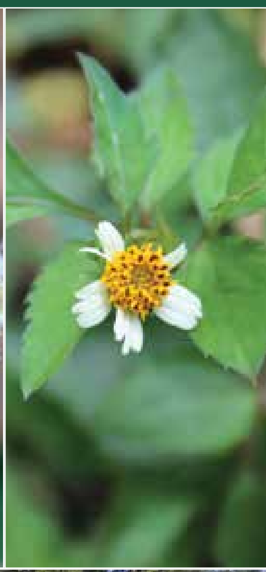
ICIMOD Working Paper 2018/2

ICIMOD

FOR MOUNTAINS AND PEOPLE

Inventory and Impact Assessment of Invasive Alien Plant Species in Kailash Sacred Landscape








About ICIMOD

The International Centre for Integrated Mountain Development (ICIMOD), is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalaya – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

Corresponding author: Srijana Joshi, srijana.joshi@icimod.org

ICIMOD gratefully acknowledges the support of its core donors: the Governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Sweden, and Switzerland.

ICIMOD Working Paper 2018/2

Inventory and Impact Assessment of Invasive Alien Plant Species in Kailash Sacred Landscape

Authors

Bharat Babu Shrestha[1], Srijana Joshi[2], Neha Bisht[2], Yi Shaoliang[2], Rajan Kotru[2], Ram Prasad Chaudhary[3], Wu Ning[2]

[1] Central Department of Botany, Tribhuvan University, Kirtipur, Nepal
[2] International Centre for Integrated Mountain Development, GPO Box 3226, Kathmandu, Nepal
[3] Research Centre for Applied Science and Technology, Tribhuvan University, Kirtipur, Nepal

International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, March 2018

Published by
International Centre for Integrated Mountain Development (ICIMOD)
GP Box 3226, Kathmandu, Nepal

ISBN 978 92 9115 591 0 (electronic)

Production team
Beth Duncan (Consultant editor)
Christopher Butler (Editor)
Dharma R Maharjan (Layout and design)

Photos: Photos by Bharat Babu Shrestha, Jitendra Bajracharya, Neha Bisht, and Srijana Joshi

This publication is available in electronic form at www.icimod.org/himaldoc

Citation: Shrestha, B.B., Joshi, S., Bisht, N., Yi, S., Kotru, R., Chaudhary, R.P. & Wu, N. (2018) *Inventory and impact assessment of invasive alien plant species in Kailash Sacred Landscape*. ICIMOD Working Paper 2018/2. Kathmandu: ICIMOD

Contents

List of Tables

List of Figures

List of Photographs

Annexes

Acknowledgements

We are thankful to authorities of Api-Nampa Conservation Area (ANCA) for granting permission to undertake this research; part of the study area (Darchula District) lies within ANCA. Warden Ashok Kumar Ram, Assistant Warden Raju Ghimire, Ranger Indra Nagari, and local field staff Shanker Badal assisted us and provided useful information during field work.

Two research assistants, Mohan Pandey and Roshan Chhetri, MSc Botany students of the Central Department of Botany, Tribhuvan University (CDB, TU), helped in vegetation sampling, plant collection, and socioeconomic surveying. Mohan Pandey also helped in management of herbarium specimens, field data management, and compilation of secondary data from various sources. We are also thankful to the participants of key informant interviews, focus group discussions, and household surveys. Bir Singh Thaguna helped during vegetation sampling while Sita Mahara helped during socioeconomic surveying in Khar VDC. Mohan Ayer served not only as our driver but also as a field guide during survey work.

Eklabya Sharma, Janita Gurung, Brij Rathore, Kamal Aryal, Pradyumna Rana, Popular Gentle, Corinna Walrapp, Vishwas Sudhir Chitale, and Swapnil Chaudhary of ICIMOD provided information and helpful comments in the report, and Gauri Dangol of ICIMOD prepared the maps. Similarly, Yadav Uprety of Research Centre of Applied Science and Technology (RECAST), Tribhuvan University, provided several unpublished documents related to Kailash Sacred Landscape-Nepal and Khar village development committee. Bijaya Subedi of RECAST also provided some help in the field. Kamal Mohan Ghimire of RECAST and Minu Adhikari of CDB, TU, collected data on the distribution of invasive alien plant species from Chamelia Valley. Prakash Bhattarai provided lists of plant species collected from Humla District during his MSc dissertation. Samden Sherpa, Wang Jinniu and Jiwan Tamang of ICIMOD provided support while conducting hands on training on bio-briquettes and bio-composting for effective management of invasive alien plant species in Khar VDC, Darchula.

We would like to extend our thanks to Ministry of Forests and Soil Conservation, Government of Nepal for their support in conducting this work and steering Kailash Sacred landscape Initiative activities. We are thankful to Dhanraj Kandel of the National Herbarium and Plant Laboratories, Godawari (KATH), for identification of pteridophytes; Keshav Raj Rajbhandari for identification of monocot species; and Ramesh Basnet, Chief of the NHPL, for providing access to the herbarium for identification. We are also thankful to Rosa Raut of the Aquatic Ecology Centre (AEC) at Kathmandu University, Dhulikhel, for laboratory analyses of soil samples. We thank Anil Shrestha, Visiting Scientist, ICIMOD and Professor, Department of Plant Science, Fresno State University, USA, for reviewing the document and providing constructive feedback.

Acronyms and Abbreviations

ANCA	Api-Nampa Conservation Area
IAPS	Invasive alien plant species
IAS	Invasive alien species
KATH	National Herbarium and Plant Laboratory, Godawari, Lalitpur
KSL	Kailash Sacred Landscape
KSLCDI	Kailash Sacred Landscape Conservation and Development Initiative
MoFSC	Ministry of Forest and Soil Conservation, Kathmandu, Nepal
NTFP	Non-timber forest product
RECAST	Research Centre for Applied Science and Technology, Tribhuvan University
TUCH	Tribhuvan University Central Herbarium
VDC	Village development committee

Executive Summary

Biological invasion is a major component of global environmental change and it has negative impacts on native biodiversity, ecosystem services, infrastructures, agriculture production, and human and animal health. Direct and indirect economic costs of biological invasions amount to several hundred billions of dollars annually. Lowlands with high urbanization, industrialization, and other economic activities are adversely affected by biological invasions, whereas mountain regions were considered to be relatively less affected by this phenomenon. However, recent research and meta-analyses have revealed that biological invasions are occurring in mountain regions at an alarming rate. Management of invasive alien species (IAS) is more challenging in mountains due to the rugged topography.

Kailash Sacred Landscape (KSL), a transboundary landscape, is a culturally unique, economically less developed, biologically diverse, geographically heterogeneous, and environmentally vulnerable part of the Hindu Kush Himalaya region. It encompasses parts of Tibet Autonomous Region of China (KSL-China); Pithoragarh and Bageshwor Districts of Uttarakhand, India (KSL-India); and Baitadi, Bajhang, Darchula, and Humla Districts in northwestern Nepal (KSL-Nepal). Widespread environmental degradation, a high volume of tourists (particularly in KSL-China), socioeconomic transformations, and the increasing flow of commercial goods to support tourism and mountain livelihoods have increased propagule transport and influx of invasive alien plant species (IAPS) from the surrounding lowlands, particularly in KSL-India and KSL-Nepal. Communities in low mountain regions of KSL-Nepal have been facing problems like declines in farm productivity, rangeland forage production, forest regeneration, and important native species due to the rapid spread of some IAPS. In this context, as part of the Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI), we assessed the distribution patterns of IAPS in KSL-Nepal, in general, and the Khar village development committee (VDC) of Darchula District (one of the KSLCDI pilot sites in Nepal). Furthermore, we also assessed their impacts on ecosystems and livelihoods and developed recommendations for their management. This work is in line with the national targets set by the Government of Nepal in the National Biodiversity Strategy and Action Plan (2014–2020) to address the increasing problem of biological invasions in Nepal.

In this assessment, which focused only on species, information was collected in different spatial scales: vegetation sampling in forest and cultivated lands of Khar VDC (plot and ecosystem levels); socioeconomic survey and exploration of vascular plants in Khar VDC (VDC level); distribution mapping of IAPS along road (and trail) networks; and preparation of a checklist of native, naturalized, and IAPS found in KSL-Nepal from primary and secondary sources (landscape level).

There are 1,073 vascular plant species reported from KSL-Nepal: 54 species are pteridophytes, 14 gymnosperms, 779 dicots, and 226 monocots. Among dicots, about 5.5% (43 species) are naturalized and 35% (15 species) of the naturalized species are invasive in the region. Similarly, at least 3 species of monocots are naturalized and none of them are invasive. In Khar VDC (an area of 25.95 km^2), 41 species of pteridophytes, 166 dicots, and 42 monocots have been documented. Among them, 8 species of dicots are considered invasive in Nepal.

Among 15 IAPS found in KSL-Nepal, *Ageratina adenophora* and *Lantana camara* are problematic in forests and shrublands; *Ageratum conyzoides, A. houstonianum, Bidens pilosa, Erigeron karvinskianus, Galinsoga quadriradiata,* and *Oxalis latifolia* are common in cultivated lands; *Amaranthus spinosus, Parthenium hysterophorus, Senna occidentalis, S. tora,* and *Xanthium strumarium* are spreading in grazing lands and urbanised areas (including roadside vegetation); and the remaining two species, *Ipomoea carnea* ssp. *fistulosa* and *Pistia stratiotes,* are wetland species. Along road verges, *A. adenophora* is the most frequent followed by *B. pilosa*. The most problematic IAPS in KSL-Nepal are *A. adenophora, L. camara* (one of the 100 of the world's worst invasive species), *A. houstonianum,* and *E. karvinskianus*, while in Khar VDC *A. adenophora* and *E. karvinskianus* are the most damaging. *P. hysterophorus* is rapidly spreading in KSL-Nepal and may be problematic in the very near future. Long-distance dispersal of IAPS, particularly *P. hysterophorus,* is mainly by vehicle movements and material transports. *X. strumarium* is dispersed by livestock while *L. camara* is dispersed by birds. A few species, like *I. carnea* ssp. *fistulosa*, have been introduced for revegetation along roadsides to control landslides.

Roadside surveys and vegetation sampling revealed that the number of IAPS declined with increasing elevation. Numbers are higher in agroecosystems than in adjacent natural vegetation such as forest and shrublands. According to local communities, the IAPS have affected ecosystem services by preventing tree regeneration in degraded forests (by *Lantana camara*), reducing forage production in rangelands (by *A. adenophora* and *E. karvinskianus*), displacing native forage species (by *E. karvinskianus*), and degrading habitat of non-timber forest product yielding species like allo (*Girardinia diversifolia*) (by *A. adenophora*). Similarly, IAPS have affected livelihoods by increasing labour input in cropping systems (three to five additional days to clear *Ageratum houstonianum*, *E. karvinskianus*, and *A. adenophora* during a cropping season) and reducing crop production (upto 50% reduction in maize and wheat). In grasslands used for harvesting forage, in Khar VDC, *E. karvinskianus* has reduced forage production by upto 50%. According to the local people, this species has also displaced high value native forage species such as *Pennisetum orientale, P. flaccidum* (locally called 'Biraichhe'), and C*hrysopogon gryllus* (locally called 'Salam'). Communities are responding to the increasing abundance of invasive species by utilizing their biomass (such as *L. camara* for fuelwood and *A. adenophora* for composting). Restoration of native forage species has also been initiated by communities in areas invaded by *A. adenophora* and *E. karvinskianus* in Khar VDC.

Recommendations for management of IAPS in KSL-Nepal include:

1) Eradication of small satellite populations of *P. hysterophorus, A. spinosus,* and *X. strumarium*;
2) Containment through physical and cultural methods to prevent further spread of *P. hysterophorus, L. camara, A. adenophora*, and *A. houstonianum*;
3) Biomass utilization of *L. camara* (for production of bio-briquette) and *A. adenophora* (for composting);
4) Reduction of anthropogenic disturbances in forests and implementation of conservation agriculture practices to minimize suitable habitats for invasive species;
5) Restoration of native species as a part of an ecosystem-based management of IAPS. Proactive management across the HKH to control IAPS and promote the regeneration of native species;
6) Community education and participation for identification, early detection, and management of IAPS;
7) Transboundary vigilance by communities and local conservation stakeholders to monitor spread of the IAPS across the international border; and
8) Monitor the spread and growth of IAPS in selected ecosystems – forests, pastures, and agricultural land.

To increase the effectiveness of IAPS management, future research may focus on a pilot study to restore native species in areas with a high number of IAPS, and risk assessment of the entire KSL for biological invasion. Since biological invasion is a transboundary conservation issue, a common regional management strategy for Himalayan countries is needed to protect mountain ecosystems from the adverse effects of biological invasion.

1. Introduction

1.1 Background

Biological invasion has been considered as an important component of global environmental change (Vitousek et al. 1997; Dukes and Mooney 1999) and a leading cause of decline and loss of native biodiversity (Ricciardi et al. 1998; Kohli et al. 2004; Sax and Gaines 2008) and ecosystem services (Pejchar and Mooney 2009; Vilà et al. 2010). The economic cost of biological invasion has been estimated at several hundred billion dollars in terms of management and direct and indirect negative impacts to human welfare across the world (see, for example, Pimentel et al. 2005; Xu et al. 2006; Williams et al. 2010). Recent evidences also have revealed that the current invasive alien species (IAS) in any ecosystem can facilitate the establishment of new IAS (Relva et al. 2010) as well as increase the impact of previously less damaging IAS (Grosholz 2005) leading to ''invasional meltdown'' (Simberloff and Holle 1999). The problem of biological invasion has been further aggravated by climate change as this phenomenon aids in the establishment of new invasive alien species, changes the distribution of existing species, and modifies the effectiveness of control measures (Hellmann et al. 2008; Bellard et al. 2013). Future climate change scenarios predict that the number of IAS and the severity of their impacts will increase. Therefore, frequency of new introduction, abundance of IAS, and the damage incurred by them are likely to further increase in any ecosystem and geographic unit with increasing changing climate.

Mountains may appear to be one of the few geographic areas less affected by biological invasion. However, naturalized alien plant species are not so uncommon in mountain areas — for example, there are 175 naturalized vascular plants in Australian Alps (Johnston and Pickering 2001) and nearly a thousand naturalized plant species in mountain regions worldwide (Pauchard et al. 2009; McDougall et al. 2011a). Many of them are not abundant but some have already posed serious threats to mountain ecosystems and human welfare. Recent evidence has shown that the extent of biological invasion (number of species and their impact) has been increasing over time in mountain regions worldwide (Pauchard et al. 2009). These regions often have high conservation value with diverse ecosystem services and also represent one of the few geographic areas where management of invasive species is the most challenging due to rugged topography (McDougall et al. 2011b). Therefore, preventive measures to protect the landscape from further invasion by alien species is more relevant to mountain regions than any other ecosystem (McDougall et al. 2011a; McDougall et al. 2011b). Naturalized species in mountain regions are most strongly determined by the community of naturalized species at proximal low land (McDougall et al. 2011a). Shift to higher elevations of many naturalized species is prevented by low temperatures and a short growing season. As the life zones (or climatic belts) are expected to shift to higher elevations in mountain regions under future climate change scenarios (Xu et al. 2009), a given location, which is too cold presently for lowland naturalized species, may support their growth and proliferation in the future due to increase in temperature. Therefore, it is highly likely that the problem of biological invasion in mountain regions will further increase under future climate change scenarios. Since the impact of biological invasion in mountain regions is currently not as serious as in lowlands, it provides an opportunity for scientists and managers to plan for a timely response (Pouchard et al. 2009).

Biological invasion has been considered as one of the major threats to biodiversity and ecosystem functions in Nepal (MoFSC 2002; MoFSC 2014). The emergence of new invasive alien plant species (IAPS) in agroecosystems has also been considered a challenge for achieving the goals of the Agriculture Development Strategy of Nepal (MAD 2014). At least 64 species of alien fauna are present in Nepal (Budha 2015) and 179 species of flowering plants are naturalized in different ecosystems (Shrestha et al. 2018).

