Lantana camara	Drought resistance	It is mostly spread by its bird-dispersed seeds.	When cut it re-sprouts vigorously, forming dense thickets

Parthenium hysterophorus	It degrades pasture by reducing forage production and causes health problems for livestock and people. It also changes the plant and soil chemical composition.	The seeds are easily spread by animals and water.	
Oxalis latifolia	It grows on a wide range of soil types.	Numerous bulbils remain dormant in the soil before sprouting under favorable conditions	
Xanthium strumarium	It is poisonous to livestock but goats feed on this weed, particularly during the dry season	The fruits readily stick to animal fur. It can also be dispersed by surface run-off water	The fruits of the species attached to human clothing are easily spread from one place to another
Senna tora	It produces a large number of seeds and is found in dense thickets.	The seeds can remain viable for up to many years and are also spread as a contaminant of agricultural produce.	
Leersia hexandra	It forms a dense mat, that reduces light penetration, a serious weed of rice.	It reproduces through seeds that are dispersed by water.	
Amaranthus spinosus	It displaces native plants and alters the habitat of animals.	It reproduces through seeds that are dispersed by water, and animals. A single plant can produce up to a large number of seeds.	
Ageratum houstonianum	It forms a dense ground cover along forest margins and on agricultural land, limiting the growth of other plants.	A single plant can produce a large number of small seeds which are easily dispersed by wind, water, and animals, or by contamination of	

		seed stocks and agricultural produce.	

3.2.3 Developing Effective Management Strategies:

3.2.3.1 Evaluate current management practices and their effectiveness in controlling invasive plant species.

Generally, local people practice the manual method to manage the IAPS in their local area and agricultural land.

Name of species	Current practices of local people to manage the IAPS	Suggestion of KII for effective management
Ageratum conyzoides	Manual removal by hand	
Argemone mexicana	Manual removal is difficult because of its prickly nature, but it must be removed and destroyed before it sets seed.	Herbicides could be effective for controlling the spread of this plant.
Spermacoce alata	Manual removal by hand	Manual by hand and herbicides
Ipomoea carnea	Manual removal	Manual removal and increased utilization could help to manage this species.
Ageratina adenophora	People remove plants manually from forests and agricultural lands. Using fire.	A biological (*Procecidochares utilis*) and chemical control program should be promoted.
Lantana camara	Very hard to remove	Increased tree canopy could reduce the spreading of this plant.
Parthenium hysterophorus	Manual removal by hand	Leaf feeding by Mexican beetle and winter rust are partially controlling this weed
Oxalis latifolia	Manual removal by hand	Chemical methods could be the best way to control this plant
Xanthium strumarium	Manual removal by hand	Manually uprooting before fruiting.
Galinsoga quadriradiata	Manual removal by hand	Manually uprooting before fruiting

Senna tora		Manual pulling up and burning young plants would be helpful to manage. Herbicides can be used to control it
Leersia hexandra	Manual removal, chipping and herbicides.	Hand weeding and the use of herbicides.
Amaranthus spinosus		Manually weeding by hand and herbicides could be used to control it.

The problem of IAPS can manage by increasing the utilization of such plants species in livelihood of local people.

Name of species	**Uses**
Ageratum conyzoides	Its most common uses are to treat wounds, burns, and colds.
Ipomoea carnea	It has a strong root system, planted along irrigation canals which stops the banks from eroding. Used as firewood, as green manure, and in the construction of temporary shelters. Artisan paper can be made from the bark of *Ipomoea carnea*.
Ageratina adenophora	Local people use the leaf juice to stop bleeding from minor cuts. It is used to make compost, green manure, and is also used in biogas plants. The char produced from its stem is used to make pellets, briquettes and biochar
Lantana camara	It can be used to make bioenergy and basketry products
Oxalis latifolia	Young leaves are used in pickles for their acidic taste
Xanthium strumarium	It can be used as green manure in paddy fields
Senna tora	Young leaves are used as a vegetable. Some medicinal uses of these plants have also been reported.
Leersia hexandra	Have revealed the capacity of this plant to remove heavy metals such as chromium and nickel from waste wate

In Karnali Province, there were not any records of any management plans and strategies for IAPS. The local people addressed that, DFO, CFUGs/ BZUGs/ UGs, Local governments, NGOs/ INGOs, Research organizations, and other local groups were responsible for managing the problems created by IAPS. Altogether 23% responded that DFO, CFUGs/ BZUGs/ UGs were responsible for managing the IAPS and developing the appropriate management plan and strategies, 20 % responded local government, 13 % responded NGOs/ INGOs, 15 % responded research organizations and only 5 % responded had addressed others like themselves.