Most of the naturalized plant species (74%) in Nepal are native to the Americas and their distribution in Nepal follows a unimodal relationship with elevation having species richness peak at around 1,000 m above sea level (Bhattarai et al. 2014). Twenty-one of the gradient naturalized plant species were reported as invasive in Nepal by Tiwari et al. (2005) through a national level assessment. Field observations and community consultation conducted during a distribution survey of IAPS revealed that four more naturalized species have turned out to be invasive, particularly in agroecosystems (Poudel 2016; Shrestha BB —unpublished data). Therefore, at least 25 species of flowering plants are invasive in Nepal (Shrestha 2016; Annex 1). The number of naturalized plant species is higher in eastern and central Nepal than in western Nepal (Bhattarai et al. 2014) and the concentration of IAPS is higher in Tarai and Siwalik regions than in the hills of western Nepal (Poudel 2016). Some of the noxious invasive weeds are widespread in eastern and central Nepal but are either 'absent' or present at only a few locations in western Nepal. For example, *Mikania micrantha* has already posed a serious threat to biodiversity and ecosystems including protected areas in eastern and central Nepal (Siwakoti 2007; Murphy et al. 2013), but this weed has not been reported from western Nepal (Poudel 2016) though the region is climatically suitable. Another problematic IAPS, *Chromolaena odorata*, is observed quite frequently in central Nepal (Paudel 2015) but has been only recorded at a few locations in western Nepal (Poudel 2016). These cases demonstrate that the distribution of IAPS in Nepal is expanding to new regions because preventive measures have not been developed yet.

Despite the occurrence of more than two dozen IAPS in Nepal, their impacts have not been evaluated and quantified comprehensively. A few studies have indicated that the impacts range from habitat degradation of endangered wildlife, such as the great one-horned rhinoceros (Murphy et al. 2013), to alteration of species composition and soil chemistry of grasslands (Timsina et al. 2011) to negative effects on the livelihood of rural communities (Rai et al. 2012) to health hazards to humans and livestock (Shrestha et al. 2015). Many of the wetlands, including Ramsar sites (such as Beeshajari Lake of Chitwan, Pokhara lake system), have been negatively affected by *Eichhornia crassipes*. To address these problems and as a compliance to biodiversity-related international treaties and conventions, the Government of Nepal has targeted a number of activities by 2020 to manage invasive alien species,including: 1) a nationwide survey of invasive species distribution; 2) preparation of an atlas of invasive alien species for early detection, prevention, and management; 3) enhancing quarantine and detecting capacity of concerned offices; 4) raising public awareness of invasive alien species, their impacts, and management; and 5) assessment of biological control methods (MoFSC 2014). In line with these national targets, a few distribution mapping activities have been completed, such as IAPS in central Nepal by Paudel (2015), IAPS in western Nepal by Poudel (2016), and a nationwide survey of *Parthenium hysterophorus* by Shrestha (2014). However, these mappings were done along road networks and thus are mainly limited to the Tarai, Siwalik, and Mid Hill regions. Mountain areas in general and KSL-Nepal in northwestern Nepal, particularly, remained unexplored for the occurrence of IAPS and their impact on ecosystems and livelihood.

Under the Kailash Sacred Landscape Conservation and Development Initiatives (KSLCDI) baseline data on climate, hydrology, biodiversity (including agro-biodiversity), forest ecosystems, traditional knowledge, and socio-economy are being generated in KSL-Nepal for long-term monitoring. Some developmental interventions are also underway to improve the livelihood of local communities in this region. As part of these activities, an assessment of IAPS at different spatial scales was undertaken in KSL-Nepal. Information was obtained from plot-wise vegetation sampling in forest and cultivated lands (plot and ecosystem levels), extensive collection of vascular plants and socioeconomic survey (Khar VDC level), roadside survey of IAPS, and secondary sources (KSL-Nepal level). Based on the results of this assessment, a number of recommendations for prevention and control of IAPS in KSL-Nepal have been made. Biological invasion is a current (though low intensity) as well as future (potentially at high intensity) threat to the ecosystems and livelihood of mountain regions (Pauchard et al. 2009), assessments that generate baseline data for long-term monitoring can help to formulate preventive measures for the management of IAPS. In addition, this assessment is in line with the national targets set by the Government of Nepal to manage IAPS (MoFSC 2014).

1.2 Objectives

The main objective of the study was to assess the status and impact of IAPS in KSL-Nepal and recommend options for management for better ecosystem services.The specific objectives of the study were to:

- Prepare a checklist of naturalized plant species in KSL-Nepal;
- Survey the distribution of invasive alien plant species (IAPS) in KSL-Nepal;
- Analyse the status (species and scale) of the IAPS in a selected case study site of KSL-Nepal and assess trends and drivers of IAPS expansion;
- Assess the social, economic, and ecological impacts of the IAPS on the livelihoods of local communities and on the health of major ecosystems (forests, farming lands, grazing lands) from an ecosystem service perspective; and
- Recommend options for management of the IAPS leading to better ecosystem services.

2. Study Area

The study area is part of the Kailash Sacred Landscape in Nepal (KSL-Nepal) (Photo 1). Distribution mapping of IAPS was done in three out of the four districts of KSL Nepal. However, vegetation sampling and socioeconomic surveys were focused in the Khar village development committee area (Khar VDC) of Darchula District.

2.1 Kailash Sacred Landscape-Nepal

KSL-Nepal encompasses four districts (Humla, Bajhang, Darchula, and Baitadi) in northwestern Nepal with an approximate area of 13,289 km^2 and an elevation range from 518 to 7,132 masl. It lies between 80° 24′ to 82° 49′ E longitude and 29° 30′ to 30° 44′ N latitude. The area has experienced massive land use changes due to human activities as well as natural processes. Forest area has declined from 24.4% of the total area in 1990 to 22.3% in 2009; similarly in the same period,the snow/glacier area declined from 22.3% to 17.1%, whereas grassland increased from 20.6% to 22.2% and cropland from 14.1% to 15.8% (Uddin et al. 2015). Major crops cultivated in the area include rice, barley, millet, maize, and wheat. However, the available arable land is very low and the region is generally a food-deficient area.

The KSL-Nepal is at the confluence of three major floristic regions of Asia, namely Western Himalayan, Eastern Himalayan, and Central Asiatic. At least five ecoregions are represented in KSL-Nepal: Himalayan subtropical broadleaved forest, Himalayan subtropical pine forest, Western Himalayan broadleaved forest, Western Himalayan subalpine conifer forest, and Western Himalayan alpine shrubs and meadows. At least 18 types of forests, out of 35 types found in Nepal, are also represented in KSL-Nepal (Chaudhary et al. 2010). The area is also rich in species diversity with 83 species of mammals, 455 birds, 38 herpetofauna (amphibians and reptiles), and 119 fish reported so far, and an estimated >2,000 species of angiosperms (Chaudhary et al. 2010). Due to inadequate botanical exploration, a checklist of plant species is not available but a list of about 700 species of vascular plants was compiled during the preparation of the Feasibility Assessment Report of KSL-Nepal.

Photo 1: Kailash Sacred Landscape (Baitadi District)

2.2 Khar Village Development Committee

The Khar VDC of Darchula District is a part of the Api-Nampa Conservation Area (ANCA) and a KSLCDI pilot site for development intervention and long-term environmental and socioecological monitoring. The area lies about a three-hour walk from Khalanga bazaar, the district headquarters of Darchula, or about 14 km by rural road. Though a road trail passing through Khar VDC was opened about 15 years ago, vehicular movement was not possible on the trail due to the poor tract. With an area of 25.95 km^2, the Khar VDC has 698 households and a population of 4,272 people. Chettri and Brahmin are the dominant ethnic groups. Majority of the households are involved in farming and livestock rearing. Thirteen species of crops, nine vegetables, and 16 fodder and forage species have been cultivated, and the area contains 21 non-timber forest products (NTFPs) and medicinal and aromatic plant species (MoFSC, RECAST, and ICIMOD 2015a). Maize, barley, and wheat are the major crop species cultivated; other crops include millet, soybean, rice, and potato. About 15–20% of households also cultivatie allo (*Girardinia diversifolia*) and nigalo (*Drepanostachyum intermedium*) (MoFSC, RECAST, and ICIMOD 2015b). Agriculture is mainly subsistence; the additional sources of income are seasonal collection of medicinal and aromatic plants, including Chinese caterpillar fungus (*Ophiocordyceps sinensis*, locally called 'yarsa gunbu' or 'kira'), in different parts of Darchula District, and migrant labour to India and southern Nepal. 98% of the households use fuelwood for cooking and about 91% have access to electricity, mainly generated from micro-hydropower enterprises (MoFSC, RECAST, and ICIMOD 2015b). Khar VDC represents a typical remote mountain village with subsistence agriculture and low access to modern facilities such as roads, whereas Khalanga bazaar is a rapidly urbanizing mountain city with direct road connections to southern Nepal and indirect connections to large cities in India.

The elevation of the VDC area ranges from 1,324 to 3,242 masl with subtropical climate at lower and temperate climate at higher elevation. There is frequent snow during winter at the upper elevations. Nearly half of the VDC area (51.1%) is covered by forest; other land use types are agriculture (44.3%), shrubland (4.1%), water bodies (0.31%), grassland (0.11%), and settlement areas (0.07%) (ICIMOD 2013; Photo 2). Forest is mainly dominated by broadleaved evergreens such as *Quercus* species, *Rhododendron arboreum*, laurels and deciduous tree species such as *Aesculus indica, Juglans regia, Alnus nepalensis, Betula alnoides, Prunus cerasoides* while conifers such as *Tsuga dumosa, Pinus roxburghii* are found only in a limited area. Allo (*Girardinia diversifolia*), nigalo (*Drepanostachyum intermedium*), Nepalese paper plant (*Daphne bholua*), chirayito (*Swertia chirayita*), and mushrooms are the major sources of NTFPs.

Photo 2: Forest ecosystem and agricultural ecosystem are juxtaposed in Khar VDC

3. Materials and Methods

IAS can be defined as "animals, plants or other organisms introduced by man into places out of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species" ('Invasive Species Specialist Group of the International Union for Conservation of Nature', n.d.). In Nepal, 21 species of angiosperms have been reported as invasive by Tiwari et al., (2005). *Ageratum houstonianum* and *Spermacoce alata* were also found to be problematic invasive weeds in agroecosystems (Shrestha, BB unpublished data). *A. houstonianum* has also been reported as a problematic weed in India (Singh et al. 2011). In addition, two more species, *Erigeron karvinskianus* and *Galinsoga quadriradiata*— were found to be invasive in KSL-Nepal during the preliminary survey. *E. karvinskianus* has been also reported as invasive in India and *G. quadriratiada* in China (Tian et al., 2011). Therefore, a checklist of 22 IAPS was used for distribution mapping, while a checklist of 25 species was used for vegetation sampling and socioeconomic survey (Shrestha 2016; Annex 1).

3.1 Distribution Survey

Distribution of IAPS in KSL-Nepal was mapped through a roadside survey during our preliminary visit in June 2015. Road networks often serve as conduits for dispersal of IAPS because vehicles can disperse propagules long-distance (von der Lippe and Kowarik 2007) and road verges are suitable for colonization by the alien plant species (Johnston and Johnston 2004; Christen and Matlack 2006). Therefore, roadside survey is used for rapid assessment of the diversity and distribution of the IAPS at landscape level (see Kosaka et al. 2010; Shrestha 2014; Wabuyele et al. 2014). All the major road sections within KSL-Nepal which reach to the district headquarters of Baitadi (Dasharath Chand Municipality), Bajhang (Chainpur), and Darchula (Khalanga) were covered during the survey; we could not cover Humla District due to lack of road access. In addition to KSL-Nepal, we surveyed about 50 km of road stretch in Dharchula, India, near the Nepal-India border next to Darchula District. During this survey, the occurrence of IAPS was examined in a 10 m × 10 m plot of the roadside vegetation at 10 km intervals (at some places where elevation changed rapidly, the interval was 5 km). In between these sampling locations, occasional observations of less common IAPS were also recorded. At each sampling location, the name of the IAPS present, land use type, aspect, elevation, and geographic coordinates (latitude and longitude) were recorded. Wherever possible, we also asked local people about the time period when they first observed the IAPS in the area and their perception on the impact of these plants on their daily life (Photo 3). In addition to the roadside survey, the occurrence of the IAPS was also recorded along main trail in Chamelia Valley and Khar VDC. The occurrence data of IAPS from vegetation sampling done at Khar VDC and near Khalanga bazaar were also included in the distribution mapping. Altogether 189 locations in three districts (Baitadi, Bajhang, and Darchula) and Pitthoragarh district, India were examined for the presence of IAPS. From the survey data, occurrence (geographic locations) of individual IAPS was segregated and used to prepare distribution maps.

Photo 3: Interaction with local people during roadside surveys.Survey sites included A) Gokuleshwor, Darchula (note *Parthenium hysterophorus* at left) and B) Rayal, Bajhang (a local resident holds a twig of *Lantana camara* which he considered the most problematic weed in degraded forests).

3.2 Vegetation Sampling and Plant Collection

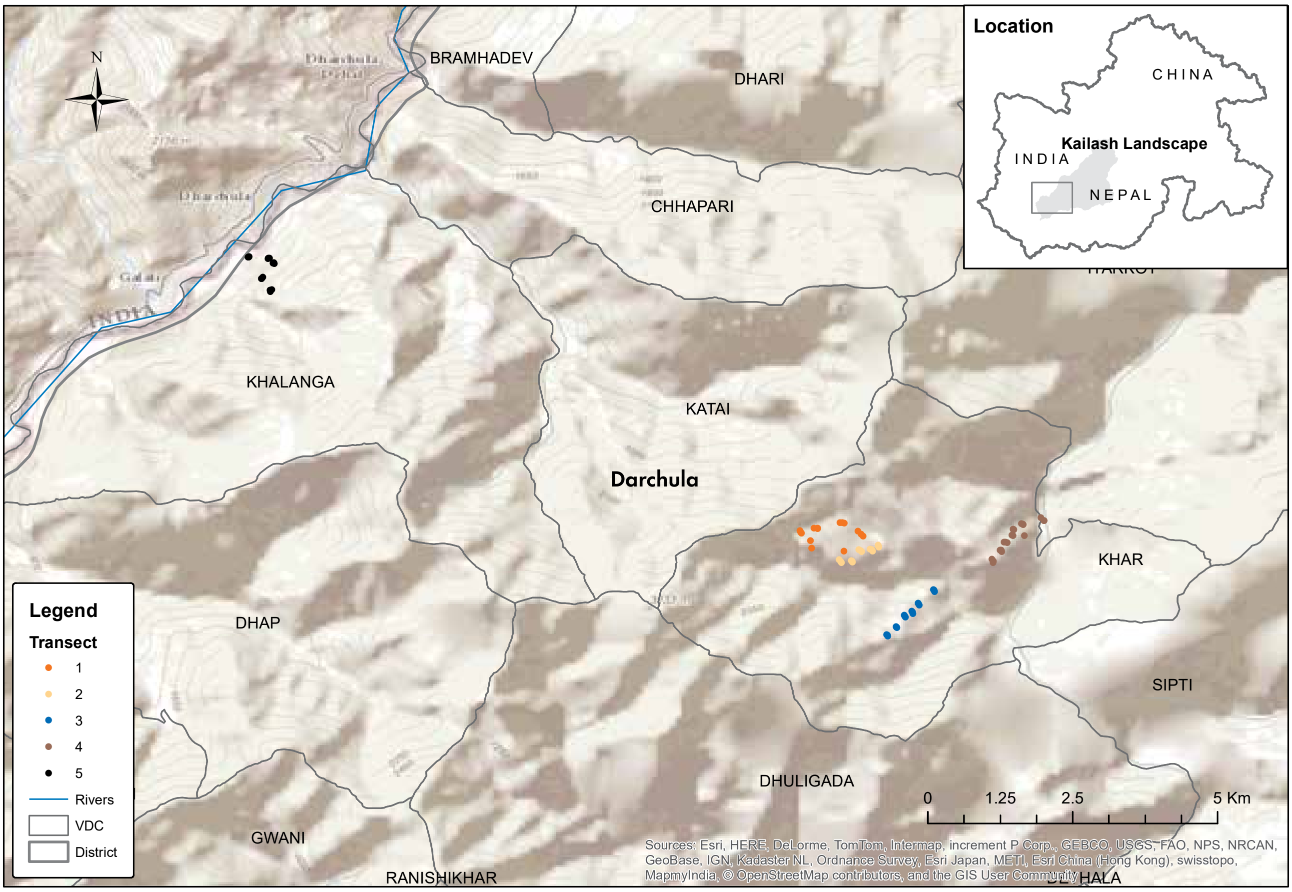
Vegetation sampling and plant collection was undertaken from 28 September to 13 October 2015. A preliminary visit and land use map of Khar VDC revealed that forest and agroecosystems (including cultivated lands, settlement areas, private grasslands used for harvesting forage, and small to large patches of shrublands used for grazing) are the major land-use types. Small to large patches of shrubland which are being used for grazing are present within the general land-use type designated as 'agroecosystem'. To represent these land-use types, vegetation sampling was done in forest (one transect), cultivated land (two transects), and shrubland (one transect) (Table 1 and Figure 1). The forest area under sampling was dominated by *Alnus nepalensis* at lower elevations, *Aesculus indica* at mid elevations, and *Quercus* spp. at higher elevations. Agricultural land mainly comprised of maize fields. The shrubland was mainly dominated by *Ageratina adenophora*. Additionally, one transect was laid out in natural vegetation areas (forest + shrubland) near Khalanga bazaar for comparison.