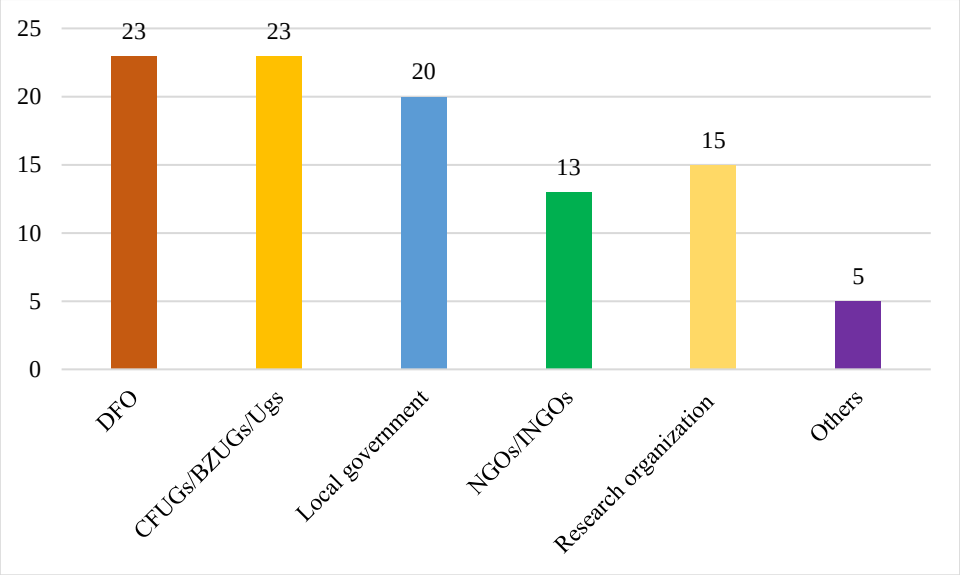


Figure 13: Reponsible organizations for managing the IAPS and developing the appropriate management plan and strategies

The invasion of IAPS can be managed by applying various strategies. As per the KII interviewed, 28% responded the awareness program regarding to distribution, impact, and controlling measures of IAPS will be very effective strategy. Similarly, 26% responded as indigenous practices, 25 % responded through social media, 17 % said that KII and only 4 % mentioned the other sectors like value change of IAPS in to income generating programs.