At each sampling site, a single vertical transect along the elevation gradient was subjectively chosen considering continuity of the land-use type and accessibility for samplings. Starting from the lowest point, sampling was done at intervals of 100 m elevation. The number of elevation bands ranged from five (transects 1, 2, and 5) to seven

Table 1: **Location and other details of the transects**

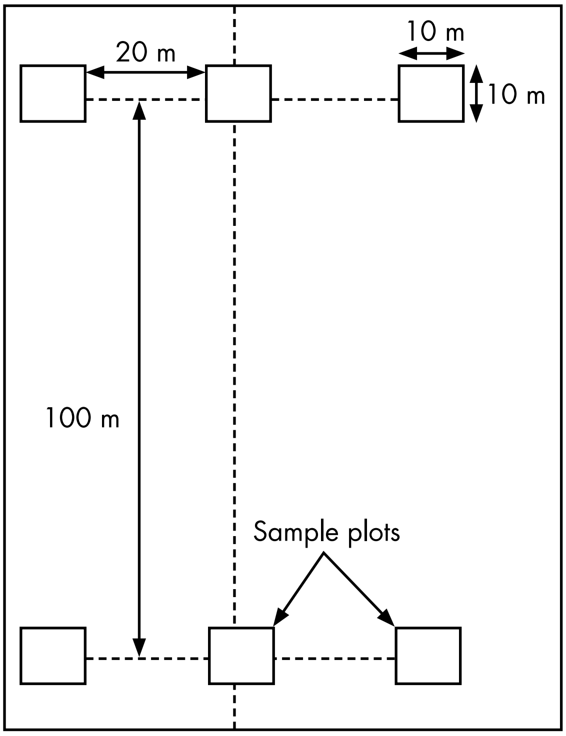
Transect number	Location	Land use	Mean slope (°)	Aspect	Elevation range (masl)	Number of quadrats
1	Khar VDC, ward no. 2	Forest	35	North-East	1836–2312	15
2	Khar VDC, ward no. 2	Cultivated land	35	North-East	1763–2150	15
3	Khar VDC, ward no. 4 & 5	Cultivated land	33	North-East	1626–2151	18
4	Khar VDC, ward no.4	Shrubland	34	North to North-East	1464–2105	21
5	Api Municipality — 13 & 14	Forest + shrubland	26	South-West to North-West	859–1223	15

Figure 1: **Location of transects in Khar VDC (transects 1–4) and Khalanga (transect 5)**



(transect 4). At each elevation band three 10 m × 10 m quadrats placed horizontally at a distance of 20 m (± 10 m) were sampled (Figure 1). Altogether 84 quadrats were sampled in five transects. At each quadrat, the geographic location (aspect, slope, elevation, latitude and longitude) with other stand characteristics, the IAPS with their cover (Daubenmire cover classes estimated visually; Daubenmire 1959), and other vascular plant species (pteridophytes, gymnosperms, and angiosperms) were recorded. In the case of forest, diameter at breast height (DBH, 137 cm) of individual trees was also measured. A herbarium specimen sample of each species was collected for identification. Herbarium specimens of identified species have been deposited at the Tribhuvan University Central Herbarium (TUCH).

Figure 2: **Sampling plot layout along the transect line**



From each quadrat of vegetation sampling, soil samples were also collected. In each quadrat five soil samples from 15 cm depth were collected from four corners and the centre; these soil samples were mixed thoroughly and about 100 g was taken as a composite sample of the plot. Soil samples collected from three quadrats of one elevation band of each transect were mixed to make a single sample for laboratory analyses. Therefore, the total number of soil samples was 28. The collected soil samples were shade dried for about five days in the field and for a week in a laboratory in Kathmandu. The dried soil samples were sieved (mesh size 0.5 mm) to remove stone particles and plant materials. They were then packed in air-tight plastic bags for storage before analyses. The pH (probe method), organic matter (dry combustion method), total nitrogen (Kjeldahl digestion method), available phosphorus (modified Olsen's method), and available potassium (atomic absorption spectrophotometry) were estimated in the soil samples at the laboratory of the Aquatic Ecology Centre at Kathmandu University, Dhulikhel, Kavre. The soil samples were generally acidic or nearly neutral (Table 2). Soil organic matter was higher in cultivated land than in natural vegetation. This probably reflects the use of organic manure in cultivated lands. Available phosphorus and potassium were also higher in cultivated lands than in natural vegetation. But total nitrogen was relatively lower in cultivated lands than in natural vegetation.

We also prepared a list of vascular plant species found in Khar VDC. Therefore, in addition to the plants present in sampled quadrats, herbarium specimens of plants found outside the plots were also collected. We traveled extensively in Khar VDC along the trails passing through different ecosystems to collect plant specimens.

Table 2: **Soil chemical properties of the vegetation sampling sites**

Transect number	Location	Land use	pH	Organic matter (%)	Total nitrogen (ppm)	Available phosphorus (ppm)	Available potassium (ppm)
1	Khar VDC, ward no. 2	Forest	5.1±0.5	7.1±2.1	1248±283	44±26	84±20
2	Khar VDC, ward no. 2	Cultivated land	5.3±0.5	9.5±1.2	1164±318	90±78	226±64
3	Khar VDC, ward no. 4 & 5	Cultivated land	5.1±0.2	8.2±1.2	1225±717	48±44	178±184
4	Khar VDC, ward no. 4	Shrubland	5.7±0.7	7.6±1.4	2634±1031	37±18	87±19
5	Api Municipality — 13 & 14	Forest + shrubland	7.3±0.2	7.8±2.8	3889±1148	27±15	92±23

3.3 Plant Identification

The collected herbarium specimens were identified with the help of various resources. Pteridophytes were identified at the National Herbarium and Plant Laboratory (KATH), Godawari, Lalitpur. The dicot species were identified by cross-matching with specimens deposited at KATH as well as Tribhuvan University Central Herbarium (TUCH). The monocot species were first identified by Dr Keshav Raj Rajbhandari (a taxonomic expert of Nepalese monocot plants) and then cross-checked with images in the Royal Botanic Gardens Kew Herbarium Catalogue.

3.4 Checklist of Vascular Plants Found in KSL-Nepal

Botanical exploration and the representation of herbarium specimens in KATH from KSL-Nepal are very meagre (Chaudhary et al. 2010). This has constrained the estimation of the contribution of naturalized plant species ("alien plants that sustain self-replacing populations for at least 10 years without direct intervention by people by recruitment from seed or ramets capable of independent growth", Pyšek et al. 2004) to the species diversity of the landscape. Since IAPS is a subset of naturalized plant species having significant negative impacts to ecosystems and economies, the region with a high number of naturalized species is also likely to have a high number of IAPS. Therefore, it is imperative to have a list of IAPS as well as naturalized plant species of a landscape for long-term environmental monitoring. As an effort to prepare a checklist of the vascular plants found in KSL-Nepal, we compiled a list of plant species from primary (present study) and published sources as well as unpublished secondary sources (such as Chaudhary et al. 2010; Bhattarai 2011; Elliott 2012; MoFSC and RECAST 2013; Ghimire 2015). Based on their biogeography, the plant species were categorized into native ("taxa that have originated in a given area without human involvement or that has arrived there without intentional or unintentional intervention of humans from an area in which they are native", Pyšek et al. 2004) and naturalized species, with the latter being further divided into noninvasive and invasive. Tiwari et al. (2005) provided a list of 166 naturalized plant species in Nepal; a revised list from Siwakoti et al. (2014) reports 218 naturalized species in Nepal. Another naturalized species, *Erigeron annuus*, has been also reported (Sukhorukov 2014). The updated checklist of 219 naturalized plant species of Nepal was used in this analysis. Other species (excluding cultivated and forestry plantation species) not listed as naturalized species in Nepal were considered native.

3.5 Estimating the Impact of *Erigeron karvinskianus*

Assessment during the preliminary visit and household survey revealed that *Erigeron karvinskianus* is one of the troublesome invasive weeds in agroecosystems of Khar VDC. But this plant has not been reported as an invasive weed elsewhere in Nepal. *E. karvinskianus* is a mat-forming herbaceous short-lived perennial that reaches a height of 30–75 cm. It was evenly distributed in three districts of KSL-Nepal: Bajhang, Baitadi, and Darchula. Therefore, we estimated the impact of *E. karvinskianus* on dry winter forage production in private grasslands. Using the local method of forage harvesting, above ground biomass was harvested from five 1 m × 1 m plots within a 1 m × 10 m rectangular plot. Biomass was harvested from eight such rectangular plots subjectively located at different parts of Khar VDC. From the fresh biomass, *E. karvinskianus* and other plant species were separated and sun dried in the field for three to five hours (Photo 4), followed by shade drying for three to five days. The biomass samples were packed separately and transported to Kathmandu for determining oven dry biomass. After at least 72 hours of oven drying at 60°C, the dry biomass was measured using electric balance (0.001 g). Subsamples of sun-dried samples from some plots with high amounts of biomass were only taken to reduce the amount being transported.

Photo 4: Harvesting forage biomass. A) A local resident assisting with biomass harvesting, B) sample plot (1 m × 1 m) after biomass harvest, and C) sun drying of biomass after segregating into *Erigeron karvinskianus* (left) and other species (right).

3.6 Socioeconomic Survey

The socioeconomic dimension of the IAPS was analysed using data collected through key informant interviews, focus group discussions, and a household survey. These interviews and discussions focused primarily on: 1) name of the IAPS in their locality, 2) year the IAPS was first sighted, 3) impacts of IAPS in their locality, 4) management intervention employed to control IAPS, and 5) willingness to participate in future management activities. The key informants were the District Forest Officer (Darchula), District Committee members of the Federation of Community Forestry Users Nepal (FECOFUN —Darchula and Bajhang), local field staff (game scout) of Api-Nampa Conservation Area at Khar VDC, and head teachers of schools at Khar VDC. Three focus group discussions were organized at Khar VDC with 7–13 participants in each (26 September 2015: 8 men and 5 women; 29 September 2015: 4 men and 3 women; and 1 October 2015: 8 men and 1 woman). The participants were selected with the help of a local facilitator (local staff of ANCA at Khar VDC) who considered individuals who 1) had good knowledge of local plants and ecosystems, 2) were long-time residents, 3) were actively involved in crop cultivation, and 4) had livestock herds. Similarly, 56 household heads were interviewed in Khar VDC (Annex 2) using a structured questionnaire. Households were also selected subjectively based on 1) availability of household head for interview [conducting in-home interviews was difficult because it was the peak harvesting season for forage from grasslands], 2) familiarity with local plants and ecosystems, and 3) potential capacity to understand the questions posed during the interview.

4. Results and Discussion

4.1 Naturalized Plant Species

A checklist of 935 taxa of vascular plants (14 pteridophytes, 14 gymnosperms, 698 dicots, and 209 monocots) has been prepared based on the secondary sources (Chaudhary et al. 2010; Bhattarai 2011; Elliott 2012; MoFSC and RECAST 2013; Ghimire 2015). We have reported 41 species of pteridophytes from Khar VDC and among them 40 species are new additions to KSL-Nepal (Annex 3). Similarly, two species of gymnosperms (*Tsuga dumosa* and *Pinus roxburghii*), 166 dicot, and 42 monocot species have been reported from Khar VDC during this study (Annexes 4 and 5).The total number of vascular plant species so far known in KSL-Nepal is 1,073 (Table 3). All species of gymnosperm are native to the region. Among dicots, about 5.5% (43 species) are naturalized, and 35% (15 species) of the naturalized species are invasive. Similarly, 1.3% of monocots (three species) are naturalized and none of them are invasive. In Khar VDC, 10.2% dicots (17 of 166 species) and 7.1% monocots (3 of 42 species) are naturalized. Among them, eight species — all dicot —are considered invasive in Nepal.

Table 3: **Summary of the number of plant species reported from KSL-Nepal**

	Pteridophyte	Gymnosperm	Dicot	Monocot	Total
Number of species reported by previous studies in KSL-Nepal	14	14	698	209	935
Number of species reported from Khar VDC in present report	41	2	166	42	251
Total number of species in KSL-Nepal	54	14	779	226	1073
Number of naturalized species in KSL-Nepal*	0	0	43 (5.5%)	3 (1.3%)	46 (4.3%)
Number of IAPS in KSL-Nepal	0	0	15		15

*Values inside parentheses are the percentage of total species naturalized in the region.

4.2 Diversity of Invasive Alien Plant Species

Among the 25 IAPS of Nepal (Annex 1), 15 were found in KSL-Nepal and 8 were found in Khar VDC in Darchula (Table 4). At least 11 of these species were present in all three districts surveyed. *Lantana camara*, one of the world's 100 worst invasive species (Lowe et al. 2000), was present in all three districts, but it has not yet reached Khar VDC. Among three districts surveyed, it was more common in Baitadi and Bajhang than in Darchula. The worst incidence of *L. camara* was observed at Rayal VDC, Bajhang, where it dominated most of the natural vegetation. This weed can easily colonize degraded/open forests, tree plantations, and shrubland forming impenetrable bush and replacing almost all other herbaceous and shrub species. Management of this weed has remained a challenge in Asia, Africa, and Australia (Bhagwat et al. 2012). Another problematic IAPS in forest, shrubland, and grassland, *Chromolaena odorata*, was not recorded in KSL-Nepal during our survey. This weed is common in central Nepal (Paudel 2015), however, and found at a few locations in western Nepal (Poudel 2016). It is also common in Uttarakhand (Mandal and Joshi 2014), part of KSL-India which lies to the west of KSL-Nepal. Therefore, it is highly likely that *C. odorata* may soon spread into KSL-Nepal either from Nepal or from India (Uttarakhand) unless management efforts are made.

Among the 15 IAPS found in KSL-Nepal, two species — *A. adenophora* and *L. camara*— have already been problematic in forest and shrublands, while in agricultural lands the problematic species were *Ageratum houstonianum*, *Erigeron karvinskianus*, and *Oxalis latifolia*. Species like *Ageratum conyzoides*, *Bidens pilosa*, and *Galinsoga quadriradiata* were also frequently found in agroecosystems; however, locals often have not considered them problematic due to their forage value. *Parthenium hysterophorus*, a rapidly spreading noxious weed of the tropical and subtropical world (Adkins and Shabbir 2014), including Nepal (Shrestha et al. 2015), was found only at a few locations as satellite populations, indicating early stage invasion in KSL-Nepal. Wetland-specific IAPS such as *Ipomoea carnea* ssp. *fistulosa* and *Pistia stratiotes* were primarily introduced to the region for erosion control (a bioengineering approach to control roadside erosion) and as ornamental plants, respectively.