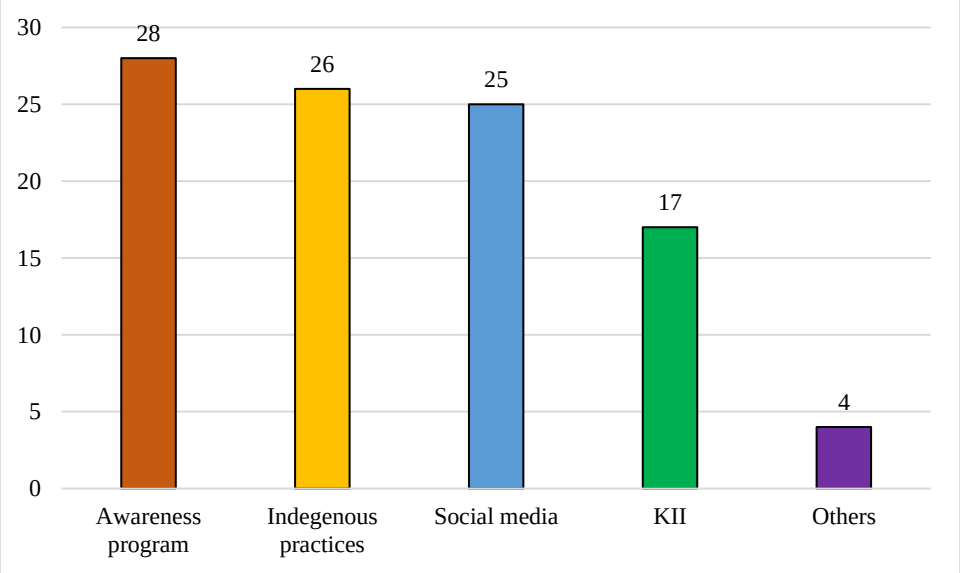


Figure 14: Effectiveness of Management strategies of IAPS

Chapter 4. Conclusion and Recommendation

4.1 Conclusion

The IAPSs are burning issues in Karnali Province, which were recorded in all the districts (N=8) of the study area. There are 18 species of IAPS were recorded among the 29 species of Nepal. The Kalo banmara (*Ageratina Adenophora),* Pattijhar (*Parathenium hysterophorus),* Kalo kuro (*Bidens pilosa),* Thakal (*Argemone Mexicana),* Chari amilo *(Oxalis latifolia)* and Kirne kada *(Lantana camera)* were the major IAPS in the area. The invasion of IAPS varies as per land use change, where the barren land and roadsides pose more species of IAPS than others. However, the number of IAPS was decreasing as per increasing altitude, the invasion was recorded in all elevation belts of the study area. The invasion of IAPS has affected various ecosystem services like soil, water, fodder, and medicinal plants including other sectors, though that there are some uses of IAPS in the daily life of local people. Plants like *Ageratina adenophora, Ageratum conyzoides* are used to stop bleeding from minor cuts, additionally some young plants of *Senna tora* and *Amaranthus spinosus* are used as vegetables, Ipomoea carnea is used at the irrigation canal to reduce soil erosion. Many IAPS were found as compost manure for agriculture. However, the local people have seen that the rate of invasion of IAPS has been increasing in the last five years than previous decades, they do have not any modern ideas like biological and chemical mechanisms to control and manage the IAPS, rather than their indigenous practices. The manual removal by hand was a very effective process to remove the IAPS in the area. However, the impact of IAPS is disturbing the ecosystem services and plant composition of that area, there were no records of any management plans and strategies regarding IAPS. The local people addressed, DFO, CFUGs/ BZUGs/ UGs, Local governments, NGOs/ INGOs, Research organizations, and other local groups as a reliable body for properly managing the problems created by IAPS. However, the invasion of IAPS was not new.

4.2 Recommendation

The Karnali Province is one of the richest among the seven provinces of Nepal, in terms of biodiversity, agricultural products, and forest resources, the effective long-term management of IAPS is crucial to conserving significant habitats. Here are some recommendations and strategies to manage and control the invasion of IAPS in Karnali Province.

1. Awareness about the mode of distribution and impact of IAPS: The local people and stakeholders must know about the mode of invasion and its impact on the ecosystem services, including the measurable changes in social economy and environmental

features. Therefore, awareness programs regarding the IAPS distribution, mode of invasion, and impact of IAPSs should be conducted by involving the local people, and stakeholders of various agencies (DFO, CFUGs, BZUGs, local governments) through various modes of delivery methods like in-person, social media, and KII.

2. Early Detection and Rapid Eradication: Once an invasive species arrives in a new area, early detection and swift eradication efforts should be applied to limit their negative impacts. Therefore, regular monitoring and timely actions are essential to control the invasion of IAPSs.
3. Comprehensive strategies: Effective management strategies should be developed involving a range of actions at different invasion stages from the prevention at the borders (of the province) to controlling major invasions. While doing so, we should not forget that, every problem can turn into an opportunity, therefore the way out should be developed to convert the IAPS into income-generating resources for local people. Therefore, various skill-developing training must be conducted to empower the local people to change the value of IAPS.
4. Regulating trade and movement: The introduction and spread of IAPS through trade regulation is highly effective. So, entry of IAPS must be limited to avoid the long-term management challenges of IAPS.

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Annexes

Annex 1: Field Photographs

FGD at Rakam Karnali

KII at the Gurase, Dailekh

Consultation meeting at DFO Jumla

Consultation meeting at Rara National Park

Consultaion meeting at Rara National Park

Vegetation sampling

Ageratina adenophora in pine forest

Vegetation sampling

Vegetation sampling

Vegetation sampling

Annex 2: KII and consultation meeting/ FGDs

S.N.	District	KII	Consultation meeting/FGD	Remark
1	Dailekh	5	1	
2	Jajarkot	2	1	
3	Jumla	5	3	
4	Kalikot	3	1	
5	Mugu	5	1	
6	Salyan	1	1	
7	Surkhet	5	2	
8	West Rukum	3	1	
	Total	29	11	

Annex 3: List of KII

S.N.	Name	Post	Organization/Address
1	Raju Ghimire	Warden	Rara National Park
2	Sunil Kumar Gupta		Basin Management, Jajarkot
3	Jib Raj Mahat	Ranger	DFO. West-Rukum
4	Padam Bahadur Shahi	Chair-person	Agriculture department, Tilagufa Municipality-6
5	Ram Krishna Budhthapa	Local leader	Chandannath Municipality, Jumla
6	Khadka lal Nepali	Forest Officer	Planning and Forest Management, Jumal
7	Prem Chaulagain	Ranger	Rara, Chhyanath Municipality