Table 4: **Invasive alien plant species (IAPS) found in KSL-Nepal**

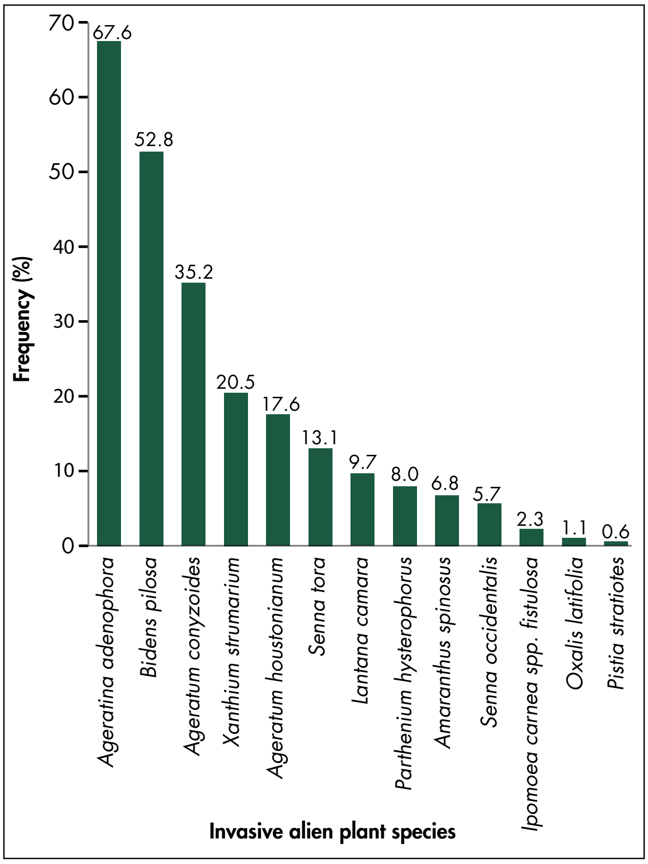
SN	Name of IAPS	Common name	Local name	Occurrence in KSL-Nepal		
				Baitadi	Bajhang	Darchula
1	*Ageratina adenophora*[#]	Crofton weed	Kalo Banmara, Gane jhar⊗	√	√	√
2	*Ageratum conyzoides*[#]	Billy goat	Raunne/Gandhe	√	√	√
3	*Ageratum houstonianum*[#]	Blue billy goatweed	Nilo gandhe, Gane jhar⊗	√	√	√
4	*Amaranthus spinosus*[#]	Spiny pigweed	Kande lude	√	√	√
5	*Bidens pilosa*[#]	Black jack	Kalo kuro	√	√	√
6	*Erigeron karvinskianus*[#]	Karwinsky's fleabane	Phule Jhar⊗	√	√	√
7	*Galinsoga quadriradiata*[#]	Shaggy soldier	Jhuse Chitlange			√
8	*Ipomoea carnea* ssp. *fistulosa*	Bush morning-glory	Besaram	√		√
9	*Lantana camara*[*]	Lantana	Kirne kanda, malaria jhar⊗	√	√	√
10	*Oxalis latifolia*	Purple wood sorel	Chari amilo jhar		√	
11	*Parthenium hysterophorus*	Parthenium	Pati jhar	√	√	√
12	*Pistia stratiotes*	Water lettuce	Kumbhika		√	
13	*Senna occidentalis*	Coffee senna	Panwar	√	√	√
14	*Senna tora*	Sickle pod senna	Tapre	√	√	√
15	*Xanthium strumarium*[#]	Rough cocklebur	Bhede kuro	√	√	√

* Among the world's 100 worst invasive alien species (Lowe et al. 2000)
[#] IAPS present in Khar
⊗ Vernacular names in KSL-Nepal

Ageratina adenophora was the most frequent species among the IAPS found in KSL-Nepal (Figure 3). In an assessment conducted more than a decade ago, this species ranked first among the IAPS in Nepal (Tiwari et al. 2005). Low frequency of species like *Lantana camara* and *Parthenium hysterophorus* in KSL-Nepal indicates the early stages of colonization and spread because they already occur more frequently in other parts of Nepal (Paudel 2015). Unless control measures are initiated soon, these species are likely to spread rapidly in KSL-Nepal.

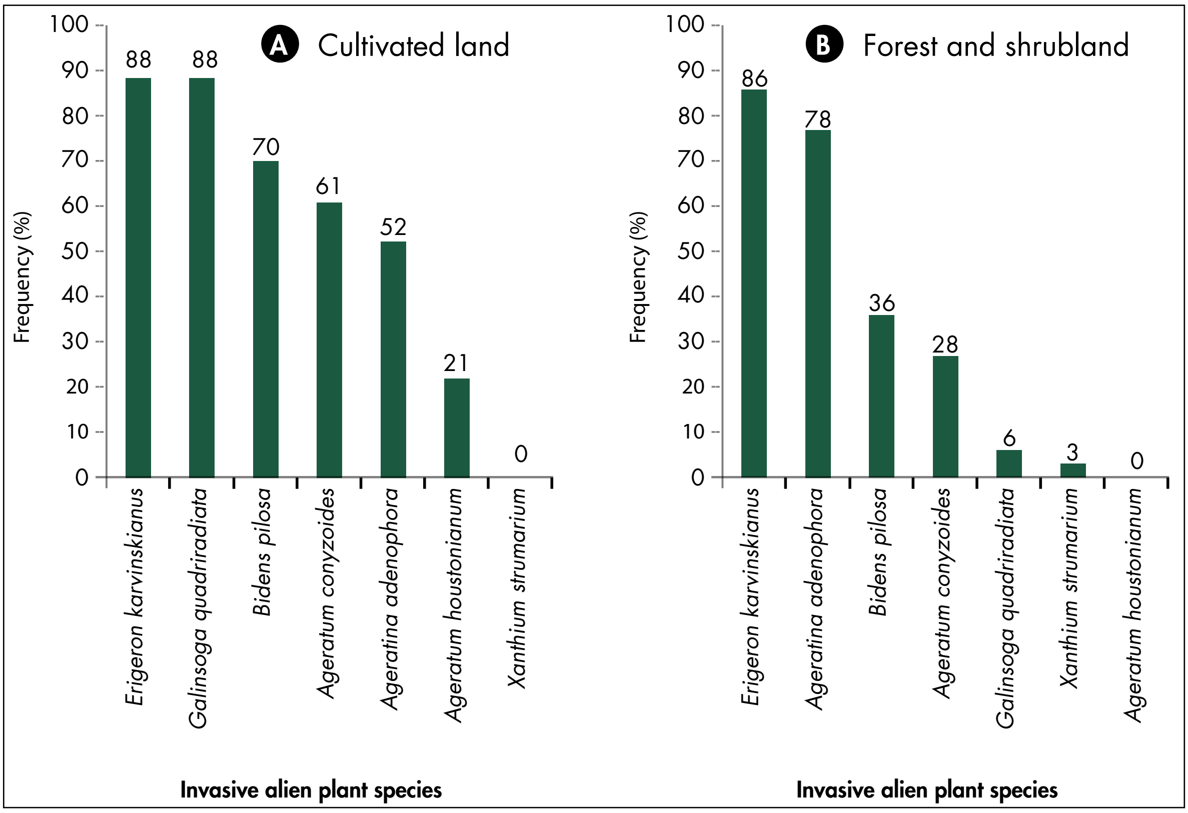
In Khar VDC, Darchula, *Erigeron karvinskianus* was the most frequent IAPS both in cultivated and natural areas (forest + shrubland) (Figure 4). Six IAPS were found in cultivated land and six in natural areas, but in the former, five of the six species had frequency >50% while in the latter, only two species had frequency >50%. *Ageratum houstonianum*, which was present in one-fifth of the sampled plots of cultivated land, could be the next problematic weed in the agroecosystem. This weed was not considered serious in an assessment conducted over a decade ago (Tiwari et al. 2005), but a recent survey in western Nepal (Poudel 2016) and our field observations during this assessment in Nepal and India have revealed the weed is a serious problem with negative impacts on crop production and livestock health.

Figure 3: **Frequency of invasive alien plant species in KSL-Nepal based on distribution survey**



The 176 locations surveyed were distributed in Baitadi, Bajhang, and Darchula. Frequency of two species, *Erigeron karvinskianus* and *Galinsoga quadriradiata*, was not calculated due to incomplete data.

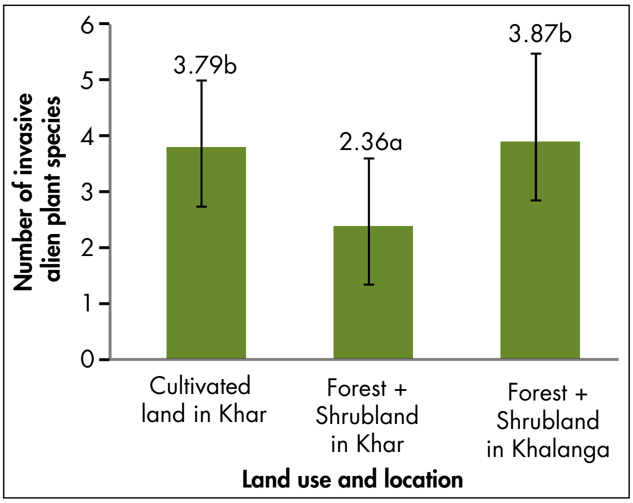
Figure 4: **Frequency of invasive alien plant species in vegetation sample plots at Khar VDC**



Note: *Amaranthus spinosus* was recorded outside the sample plot and thus not included in the frequency calculation.

Species richness of IAPS (measured as the number of IAPS in each vegetation sample plot of 10 m × 10 m) was higher in cultivated than in natural areas (forest + shrubland) in Khar VDC. The IAPS richness was relatively high in shrubland, but in intact forest stands only a few IAPS were present or were absent altogether. The natural vegetation at Khalanga (Api Municipality), a reference site near an urban area, had higher IAPS richness than the similar vegetation in Khar VDC (Figure 5). This could reflect high propagule pressure of the IAPS in Khalanga, which is also a major border entry point in northwestern Nepal from India.

Figure 5: **Mean number of invasive alien plant species per sampling plot (10 m × 10 m)**



Mean values with the the same letter are not significantly different (one way ANOVA followed by Tukey's B test of homogeneity). The dataset had equal variance (Levene test, $p = 0.064$).

4.3 Distribution and Dispersal of IAPS

4.3.1 Distribution of individual IAPS

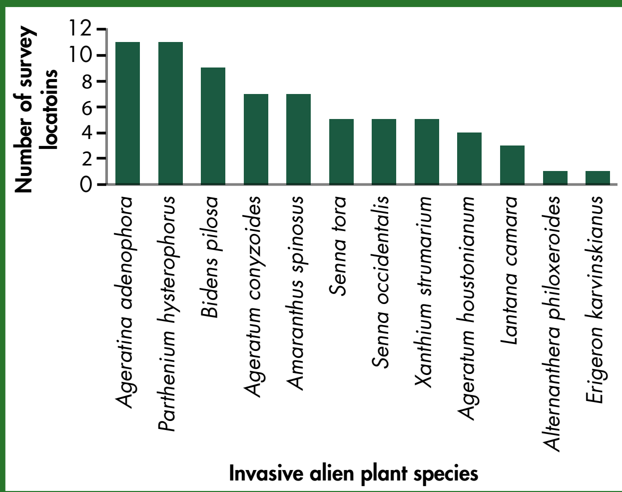
Ageratina adenophora and *Bidens pilosa*, the most frequently occurring IAPS in KSL-Nepal, were distributed almost uniformly across the study area (Figure 6; Annex 7d). *Ageratum conyzoides* was less frequent in Bajhang than in Baitadi and Darchula (Annex 7a) while *A. houstonianum* was frequent near the Nepal-India border (Annex 7b). *Amaranthus spinosus* occuured in all three districts at low frequency but was not found in Chamelia Valley, Darchula (Annex 7c). Nearly uniform distribution of *Erigeron karvinskianus* was also observed in all three districts (Annex 7e). Distribution of *Lantana camara* was concentrated at three sites—one at each district (Annex 7f).

Parthenium hysterophorus was frequently found near the international border in Dharchula, India, but at only a few survey locations in Nepal (Annex 7g). *Senna occidentalis* and *S. tora* were less common in Baitadi than in Bajhang and Darchula (Annex 7h-i). *Xanthium strumarium* was more common in Darchula than in Baitadi and Bajhang (Annex 7j). *Ipomoea carnea* ssp. *fistulosa* occurred in Baitadi and Darchula while *Oxalis latifolia* was found in Darchula and Bajhang (Annex 7 k). *Pistia stratiotes* was observed at a single location in Bajhang.

Box 1: **Invasive alien plant species in Dharchula, India (part of KSL-India)**

A section of road running south to north parallel to the Nepal-India border in Dharchula, India, between Ghatibagar (south) and Tawaghat (north) was examined for the presence of IAPS every 5 km. Altogether 12 IAPS were recorded with an average of 5.3 (± 1.6) species at each location. This average was higher than that in KSL-Nepal (3.15 ± 1.72) as well as in Khalanga (3.87) and Khar VDC (2.36 in natural vegetation and 3.79 in cultivated lands). Among the IAPS found in Dharchula, *Ageratina adenophora* and *Parthenium hysterophorus* were the most frequent followed by *Bidens pilosa*, *Ageratum conyzoides*, and others (Figure 1). The wetland-specific IAPS *Alternanthera philoxeroides*, which was not observed in KSL-Nepal, was also spotted at one location. *P. hysterophorus* was quite dominant along road verges and in settlement areas whereas *Ageratum houstonianum* was problematic in agroecosystems.

Number of survey locations (N = 13) in which a particular invasive alien plant was present

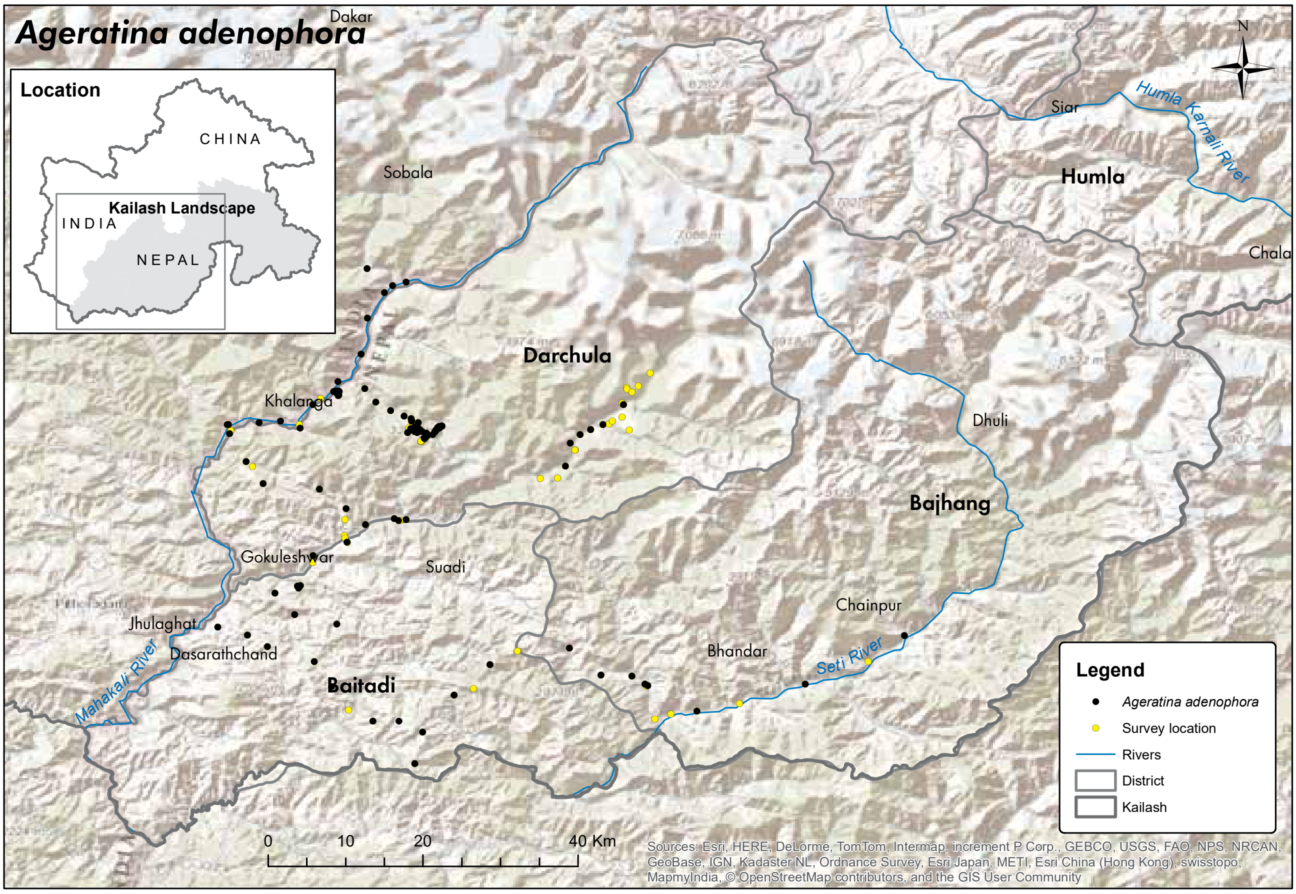


A) *Parthenium hysterophorus* along road verges and B) *Ageratum houstonianum* in agroecosystems

4.3.2 Highest elevation of occurrence

Most of the IAPS and the other naturalized plant species of Nepal are native to the tropical and subtropical Americas (Bhattarai et al. 2012). Due to climatic suitability, a high number of IAPS in hot, southern lowland Nepal is expected. This prediction is supported by a recent roadside survey of the IAPS in western Nepal where Tarai districts had a higher number of IAPS than districts in the midhills (Poudel 2016). It appears that from the southern lowland, the IAPS are spreading northward and upward through natural (e.g., river valleys with warm climate) as well as human-made corridors (e.g., road networks). These species can continue to move up to the elevation beyond which plant growth is climatically constrained. The highest elevations of occurrence of species like *A. adenophora* (2,313 masl), *Ageratum conyzoides* (2,085 masl), *A. houstonianum* (1,936 masl), and *Bidens pilosa* (2,150 masl) in Khar

Figure 6: **Distribution of *Ageratina adenophora* in KSL-Nepal**



and Khalanga are similar as elsewhere in Nepal (Table 5). But the highest elevations of occurrence of *Lantana camara* and *Parthenium hysterophorus* were more than 700 m lower than in the other regions of Nepal. Therefore, a wide elevation band of this region is still climatically suitable for growth of these two weeds. Small, isolated populations of these two weeds that are currently present at lower elevations in the region can serve as sources of propagules for further spread into upper elevations. Control of these satellite populations (such as *P. hysterophorus* at Jhulaghat and Tripura Sundari temple area of Baitadi, Khalanga and Gokuleshwor of Darchula, and Baghthala of Bajhang districts) should be a priority for managing IAPS in the KSL-Nepal.

Table 5: **Highest elevation of occurrenceof the invasive alien plant species (IAPS) in the present study area (Khar VDC and Khalanga, Darchula District) obtained from vegetation sampling**

SN	Name of IAPS	Highest elevation of occurrence (masl)		
		Present study area	Western Nepal	Central Nepal
1	*Ageratina adenophora*	2,312	2,193	2,570
2	*Ageratum conyzoides*	2,085	1,816	1,990
3	*Ageratum houstonianum*	1,936	1,743	NA
4	*Amarathus spinosus**	1,879	1,635	1,750
5	*Bidens pilosa*	2,150	2,193	2,320
6	*Erigeron karvinskianus*	2,306	NA	NA
7	*Galinsoga quadriradiata*	2,306	NA	NA
8	*Lantana camara*	1,219	1,942	1,725
9	*Parthenium hysterophorus*	861	1,743	1,545
10	*Senna tora*	861	1,066	1,127
11	*Xanthium strumarium*	1,474	1,831	1,810

Similar data from western Nepal (Poudel 2016) and central Nepal (Paudel 2015) were obtained from roadside surveys
* Recorded outside the sample plots. NA: Data not available

The most important natural constraint for the upward movement of the IAPS growing in the surrounding lowland is low temperature in the high mountain environment. However, this constraining factor is likely to be weaker as temperature increases and climatic belts shift upwards under future climate projections in mountain regions (Pauchard et al. 2009; Xu et al. 2009; Lamsal et al. 2018). Therefore, unless management is initiated to control many of the IAPS currently problematic in the surrounding lowlands and low elevation regions of KSL-Nepal, these IAPS may become problematic in high elevation regions too.

4.3.3 Dispersal of IAPS

It appears that urbanizing are a like district headquarters located at or near international border points are a source of propagules for further dispersal. In Khalanga, the headquarters of Darchula District at the border point with India, the number of IAPS decreased as we moved southward in Nepal along the highway.

Field observations across the border clearly indicated that many of the IAPS are spreading into Nepal from India through Khalanga bazaar. For example, *Parthenium hysterophorus* and *Lantana camara* were widespread in the Indian city of Dharchula (Khalanga bazaar's counterpart) but were at the early stage of colonization and spread in Darchula. These two weeds were present mainly around Khalanga bazaar (except for a small population of *P. hysterophorus* at Gokuleshwor). Though vehicles cannot cross the border, hundreds of people from Khalanga and the surrounding area visit Indian markets at Dharchula and thousands of people in Darchula depend on agriculture and other trade commodities transported through this border point from India. Dispersal of *P. hysterophorus* primarily depends on human movement and transport of agriculture products while *L. camara* is also dispersed by birds. In Baitadi District too, these two problematic weeds were present near the Nepal-India border. *P. hysterophorus* was observed at Jhulaghat (a border entry point) and Tripura Sundari temple area (about a one-hour walk from Jhulaghat and mostly visited by Indian pilgrims) of district headquarters (Dasharath Chand Municipality), and it remained absent upto Dadeldhura towards Nepal (except for a single individual spotted at Patan, which was destroyed during the June 2015 survey). In contrast, a relatively low number of IAPS were found in Chainpur, the Bajhang district headquarter, which is located away from international border.

Dispersal of species like *P. hysterophorus* is clearly linked with vehicle movement and transport of commercial goods. For example, the weed was absent between Satbanjh and Dhaap (near Khalanga bazaar) along the Mahakali Highway except for a small population at Gokuleshwor, which was found at a site where vehicles stop and commercial goods are unloaded (Photo 3A). According to locals, *P. hysterophorus* was first noticed there in 2013.

Livestock is also an important means of IAPS dispersal. Most of the respondents in Khar VDC believed *Xanthium strumarium* arrived there along with sheep and goats. The stiff hairs on its surface can firmly attach to the fur of goats and sheep, allowing it to hitchhike long distances. In addition to unintentional introduction, two wetland-specific IAPS — *Ipomoea carnea* ssp. *fistulosa* and *Pistia stratiotes*— are being introduced by local communities to control roadside erosion and as ornamental plants, respectively (Photo 5). *I. carnea* ssp. *fistulosa* can be

Photo 5: Intentional introduction of invasive alien plant species in Baitadi and Bajhang Districts.

A) *Ipomoea carnea* ssp. *fistulosa* planted to control roadside erosion along Satbanjh-Gokuleshwor road, in Baitadi District and B) *Pistia stratiotes* grown as a garden plant at Jhota along Khodpe-Chainpur road, Bajhang District.

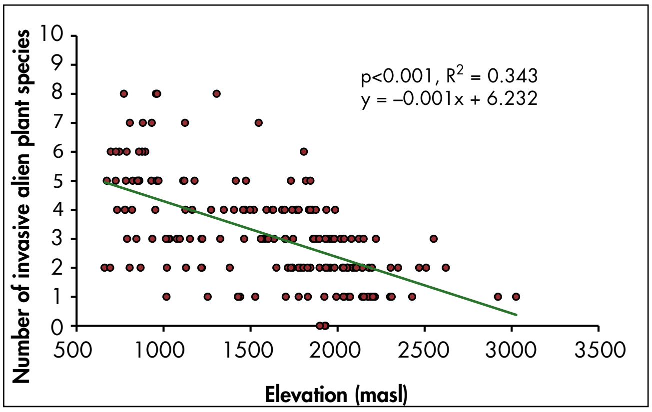
propagated easily through stem cuttings, and their survival is high when planted at moist landslide areas. It has also been observed along roadsides in other hilly districts in western Nepal (Poudel 2016). This species is primarily problematic in the wetlands of the Tarai and Dun valleys where it interferes with water flow along seasonal springs and displaces other aquatic plants (Tiwari et al. 2005). Currently, this plant is not problematic in KSL-Nepal, but it may spread into wetlands and along water courses in the future. *P. stratiotes* was found only at a single location (Jhota bazaar along the road to Chainpur from Khodpe) in Bajhang District where it was grown in a pot. The owner informed us that the plant was transported from the Tarai region to grow in the garden. Accidental escape of this plant from the garden to natural wetlands cannot be ruled out. These two examples showed that people are introducing IAPS intentionally due to lack of awareness.

4.4 IAPS along Elevation Gradient

4.4.1 IAPS richness

IAPS ranged from 0 to 8 with an average of 3.15 (±1.72). It declined consistently along with elevation gradients between 500 and 3,000 masl in KSL-Nepal (Figure 7). From interpolated data, Bhattarai et al. (2014) reported a unimodal relation of naturalized (including invasive and noninvasive aliens) plant species richness with elevation peaking at around 1,000 masl. From a roadside survey of IAPS Paudel (2015) and Poudel (2016) also reported a unimodal relation of IAPS richness with elevation in central Nepal (between 100 and 2,600 masl), and western Nepal (between 200 and 2,500 masl). But IAPS richness peaked at around 500 masl in central Nepal and at around 1,000 masl in western Nepal. Another study in central Nepal (focused on Chitwan-Annapurna Landscape) covering representative natural vegetations (forest, shrubland, and grassland) and all physiographic regions (Tarai to high Himal) had uniform decline in IAPS richness with elevation (Siwakoti et al. 2016). Lack of a consistent pattern among studies could be due to different methods of data collection and the geographic scale covered. However, all these studies have clearly indicated that IAPS richness is generally greater in lowlands than in mountains.

Figure 7: **Variation in the number of invasive alien plant species (IAPS richness) with elevation**



Test statistics and fitted lines are based on linear regression

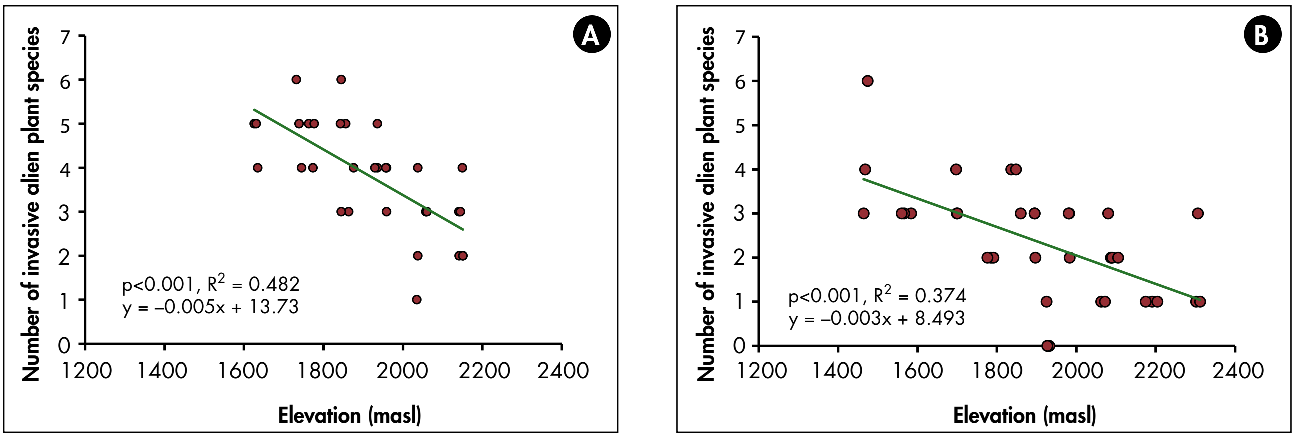
Continuous decline in IAPS richness with elevation was also observed in both cultivated and natural areas in Khar VDC and the Khalanga area (Figure 8). In Khar VDC, the decline of species richness was stronger in cultivated than in natural areas. Species like *Xanthium strumarium*, *Ageratum conyzoides*, and *Amaranthus spinosus* were at an early stage of colonization in Khar VDC. As they become more abundant, the relationship between IAPS species richness and elevation may change.

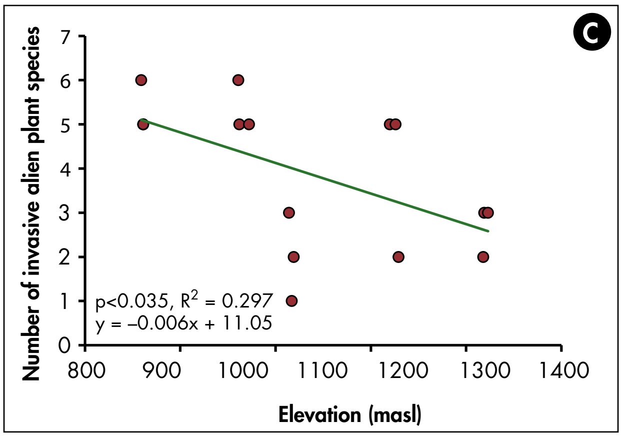
4.4.2 IAPS cover

Within the elevation range of distribution, the abundance of IAPS was not uniform. For example, in Khar VDC, *A. adenophora* (one of Khar's two most problematic weeds) was present upto 2,300 masl in natural vegetation but its cover did not exceed 10% in plots located above 1,900 masl (Figure 9A), whereas the cover frequently exceeded 80% at lower elevation (Figure 9B). The weed first appeared at lower elevations of Khar VDC about 15 years ago and is now dispersing upwards along natural corridors of spring bank. It is very likely that this weed will colonize grazing shrublands at higher elevations (above 1,900 masl) within a short period (less than a decade) and increase its abundance, thereby displacing other plant species. Due to regular weeding, the cover of *A. adenophora* did not change significantly with elevation in cultivated areas.

Cover of another problematic weed in Khar VDC, *Erigeron karvinskianus*, did not vary consistently with elevation (Figure 9 C and D). Micro habitat variation could be more important than elevation within the distribution range of this weed.

Figure 8: **Variation in the number of invasive alien plant species in vegetation sample plot (10 m × 10 m) with elevation**





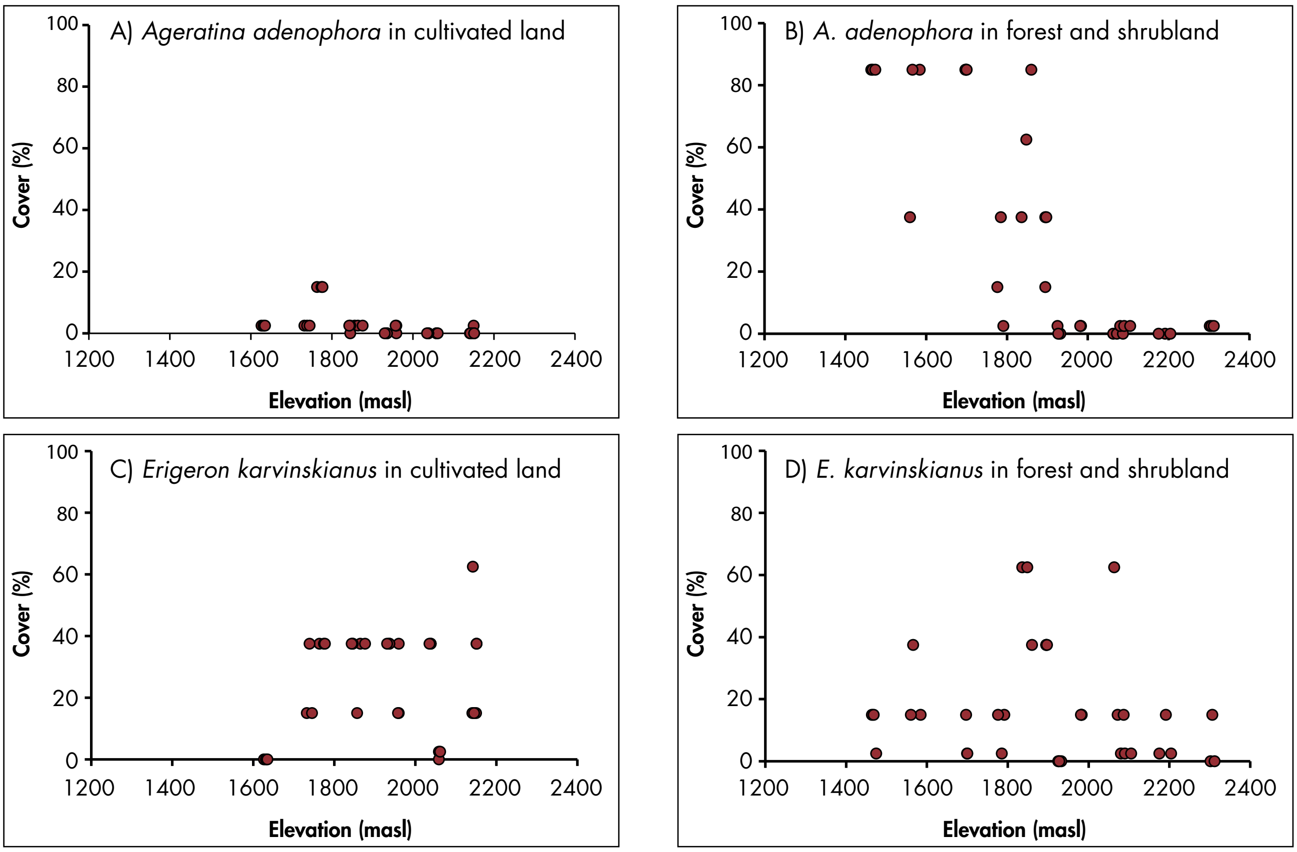
A) Cultivated land in Khar

B) Forest and shrubland in Khar

C) Forest and shrubland in Khalanga

The test statistics and fitted lines are based on linear regression.