Annex 4: Meeting minutes

आज मिति २०८१।१।६ गतेका दिन कर्णाली प्रदेशको अछपीस नगरपालिको वडा नं ४ राकमसा स्थानिय हरुसंग मिचाहा वनस्पतिको अवस्था र त्यसको प्रभावहरुको बारेमा छलफल गरियो। उक्त छलफल सभामा उपस्थित महानुभावहरु निम्न छन् ।

	नाम	ठेगाना	सम्पर्क नं.	हस्ताक्षर
१	धिरेन्द्र ब. शाही	राकम	9861120866	धिरेन्द्र
२.	तिर्थ परियार	"	9865948443	
३.	रुप बहादुर बिक	"	9841105707	
४.	प्रेम बहादुर शाही	आठविस - ४ राकम	9841460138	प्रेम
५.	गंगा तारामी मगर	दैलेख "	9841243597 गणेश	—
६.	जोगेश धामा	दुङ्गेश्वर, १ चप्रा		
७.	रेन ब. शाही	राकम, दैलेख		-

समस्याहरु

१. मिचाहा प्रजातिका वनस्पतिहरु तिव्र रुपमा बढेको रोक्नीयोग्य जग्गामा असर पार्ने,

२. मिचाहा प्रजातिका वनस्पतिहरु बढेर बस्ने गाईवस्तु लाई चाहिने घास कम गर्नु का साथै डढेलो लाग्नेको सम्भावना बढेको छ ।

समाधानका उपायहरु तथा सुझावहरु

१. कुन स्थानिय वहनाट प्रभावकारी रणनिति अपनाएर मिचाहा वनस्पतिको व्यवस्थापन गर्नु ।

२. पत्रफाडानी कम गर्नु र सडक छेउका खाली जग्गाहरु लाई उचि व्यवस्थापन गर्नु ।

धिरेन्द्र प्रेम

आज मिति २०८१।२।७ गतेका दिन ~~म्याग्दी~~ जिल्लाको तिलागुफा नगरपालिका वडा नं. ६ मा स्थानियहरुको उपस्थितिमा मिचाहा प्रजातिका वनस्पतिहरुको ~~अ~~ अवस्था र प्रभावहरुको बारेमा छलफल गरियो । उक्त छलफलमा उपस्थिति महानुभावहरु निम्न छन् ।

नाम	ठेगाना	सम्पर्क	हस्ताक्षर
①. पदम ब. शाही	तिलागुफा-६	9845321050	पदम
②. गोमनसरा पुन	तिलागुफा-१	9846656664	गोमनसरा
③. तुल ब. पुन	तातोपानी-६	97-666957 ~~99~~	Tulb.
④. पिर चन्द्र रोकाया	"	—	
⑤. कमल पुन	तिलागुफा-२	9767432310	

समस्याहरु

① मिचाहा प्रजातिका वनस्पतिहरु धेरै उपयोग नहुनु ।

② तिव्रगतिमा हावापानी लगायत विभिन्न कारणले मिचाहा ~~का~~ प्रजातिका वनस्पतिहरु बढ्नु र स्थानिय ठाउँमा पाईने धेरैजसो वनस्पति लाई असर गर्नु ।

समस्याबाट उपायहरु तथा सुझावहरु

① मिचाहा प्रजातिहरु आउन नदिनु ।

~~③ विभिन्न संस्थाहरु जस्तै स्था~~

② स्थानिय सरकार, वन लगायत विभिन्न संस्थाहरुले यसको प्रभाव र उचित व्यवस्थापन लागि जनचेतना मुलक कार्यक्रम हरु संचालन गर्नु र ऐनानितिहरु तयार गर्नु ।

पदम गोमनसरा

Annex 5: List of IAPS

Patijhar/ *Parthenium hysterophorus*

Besaram/ *Ipomoea carnea*

Kirne kanda/ *Lantana camara*

Kalo Banmara/ *Ageratina Adenophora*

Thakal/ *Argemone mexicana*

Alu Pate Jhar/ *Spermacoce alata*

Nilogandhe/ *Ageratum houstonianum*

PhuleJhar/ *Erigeron karvinskianus*

Chari amilo/ *Oxalis latifolia*

Lajjawati/ *Mimosa pudica*

Bhede kuro/ *Xanthium strumarium*

Jhuse Chitlange/ *Galinsoga quadriradiata*

Seto Banmara/ *Chromolaena odorata*

Tapre/ *Senna tora*

Raunne/Gandhe/ *Ageratum conyzoides*

Karaute ghans,Navo dhan /*Leersia hexandra*

Kandelude/ *Amaranthus spinosus*

Kalokuro/ *Bidens pilosa*