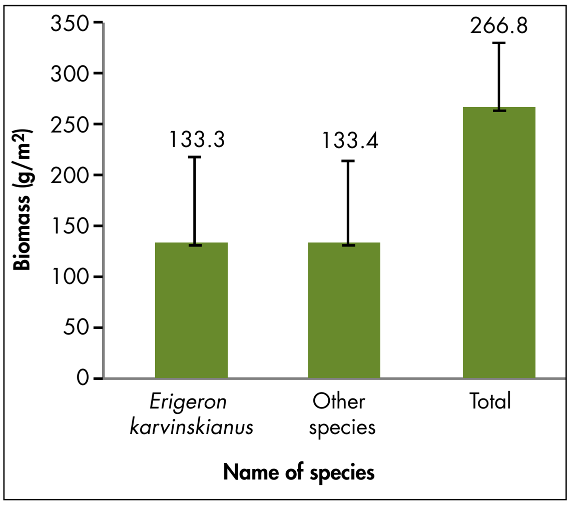
Figure 9: **Variation in cover of two major invasive alien plants species (*Ageratina adenophora* and *Erigeron karvinskianus*) in Khar VDC**



4.5 Impact of *Erigeron karvinskianus* on Forage Production

Erigeron karvinskianus was equally prevalent in natural-and in agro-ecosystems. The focus group discussion and household survey revealed that it has greatly reduced the abundance of native and high value forage species. We estimated aboveground biomass of privately managed grasslands and found that 50% of the total biomass was contributed by *E. karvinskianus*, which has low fodder value (Figure 10). Local people often harvest all above ground biomass due to difficulties in separating *E. karvinskianus* from the rest of the species. Therefore, the data showed that net forage biomass of the grasslands has been reduced by up to 50% due to growth of *E. karvinskianus*.

Figure 10: **Above ground biomass of *Erigeron karvinskianus* and other species in privately owned grasslands in Khar VDC**



Error bar indicates one standard deviation.

4.6 Community Perceptions and Impacts

4.6.1 KSL-Nepal

Communities were aware of the arrival of new IAPS and faced serious problems due to them. They considered *A. houstonianum* (Gokuleshwor, Darchula), *Lantana camara* (Rayal VDC, Bajhang), and *A. adenophora* and *E. karvinskianus* (Khar VDC, Darchula; see section 4.6.2 for detailed description) as the problematic IAPS. For example, all the local people who interacted at Gokuleshwor VDC mentioned that *A. houstonianum* has been creating serious problems in their livelihood because: 1) the weed is not preferred by livestock as forage; 2) but, when freed in the evening, hungry oxen rampantly graze on *A. houstonianum* growing on the bund of cropland, which results in diarrhoea, other stomach disorders, and occasionally cause animal death; and 3) the biomass of *A. houstonianum* takes a long time to decompose when mixed into soil.

Lantana camara was found most problematic at Rayal and Jhota in Bajhang District where the weed was dominant in natural areas (degraded forest and shrubland) and common in agroecosystems (Photo 6A). *L. camara* has reduced forage production in rangelands, prevented regeneration of tree species in degraded forests, and competitively displaced a native shrub species, *Woodfordia fruticosa*. Due to the high abundance of *L. camara* and scarcity of other suitable species, locals have been using the stem of this weed as fuelwood. According to a local elderly person, the weed was dispersed to the region about 50 years ago by birds. Initially, farmers grew the weed as a hedge plant in farmland. In Darchula, *L. camara* was found only at Khalanga (Photo 6B) where locals first noticed it 8–10 years ago. The weed was already common in residential areas, road verges, and surrounding natural areas. A local woman at Kimtadi (near Khalanga bazaar) stated that forage production of rangeland has been substantially

Photo 6: *Lantana camara.* A) *L. camara* as dominant species in shrublands and degraded forests near Jhota, Bajhang, and B) ripe fruits of *L. camara* at Khalanga, Darchula, being collected by children to eat.

reduced due to *L. camara*. However, FECOFUN district committee members as well as many local people were not aware of its current and potential impacts on biodiversity and ecosystem services. It appears that *L. camara* is spreading south and north from the Khalanga area. If immediate action is not taken to conrol this weed, further spread to other parts of Darchula is highly likely. Fortunately, it has not reached Khar VDC.

P. hysterophorus was found only at a few locations in KSL-Nepal (for example, at Jhulaghat and Tripura Sundari temple area of Baitadi District, at Baghthala and Rayal area of Bajhang, and at Gokuleshwor and between Dhaap and Khalanga bazaar of Darchula) (Photo 7). Since this weed was dispersed into these locations in less than five years, according to locals in those communities, it was sparsely distributed with a small population size. In all these locations, the local people did not know its name, neither were they aware of any negative impacts. As the weed was at an early stage of dispersal and colonization, its impact on forage production, native biodiversity, and livestock and human health have not been apparent.

Photo 7: *Parthenium hysterophorus*. A) Near the gate of Tripura Sundari Temple at Dasharath Chand Municipality, Baitadi, and B) at Gokuleshwor, Darchula.

4.6.2 Khar VDC

Local people in Khar VDC were well aware of the arrival of new problematic IAPS (or weeds) in their surroundings but ignorant of their ultimate origin. During the focus group discussion and household survey in Khar VDC, participants and respondents almost unanimously reported that *Erigeron karvinskianus* (locally called 'Phule jhar') in agroecosystems (cultivated lands and private grasslands) and *Ageratina adenophora* (locally called 'Gane jhar') in natural areas including grazing lands were the most troublesome weeds to have arrived within the last two decades. Another commonly found IAPS in cultivated land was *Galinsoga quadriradiata* but locals didnot consider it problematic because of its fodder value. During October, they harvest *G. quadriradiata* and other weed biomass from cultivated lands, sun-dry it, and store it for use as dry fodder during winter. Due to good palatability, local people also did not consider *Bidens pilosa* and *Ageratum conyzoides* troublesome. The remaining three IAPS found in Khar VDC (*Ageratum houstonianum, Xanthium strumarium,* and *Amaranthus spinosus*) were less common and not considered problematic.

According to local people, *E. karvinskianus* was first noticed in agroecosystems about 18–20 years ago while *A. adenophora* was noticed along spring sides about 12–15 years ago. Similarly, *Xanthium strumarium* was first observed in grasslands about 8–10 years ago and *A. houstonianum* in cultivated land about 4–6 years ago. Locals have noticed that *X. strumarium* was dispersed to Khar VDC by goat and sheep when these livestock were seasonally moved between Khar VDC and warm regions to the southern part of Nepal. The local people reported that the IAPS have negatively affected community livelihood as well as ecosystem services. The negative impact of IAPS was greater in grasslands (commonly used for harvesting forage), shrublands (commonly used for livestock grazing), and spring side and cultivated lands than in intact forests. Wheat fields were the most seriously affected by *Erigeron karvinskianus*, and crop (mainly maize and wheat) yield reduction up to 50% was reported by some respondents. People must spend an additional three to five days to remove the IAPS every cropping season. According to the local respondents, *E. karvinskianus* has displaced high value native forage species such as *Pennisetum orientale* (Photo 8A), *P. flaccidum* (locally called 'Biraichhe'), and *Chrysopogon gryllus* (locally called 'Salam'). Similarly, *A.*

adenophora was growing in the habitat of *Girardinia diversifolia* (locally called 'allo' or 'Bhote sisnu'), an important fibre plant for local livelihood, and has competitively displaced the latter (Photo 8B). Community perception and field observations, therefore, revealed that the IAPS have reduced agriculture production (the combined effect of reduced crop yield and increased labour for weeding) as well as provisioning ecosystem services of natural vegetation (for example, reduced supply of forage and non-timber forest products).

Photo 8: A) *Pennisetum orientale* and B) *Ageratina adenophora* (seen on left side and on ground) growing in the habitat of *Girardinia diversifolia* (flowering twig growing horizontally).

4.7 Community Responses to IAPS

4.7.1 KSL-Nepal

Communities have been responding to the rapid spread of highly problematic IAPS by maximizing biomass utilization and physical removal. *Ageratina adenophora* has been commonly used as animal bedding and subsequently for composting. *A. adenophora, Ageratum conyzoides*, and *A. houstonianum* also have some medicinal uses and local people use them for healing wounds and cuts. *L. camara* has been used as fuelwood (for example, in Rayal, Bajhang District) where other suitable fuelwood species are scarce.

Currently the number of highly problematic IAPS is relatively low in KSL-Nepal as compared to lowland Nepal. However, the local communities perceive that the number as well as abundance/distribution of IAPS have been increasing. In a council meeting of the Api-Nampa Conservation Area (ANCA), council members stated that *A. adenophora* has been a serious problem in forest and grazing lands but they did not know how to address it. The key informant interviews, focus group discussions, and household survey all revealed that communities and local stakeholders have not been made aware of the negative impacts of the IAPS and thus no management effort has been initiated by any governmental or non-governmental organizations in KSL-Nepal. Most of the people in affected areas showed willingness to adopt control measures if suitable management tools are made available to them. Additionally, if communities are made aware of the potential threat of currently less common IAPS, they may participate actively in their management. For example, after we noticed a small population of *Parthenium hysterophorus* at Gokuleshwor (Darchula), we informed a few local people about the long-term consequences of widespread occurrence of the weed and distributed educational materials about it. Within a week, they had cleared the population of *P. hysterophorus* (Photo 9).

4.7.2 Khar VDC

Communities were trying to manage new problems of IAPS in their own traditional ways. Uprooting, drying, and subsequent burning were the most commonly practised management strategies for *A. adenophora*. In this way, locals were able to protect private grasslands from being colonized by *A. adenophora* (Photo 10A). In the field, we also observed that *A. adenophora* was highly abundant in public grazing lands but almost absent in the adjacent private grasslands. Locals have also been using biomass of *A. adenophora* for animal bedding materials (Photo 10B) and subsequently for composting with animal dung. Locals were almost helpless to manage the

Photo 9: Community participation is crucial for management of invasive alien plant species. A) A small population of *Parthenium hysterophorus* at Gokuleshwor, Darchula, as observed on 25 September 2015. B) *P. hysterophorus* cleared from the site as observed on 3 October 2015.

Photo 10: Local efforts to manage *Ageratina adenophora* in Khar VDC. A) Local people uprooting *A. adenophora* during harvest forage from private land, and B) collecting biomass of *A. adenophora* for use as animal bedding.

problem created by *E. karvinskianus* in agroecosystems. They were harvesting this weed along with other forage species because it was not possible to separate it from other species.

A remarkable response of the local community to the increasing problems of IAPS was the restoration of native species with high forage value. Along the spring banks of Ghatte Khola (a small spring running below Dallekh), a stand covered almost completely by *A. adenophora* was cleared by uprooting and subsequent burning. This was followed by plantation of *Pennisetum orientale*, *P. flaccidum*, and *Chrysopogon gryllus*, which were believed to be displaced after colonization by *Ageratina adenophora* (Photo 11A and 11B). These native species were also planted on the bunds of terraced cultivated lands covered by *E. karvinskianus* (Photo 11C).

Photo 11: Local community's initiative to restore native species. A) *Pennisetum orientale, P. flaccidum,* and *Chrysopogon gryllus* were planted after *Ageratina adenophora* was cleared along the spring side. Note that *Erigeron karvinskianus* still covered the most of the ground surface. B) Successful establishment of *C. gryllus* at the restoration site along the spring side and C) plantation of native forage species on the bund of terraced agriculture land covered by *E. karvinskianus.*

5. Recommendations for IAPS Management

5.1 Eradication of Small Satellite Populations

A satellite population (*sensu* Radosevich et al. 2007) of IAPS is established when their propagules are dispersed long distance as contaminants of commercial goods, when hitchhiked on vehicles, or when introduced intentionally by humans. IAPS that can form several satellite populations at the early stage of invasion get established at the landscape level faster. Since satellite populations expand faster than source populations (Radosevich et al. 2003), the occurrence of satellite populations in climatically suitable regions is of great concern from a management point of view. When the population is small, eradication should be possible for a new satellite population but this would not be practical for an established large population (Wittenberg and Cock 2001). The rapidly spreading IAPS *Parthenium hysterophorus* has formed a few satellite populations in KSL-Nepal, including Gokuleshwor, Darchula; the Baghthala-Rayal area of Bajhang; and Patan, Baitadi. Given the small population size and area infested, eradicating *P. hysterophorus* from these locations is practically possible. Physical (e.g., uprooting before flowering) and chemical (e.g., applying weedicide) methods can be used to destroy these small satellite populations. Since this weed can also reappear from perennial soil seed banks as well as subsequent dispersal of seeds, communities need to be vigilant to spot and destroy this weed species. Similarly, satellite populations of *A. spinosus* and *X. strumarium* were present in Khar VDC and their eradication has been also recommended.

5.2 Containment

Where eradication is not possible, the next option is containment, which involves preventing further spread of the IAPS from the established population. Containment requires control measures — physical, cultural, and chemical methods —as well as continuous vigilance in the potential dispersal sites. Use of control measures helps to reduce propagule pressure to the surrounding areas. *L. camara* and *P. hysterophorus* are present in Khalanga and Dasharath Chand municipality in Baitadi and the presence of these populations also continue on the Indian side. Up to the time of this assessment, these species were not widespread in these districts of Nepal. Therefore, if we can prevent further spread of these species into new locations, local biodiversity and ecosystems can be protected from their negative impacts. Through public education, communities can be encouraged to physically remove these weeds growing along road verges and in agroecosystems. Careful use of their biomass for composting (biomass of *P. hysterophorus* collected before the plant flowers) and fuelwood (stem of *L. camara*) can reduce propagule pressure to the surrounding areas.

In Khar VDC, *A. adenophora* was already widespread with high cover at lower elevation zones (below 1,900 masl); at higher elevation zones, the weed was present but less frequently. *A. adenophora* can be completely removed by uprooting the plant from these higher elevation zones through community participation. If some incentive is available, student volunteers can also be mobilized for this purpose. This approach will be effective only when propagule pressure (seed in this case) of the plant from lower elevation zones is reduced by physical (uprooting and biomass utilization) and cultural (competitive displacement by native species) control measures. The same strategy can be applied for *A. houstonianum* in Khar VDC where the weed is already established at lower elevation zones and virtually absent at higher elevation zones.

5.3 Biomass Utilization

Biomass utilization of IAPS can be an effective control tool with the double benefit of: 1) reducing propagule pressure (i.e., seed production) of IAPS, and 2) meeting communities' biomass demand (for organic manure, fuelwood, etc.). However, communities should not be encouraged to spread IAPS to new habitats as a 'sustainable' use of the biomass. Biomass utilization needs to be implemented as a component of an integrated approach of IAPS management. The local communities of KSL-Nepal have already started using IAPS to meet their biomass demand.

To have a significant impact on the abundance of IAPS, the amount of biomass used should be maximized. This can be accomplished by transfering simple, community-friendly technologies to the communities. For example, use of *A. adenophora* biomass in Khar VDC can be maximized through an improved composting technique. In current practice, animal dung and biomass are mixed and piled up above the ground (Photo 12), which leaves more than half of the biomass undecomposed even after about six months when farmers need manure during the early cropping season. If the use of compost pits is introduced, the composting process can be speeded up and more organic manure can be produced. The addition of *A. adenophora* biomass will further increase the amount of organic manure produced which may ultimately increase the productivity of farmlands. This can be an important benefit as many local communities are facing declining productivity of farmlands.

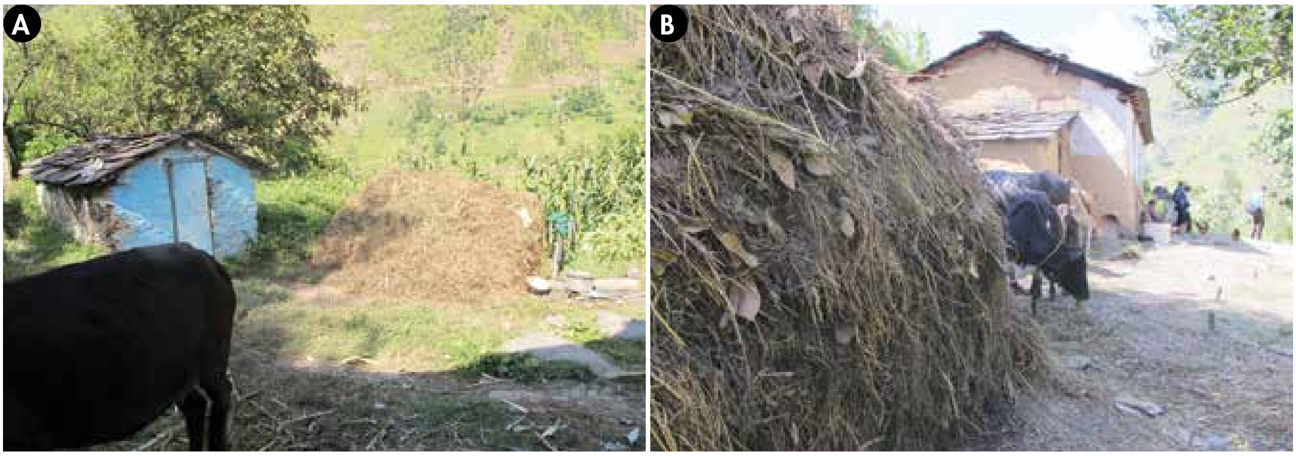


Photo 12: Current composting practice in Khar VDC. Plant biomass is mixed with dung and piled above the ground, as seen (A) on upper right and (B) at left.

L. camara is being used as fuelwood where the scarcity of fuelwood is very high. Use of biomass for energy can be further increased by introducing the technique of bio-briquette preparation in KSL-Nepal. The prospect of commercial production of bio-briquette is high in Rayal and Jhota area of Bajhang District. Intact forest is apparently absent in these areas and shrublands are dominated by *L. camara*. Due to the woody biomass of this weed, energy output of the bio-briquette may be higher and production costs may be lower as compared to other IAPS being used for this purpose elsewhere in Nepal (MoFSC 2009). Marketing of the bio-briquette would not be a major concern as the area is directly connected by road to district headquarters and other urban areas where bio-briquette demand is likely to be high. Production of bio-briquette from *L. camara* can also be an effective way to contain the weed in Khalanga and in Dasharath Chand municipality of Baitadi.

Invasive plant biomass has been also used to produce biochar elsewhere in the world (Liao et al. 2013; Vithanage et al. 2014). Use of biochar in agroecosystems has multiple environmental benefits such as carbon sequestration, nutrient retention, and soil quality improvement (for example, water percolation) (Ippolito et al. 2012). Biochar use is particularly beneficial in nutrient-poor and degraded soil. Biochar production also has some prospects in KSL-Nepal. However, this technology should be carefully assessed before its introduction because the use of biochar may not always improve farm production and its production is not always economically beneficial (Spokas et al. 2012).

5.4 Reduction of Anthropogenic Disturbances

Anthropogenic disturbances leading to loss of vegetation in terrestrial ecosystems and eutrophication in freshwater aquatic ecosystems provides suitable habitats for the establishment of IAPS. In forest ecosystems, canopy opening (due to deforestation) and removal of ground vegetation of native species increase the abundance of IAPS. In rangeland, overgrazing reduces the competitive ability of palatable native species thereby creating favourable conditions for colonization by nonpalatable IAPS. In Rayal and Jhota area of Bajhang, intact forest is not visible from the highway. Forest clearing in the past has facilitated colonization and rapid spread of *L. camara* in the area. According to local people in Rayal, the native tree species *Acacia catechu* (khayer) can regenerate successfully from within the patches of *L. camara*. If regeneration of this and other similar tree species is allowed by reducing anthropogenic pressure (such as felling of tree saplings or grazing), the abundance of *L. camara* will be reduced. Reduction in abundance of another IAPS, *Chromolaena odorata*, has been observed due to an increase in tree canopy in forest areas of Dun Valley (inner Tarai) and the midhills of central Nepal (personal observation, Shrestha BB). In these areas, community forestry programs have substantially increased the tree canopy in previously degraded forests.

In Khar VDC, the practice of removing vegetation cover from the terraced surface of farmland has exposed soil surface which is very suitable for the establishment of *Erigeron karvinskianus*, the most problematic IAPS in the agroecosystem of Khar VDC. Numerous anemophilous small seeds of this plant can easily stick on the exposed soil surface and rapidly form a dense mat, preventing the establishment of other species that have fodder value. Therefore, we recommend minimizing the practice of slicing bunds and terraces when preparing farmland for cropping.

5.5 Restoration of Native Species

Restoration of native species, preferably those with some useful properties (such as fodder, timber, or medicines), is an important cultural method of IAPS management. Restoration needs to be coupled with reducing anthropogenic pressures as mentioned in Section 5.4. Species should be selected based on the natural history of the region and habitat suitability of the species, and in consultation with local communities. In natural vegetation, plantation of seedlings or direct seeding, depending on the species, can be done. Where IAPS cover is dense, partial removal of their biomass is needed to encourage the growth of seedlings of there stored species. Complete removal of IAPS by uprooting before the native species is established may be counterproductive in some instances. For example, many landslide areas are covered by IAPS such as *A. adenophora* and *L. camara*. These species protect soil and help restore landslide-damaged areas. Uprooting these species may initiate new cycles of soil erosion and landslide. Proactive management across the HKH is needed to control IAPS in forest ecosystems. Proactive management must promote the natural regeneration of native species.

In Khar VDC, the habitat of the locally important NTFP species *Girardinia diversifolia* (allo) is being colonized by *Ageratina adenophora*. Field observations and community consultations revealed that this colonization could be an important cause for decline in the abundance of *G. diversifolia*. Removal of *A. adenophora* biomass for composting (as mentioned in Section 5.3) can be coupled with restoration of *G. diversifolia*. This will help to sustain *G. diversifolia*-based local enterprises and thus improve local livelihood.

Restoration of native forage species (e.g. *Pennisetum orientale, P. flaccidum,* and *Chrysopogon gryllus*) at sites colonized by *Ageratina adenophora* and *E. karvinskianus* has already been initiated on a small scale by local communities in Khar VDC (see Section 4.7.2). We need to popularize this approach and encourage local communities to adopt it in their private lands. We also recommend restoration of native species in natural vegetation for piloting particularly in shrublands where abundance of IAPS such as *A. adenophora* is high.

5.6 Community Education and Participation

For IAPS management, public participation is essential from an ethical point of view, to meet legal compliance, and for the effectiveness of management approaches (Boudjelas 2009). Before active public participation is anticipated, communities need to be educated on the current and potential impacts of IAPS not only on their farmland and livelihood but also to natural ecosystems and native biodiversity. In fact, implementation of all the above recommended management strategies largely depends on public participation. Educational materials describing IAPS found in their locality (with colour photographs), IAPS that might spread to their locality, impacts on the economy and environment, and control measures that can be implemented at the local level can be published and distributed. Coordination of community education programs by local stakeholders such as district government offices (such as District Forest Office and District Agriculture Development Office), various organizational networks of Api-Nampa Conservation Area, and community-based organizations (such as district and local community forest user groups) will be crucial for improving community awareness of IAPS problems and management. In the meantime, communities can internalize the gravity of the IAPS problem rapidly by sharing experiences and problems. For example, in Khar VDC, where the spread of *A. houstonianum* is in the early stages, many people were unconcerned about the weed, while the farmers of Gokuleshwor, where the weed is widespread, considered it a serious problem in their agroecosystems. Having representative farmers of Khar VDC visit Gokuleshwor to learn about this problem can encourage them to adopt IAPS management methods. Similarly, representative farmers and

Photo 13: Awareness raising programme and training for biomass utilisation of invasive plants

local stakeholders in Khar VDC and Khalanga can visit Rayal and Jhota in Bajhang to learn about the problem of *L. camara*.

Local communities can also help locate IAPS satellite populations and invasion fronts. Once these sites are precisely located, future monitoring of the upward and northward spread of the IAPS would be possible.

5.7 Transboundary Vigilance

Because vehicles and people move freely through the country's porous border, particularly with India, IAPS management in Nepal is a transboundary issue. Almost all IAPS found in Nepal entered via India by natural dispersal or human activities. There is a clear indication that *L. camara* and *P. hysterophorus* are spreading into KSL-Nepal (Darchula and Baitadi) from India (Uttarakhand). Due to a high abundance of these two IAPS in India near the Nepal-India border, the success of any management effort in KSL-Nepal depends on the propagule pressure (which largely depends on weed abundance under current regulation at border points) from Indian populations of the weed. *Alternanthera philoxeroides* was found in Dharchula, India, near the Nepal-India border but not in KSL-Nepal. It is highly likely that the weed may enter KSL-Nepal through Khalanga, Darchula District. Similarly, *Chromolaena odorata* has not been reported west of the Karnali River in Nepal (Poudel 2016) but is already widespread in Uttarakhand, India (Mandal and Joshi 2014). It is highly likely that *C. odorata* may also enter KSL-Nepal through the western border with India. Therefore, continued vigilance by local stakeholders and communities across international borders is vital to control the spread of IAPS in the landscape. Government bodies and conservation partners should establish a mechanism through which border region communities will be able to inform authorities about the arrival of new IAPS so that they can be eradicated.

5.8 Research and Monitoring

Across the HKH, the management of invasive species is not given due attention. With the impacts of climate change, IAPS could present a more alarming challenge in the future. Preliminary research and inventories must be conducted on a regular basis in vertical and horizontal monitoring plots that are annually observed in the field to identify existing invasive species and potential threats. This will provide information on the identity, location, and abundance of invasive plants within the given area, which is critical to making well-informed management decisions.

6. Way Forward

In addition to the management activities, the following research activities can be undertaken to improve their effectiveness:

1. **Piloting restoration of native species:** Using participatory approaches, experimental plots can be established at different climatic regions and at sites invaded by highly problematic IAPS (such as *A. adenophora* and *L. camara*) to assess the effectiveness of restoring native species after removal of the IAPS.

2. **Risk assessment of KSL for IAPS:** Due to similar climate and topography, the risk of IAPS in KSL-India is likely to be similar to KSL-Nepal. The problems associated with the IAPS are already serious in the surrounding lowlands of these regions, and the present assessment in KSL-Nepal has clearly indicated that many of these problematic species are moving upward and northward. Climate change and infrastructure development are likely to speed this process in the future. Therefore, risk assessment (using ecological niche modeling) of the entire KSL region, including KSL-China, for biological invasion is urgently needed to evaluate invasibility of the region and implement preventive measures to protect it from potentially noxious IAPS (Lamsal et al. 2018).

Policy makers and practitioners have not yet paid close attention to IAPS. A cost-benefit analysis or valuation study that shows how ecosystem services are affected by IAPS could generate greater attention that may also be transboundary in nature. From a policy point of view, a regional strategy is essential to cope with the problems of IAPS. Biological invasion is a transboundary conservation issue and its negative impacts can be reduced only through the coordinated efforts of the countries in the region. These countries need to work under a common regional strategy to protect the Himalayan ecosystems from the risk of biological invasion.

References

Adkins, S.W. & Shabbir, A. (2014). Biology, ecology and management of the invasive parthenium weed (P*arthenium hysterophorus* L.). *Pest Management Science* 70:1023-1029.

Bellard, C., Thuiller, W., Leroy, B., Genovesi, P., Bakkenes, M. & Courchamp, F. (2013). Will climate change promote future invasions? *Global Change Biology* 19:3740-3748.

Bhagwat, S.A., Breman, E., Thekaekara, T., Thornton, T.F. & Willis, K.J. (2012). A battle lost? Report on two centuries of invasion and management of *Lantana camara* L. in Australia, India and South Africa. *PLoS ONE* 7(3): e32407. Doi:10.1371/journal.pone.0032407.

Bhattarai, K.R., Maren, I.E. & Subedi, S.C. (2014). Biodiversity and Invasibility: Distribution patterns of invasive plant species in the Himalayas, Nepal. *Journal of Mountain Science* 11: 688-696.

Bhattarai, P. (2011). *Vascular Plant Species Richness along Elevation Gradient of the Karnali River Valley, Humla District, Nepal Himalaya* [MSc thesis]. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Boudjelas, S. (2009). Public participation in invasive species management. In: MN Clout and PA Williams (eds.) *Invasive Species Management: A Handbook of Principles and Techniques*. Oxford University Press, UK. Pp 93-107.

Budha, P.B. (2015). Current state of knowledge on invasive and alien fauna of Nepal. *Journal of Institute of Science and Technology* 20: 68-81.

Chaudhary, R.P., Shrestha, K.K., Jha, P.K. & Bhatta, K.P. (2010). *Kailash Sacred Landscape Conservation Initiative Feasibility Assessment Report — Nepal*. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Christen, D. & Matlack, G. (2006). The role of roadsides in plant invasion: a demographic approach. *Conservation Biology* 20: 385-391.

Daubenmire, R.F. (1959). Canopy-coverage method of vegetation analysis. *Northwest Science* 33:43-64.

Dukes, J.S. & Mooney, H.A. (1999). Does global change increase the success of biological invaders? *Trends in Ecology and Evolution* (TREE) 14:135-139.

Elliott, A. (2012). *Botanical Exploration of Darchula District, Far Western Nepal — 2012*. A field report submitted to Scottish Rock Garden Club, Scotland, UK.

Ghimire, S.K. (2015). *Setting up of Long-term Observation Sites for Monitoring the Effects of Climate Change on Biodiversity in Api-Nampa Conservation Area, Nepal*. Interim Report submitted to Research Center for Applied Science and Technology (RECAST), Tribhuvan University, Kathmandu.

Grosholz, E.D. (2005). Recent biological invasion may hasten invasional meltdown by accelerating historical introductions. *PNAS* 102:1088-1091.

Hellmann, J.J., Byers, J.E., Bierwagen, B.G. & Dukes, J.S. (2008). Five potential consequences of climate change for invasive species. *Conservation Biology* 22: 534-543.

ICIMOD (2013). *Feasibility Study Report and Participatory Natural Resources Management Plan: Khar Village Development Committee in Api-Nampa Conservation Area, Darchula Nepal* [Unpublished report]. International Centrefor Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Invasive Species Specialist Group of the International Union for Conservation of Nature (n.d.). Retreived from http://www.issg.org/is_what_are_they.htm.

Ippolito, J.A., Laird, D.A. & Busscher, W.J. (2012). Environmental benefits of biochar. *Journal of Environmental Quality* 41: 967-972.

Johnston, F.M. & Pickering, C.M. (2001). Alien plants in the Australian Alps. *Mountain Research and Development* 21: 284-291.

Johnston, F.M. & Johnston, S.W. (2004). Impacts of road disturbance on soil properties and on exotic plant occurrence in subalpine area of the Australian Alps. *Arctic, Antarctic and Alpine Research* 36:201-207.

Kohli, R.K., Dogra, K.S., Batish, D.R. & Singh, H.P. (2004). Impacts of invasive plants on the structure and composition of natural vegetation of Northwestern Indian Himalayas. *Weed Technology* 18:1296-1300.

Kosaka, Y., Saikia, B., Mingki, T., Tag, H., Riba, T. & Ando, K. (2010). Roadside distribution patterns of invasive alien plants along an altitudinal gradient in Arunachal Himalaya, India. *Mountain Research and Development* 30: 252-258.

Lamsal, P., Kumar, L., Aryal, A., Atreya, K. (2018) Invasive alien plant species dynamics in the Himalayan region under climate change. *Retrieved from* https://doi.org/10.1007/s13280-018-1017-z

Liao, R., Gao, B. & Fang, J. (2013). Invasive plants as feedstock for biochar and bioenergy production. *Bioresource Technolgogy* 140: 439-442.

Lowe, S., Browne, M., Boudjelas, S. & DePoorter, M. (2000). *100 of the World's Worst Invasive Alien Species: A Selection from the Global Invasive Species Database*. The Invasive Species Specialist Group (ISSG), a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), New Zealand.

MAD. (2014). *Agriculture Development Strategy 2014*. Ministry of Agricultural Development (MAD), Singhdurbar, Kathmandu.

Mandal, G. & Joshi,S.P., (2014). Invasion establishment and habitat suitability of *Chromolaena odorata* (L.) King and Robinson over time and space in the western Himalayan forests of India. *Journal of Asia-Pacific Biodiversity* 7:391-400.

McDougall, K.L., Alexander, J.M., Haider, S., Pauchard, A., Walsh, N.G. & Kueffer, C. (2011a). Alien flora of mountains: global comparisons for the development of local preventive measures against plant invasions. *Diversity and Distribution* 17:103-111.

McDougall, K.L., Khuroo, A.A., Loope, L.L., Parks, C.G., Pauchard, A., Reshi, Z.A., Rushworth, I. & Kueffer, C. (2011b). Plant Invasions in Mountains: Global lessons for better management. *Mountain Research and Development* 31:380-387.

MoFSC (Ministry of Forest and Soil Conservation). (2002). *Nepal Biodiversity Strategy*. Ministry of Forest and Soil Conservation, Kathmandu, Nepal.

MoFSC (2009). *Nepal Fourth National Report to the Convention on Biological Diversity*. Ministry of Forest and Soil Conservation, Kathmandu, Nepal.

MoFSC (2014). *Nepal National Biodiversity Strategy and Action Plan 2014–2020*. Ministry of Forest and Soil Conservation, Kathmandu, Nepal.

MoFSC & RECAST (Kathmandu and Research Centre for Applied Science and Technology). (2013). *Traditional Knowledge System on Biodiversity Resources Documentation Initiated in the Village Development Committee, Humla, Karnali Zone*. Environment Division, Ministry of Forest and Soil Conservation, Kathmandu and Research Centrefor Applied Science and Technology, Tribhuvan University, Kathmandu.

MoFSC, RECAST & ICIMOD. (2015a). *Community Biodiversity Register 2015 —Khar VDC Darchula*. [Unpublished report]. Ministry of Forest and Soil Conservation, Kathmandu; Research Centre for Applied Science and Technology, Tribhuvan University, Kathmandu; International Centre for Integrated Mountain Development, Kathmandu.

MoFSC, RECAST & ICIMOD. (2015b). *Socioeconomic Baseline Study of Pilot Sites of Kailash Sacred Landscape Conservation and Development Initiative Project – Nepal* [Unpublished report]. Ministry of Forest and Soil Conservation, Kathmandu; Research Centre for Applied Science and Technology, Tribhuvan University, Kathmandu; International Centre for Integrated Mountain Development, Kathmandu.

Murphy S.T., Subedi, N., Gnawali, S.R., Lamichhane, B.R., Upadhyay, G.P., Kock,R. & Amin, R. (2013). Invasive mikania in Chitwan National Park, Nepal: the threat to the greater one-horned rhinoceros Rhinoceros unicornis and factors driving the invasion. *Oryx* 47:361-368.

Pauchard, A., Kueffer, C., Dietz, H., Daehler, C.C., Alexander, J., Edwards, P.J., Arévalo, J.R., Cavieres, L.A., Guisan, A., Haider, S., Jakobs, G., McDougall, K., Millar, C.I., Naylor, B.J., Parks, C.G., Rew,L.J. & Seipel, T. (2009). Ain't no mountain high enough: plant invasions reaching new elevations. *Frontiers in Ecology and Environment* 7: 479-486.

Paudel, N. (2015). *Diversity and Distribution of Invasive Alien Plant Species along Road Network in Central Nepal* [MSc thesis]. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Pejchar, L.,& Mooney, H.A. (2009). Invasive species, ecosystem services and human well-being. *Trends in Ecology and Evolution* 24:497-504.

Pimentel, D., Zuniga, R. & Morrison, D. (2005). Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52:273-288.

Poudel, S. (2016). *Diversity and Distribution of Invasive Alien Plant Species along Road Network in Western Nepal* [MSc thesis]. Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Pyšek, P., Richardson, D.M., Rejmánek, M., Webster, G.L., Williamson,M. & Kirschner, J. (2004). Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. *Taxon* 53:131-143.

Radosevich, S.R., Holt, J.S. & Ghersa, C.M. (2007). *Ecology of Weeds and Invasive Plants*. 3rd edition. New Jersey, USA: John Wiley and Sons Inc.

Radosevich, S.R., Stubbs, M.M. & Ghersa, C.M. (2003). Plant invasion — process and pattern. *Weed Science* 51:254-259.

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

Relva, M.A., Nunez, M.A. & Simberloff, D. (2010). Introduced deer reduce native plant cover and facilitate invasion of non native tree species: evidence for invasional meltdown. *Biological Invasion* 12:303-311.

Ricciardi, A., Neves, R.J. & Rasmussen, J.B. (1998). Impending extinction of North American fresh water mussels (Unionoida) following the zebra mussel (*Dreissena polymorpha*) invasion. *Journal of Animal Ecology* 67:613-619.

Sax, D.F. & Gaines, S.D. (2008). Species invasion and extinction: the future of native biodiversity on islands. *PNAS* 105:11490-11497.

Shrestha, B.B. (2014). *Distribution of Invasive Alien Weed Parthenium hysterophorus and its Biological Control Agent in Nepal*. Unpublished research report submitted to International Foundation for Science, Sweden.

Shrestha, B.B. (2016.) Invasive alien plant species in Nepal. In: PK Jha, M Siwakoti and SR Rajbhandary (eds.) *Frontiers of Botany.* Central Department of Botany, Tribhuvan University, Kathmandu. Pp. 269-284.

Shrestha, B.B., Budha, P.B., Wong, L. J. & Pagad, S. (2018). *Global Register of Introduced and Invasive Species-Nepal*. Version 2.2. Invasive Species Specialist Group ISSG. Checklist Dataset https://doi.org/10.15468/4r0kkr accessed via GBIF.org on 2018-02-20.

Shrestha, B.B., Shabbir, A. & Adkins, SW. (2015). Parthenium hysterophorus in Nepal: a review of its weed status and possibilities for management. *Weed Research* 55:132-144.

Simberloff, D. & Holle, B.V. (1999). Positive interactions of non-indigenous species: 'invasional meltdown'? *Biological Invasion* 1:21-32.

Singh, V., Singh, H., Sharma, G.P. & Raghubanshi, A.S. (2011). Eco-physiological performance of two invasive weed congeners (*Ageratum conyzoides* L. and *Ageratum houstonianum* Mill.) in the Indo-Gangetic plains of India. *Environmental Monitoring and Assessment* 178: 415-422.

Siwakoti, M., Shrestha, B.B., Devkota, A., Shrestha, U.B., Thapa-Parajuli, R.B. & Sharma, K.P. (2016). *Assessment of the Effect of Climate Change on Distribution of Invasive Alien Plant Species in Nepal*. Unpublished report submitted to Nepal Academy of Science and Technology (NAST), Lalitpur, Nepal.

Siwakoti, M., Siwakoty, M., Chaudhary, R.N. & Thapa-Magar, H. (2014). *Status of Invasive Alien Plant Species in the Protected Areas of Nepal with Special Reference to the Parsa Wildlife Reserve, Central Nepal*. Unpublished report submitted to University Grants Commission, Sanothimi, Bhaktapur, Nepal.

Siwakoti, M. (2007). Mikania weed: a challenge for conservationists. *Our Nature* 5:70-74.

Spokas, K.A., Cantrell, K.B., Novak, J.M., Archer, D.W., Ippolito, J.A., Collins, H.P., Boateng, A.A., Lima, I.M., Lamb, M.C., McAloon, A.J., Lentz,R.D. & Nichols, K.A. (2012). Biochar: a synthesis of its agronomic impact beyond carbon sequestration. *Journal of Environmental Quality* 41: 973-989.

Sukhorukov, A.P. (2014). *Erigeron annuus* (Compositae) — a new record for the flora of Nepal. *Newsletter of Himalayan Botany* No. 49 (December): 15-16.

Tian, M., Zhang, F., Wang, L., Liang, X., Jiang, D., Shao, X. & Ren, Y. (2011). The ecological suitability of an exotic invasive plant (*Galinsoga quadriradiata*) in Qinling Mountain. *Journal of Shaanxi Normal University* (Natural Science Edition) 39: 71-75 [Article in Chinese with English abstract].

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

Tiwari, S., Adhikari, B., Siwakoti, M. & Subedi, K. (2005). *An Inventory and Assessment of Invasive Alien Plant Species of Nepal*. IUCN Nepal, Kathmandu.

Vilà, M., Basnou, C., Pyšek, P., Josefsson, M., Genovesi, P., Gollasch, S., Nentwig, W., Olenin, S., Roques, A., Roy, D., Hulme, P.E. & DAISIE partners. (2010). How well do we understand the impacts of alien species on ecosystem services? A pan-European, cross-taxa assessment. *Frontiers in Ecology and Environment* 8:135-144.

Vithanage, M., Rajapaksha, A.U., Tang, X., Thiele-Bruhn, S., Kim, K.H., Lee, S-E. & Ok, Y.S. (2014). Sorption and transport of sulfamethazine in agricultural soils amended with invasive-plant-derived biochar. *Journal of Environmental Management* 141: 95-103.

Vitousek, P.M., D'Antonio, C.M., Loope, L.L., Rejmanek, M. & Westbrooks, R. (1997). Introduced species: a significant component of human caused global change. *New Zealand Journal of Ecology* 21: 1-16.

von der Lippe, M. & Kowarik, I. (2007). Long-distance dispersal of plants by vehicles as a driver of plant invasions. *Conservation Biology* 21:986-996.

Wabuyele, E., Lusweti, A., Bisikwa, J., Kyenune, G., Clark, K., Lotter, W.D., McConnachie A.J. & Wondi, M. (2014). Roadside survey of invasive weed *Parthenium hysterophorus* (Asteraceae) in East Africa. *Journal of East African Natural History* 103:49-57.

Williams, F., Eschen, R., Harris, A., Djeddour, D., Pratt, C., Shaw, R.S., Varia, S., Lamontagne-Godwin, J., Thomas, S.E. & Murphy, S.T. (2010). *The Economic Cost of Invasive Non-Native Species on Great Britain*. CABI, UK.

Wittenberg, R. & Cock, M.J.W. (Eds.). (2001). *Invasive Alien Species: A Toolkit of Best Prevention and Management Practices*. CAB International, Wallingford, Oxon, UK.

Xu, H., Ding, H., Li, M., Qiang, S., Guo, J., Han, Z., Huang, Z., Sun, H., He, S., Wu, H. & Wan, F. (2006). The distribution and economic losses of alien species invasion to China. *Biological Invasion* 8:1495-1500.

Xu, J., Grumbine, R.E., Shrestha, A., Eriksson, M., Yang, X.,Wang, Y. & Wilkes, A. (2009). The melting Himalayas: Cascading effects of climate change on water, biodiversity, and livelihoods. *Conservation Biology* 23:520-530

Annexes

Annex 1: **Updated list of invasive alien plant species of Nepal (Shrestha 2016)**

Name of IAPS	Common name	Local name	Family	Native range†
Ageratina adenophora (Spreng.) R.M. King & H. Rob.	Crofton weed	Kalo Banmara	Asteraceae	Mexico
Chromolaena odorata (Spreng.) King and Robinson*	Siam weed	Seto Banmara	Asteraceae	Mexico, Central & South America
Eichhornia crassipes (Mart.) Solms.*	Water hyacinth	Jalkumbhi	Pontederiaceae	South America
Ipomoea carnea ssp. *fistulosa* (Mart. ex Choisy) D.F. Austin	Bush morning-glory	Besaram	Convolvulaceae	Mexico, Central & South America
Lantana camara L.*	Lantana	Kirne kanda	Verbenaceae	Central & South America
Mikania micrantha Kunth*	Mile-a-minute weed	Lahare banmara	Asteraceae	Central & South America
Alternanthera philoxeroides (Mart.) Griseb.	Alligator weed	Jalajambhu	Amaranthaceae	South America
Myriophyllum aquaticum (Vell.) Verdc.	Parrot's feather	NA	Holaragaceae	South America
Parthenium hysterophorus L.	Parthenium	Pati jhar	Asteraceae	Southern USA to South America
Ageratum conyzoides L.	Billy goat	Raunne/Gandhe	Asteraceae	Central & South America
Amaranthus spinosus L.	Spiny pigweed	Kande lude	Amaranthaceae	Tropical America
Argemone mexicana L.	Mexican poppy	Thakal	Papaveraceae	Tropical America
Senna tora (L.) Roxb.	Sickle pod senna	Tapre	Leguminosae	South America
Hyptis suaveolens (L.) Poit.	Bushmint	Tulsi Jhar	Lamiaceae	Tropical America
Leersia hexandra Swartz.	Southern Cut grass	Karaute ghans	Poaceae	Tropical America
Pistia stratiotes L.	Water lettuce	Kumbhika	Araceae	South America
Bidens pilosa L.	Black jack/Hairy beggar-tick	Kalo kuro	Asteraceae	Tropical America
Senna occidentalis (L.) Link.	Coffee senna	Panwar	Leguminosae	Tropical America
Mimosa pudica L.	Sensitive plant	Lajjawati	Leguminosae	Mexico to South America
Oxalis latifolia Kunth.	Purple wood sorel	Chari amilo	Oxalidaceae	Central & South America
Xanthium strumarium L.	Rough cockle-bur	Bhede kuro	Asteraceae	America
Ageratum houstonianum Mill.†	Blue billy goatweed	Nilo gandhe	Asteraceae	Mexico & Central America
Erigeron karvinskianus DC†	Karwinsky's fleabane	Phule Jhar	Asteraceae	Mexico & Central America
Galinsoga quadriradiata Ruiz & Pav.†	Shaggy soldier	Jhuse Chitlange	Asteraceae	Mexico
Spermacoce alata Aubl.†	Broadleaf button weed	Alu pate jhar	Rubiaceae	West Indies &Tropical America

Annex 2: **List of household heads interviewed in Khar VDC, Darchula**

Name	Ward No.	Locality	Gender	Age	Education	Profession
Kamal Singh Dhami	3		M	60	No	Agriculture
Dama Dhami	3		F	18	8	Agriculture
Bikram Singh Thagunna	3	Chauru	M	51	3	Agriculture/Business
Nara Thagunna	8	Sundamunda	F	35	No	Agriculture
Surendra Singh Thagunna	8	Sundamunda	M	20	10	Agriculture
Ranjeet Thagunna	8	Sundamunda	M	61	9	Agriculture/Business
Gagan Singh Thagunna	8	Sundamunda	M	52	No	Agriculture
Dhauli Thagunna	8	Sundamunda	F	30	No	Agriculture
Ramji Thagunna	8	Sundamunda	M	49	7	Agriculture
Sukari Devi Thagunna	8	Sundamunda	F	40	No	Agriculture
Ambika Thagunna	9	Siarad	F	16	10	Student
Dhan Bahadur Thagunna	7	Sundamunda	M	40	8	Agriculture/Business
Mangal Singh Thagunna	7	Sundamunda	M	40	No	Agriculture
Hari Lal Thagunna	7	Tallo Sundamunda	M	38	8	Agriculture
Ganga Tamata	7	Sundamunda	F	30	No	Agriculture
Gaur Singh Thagunna	7	Sundamunda	M	51	6	Agriculture
Bir Bahadur Thagunna	6	Jamir	M	NA	B.Ed.	Teaching
Dropati Dhami	3	Kakhadi	F	24	No	Agriculture
Kalawati Thagunna	6	Jyamire	F	33	B.Ed.	Teaching
Gamthir Ram Tamata	7	Sundamunda	M	70	No	Lodhar (Agricultural equipment)
Hari Bhan Singh Thagunna	8	Sundamunda	M	40	No	Agriculture
Janak Dhami	9	Parimela	M	16	10	Student
Jagata Devi Thagunna	2	Ghatte Khola	F	62	No	Agriculture
Man Singh Dhami	2	Chaukhutte	M	72	No	Agriculture
Uday Singh Thagunna	6	Pari Khar	M	52	I.Ed.	Teaching/Agriculture/Business
Dal Bahadur Thagunna	6	Khar	M	55	5	Agriculture
Janaki Thagunna	4	Tallogaun	F	20	No	Agriculture
Amar Singh Thagunna	6	Salmat	M	35	2	Agriculture
Dhanmati Thagunna	6	Khar	F	30	No	Agriculture
Nara Bohara	4	Tallo Gaun	F	36	B.Ed.	Teaching
Pman Singh Manyal	3	Chaur	M	42	No	Agriculture
Kausadi Bohara	6	Tilmada Dhar	F	45	No	Agriculture/Business
Gagan Singh Manyal	1	Dallekh	M	52	5	Agriculture/Business
Dilendra Singh Thagunna	6	Khar	M	20	Bachelors	Student
Ujwal Sunera	3	Jhalaun Pani	M	47	No	Agriculture/Business
Chandra Devi Thagunna	2	Chauri Gaun	F	45	8	Agriculture
Padam Singh Thagunna	2	Chauri Gaun	M	56	5	Agriculture
Mahendra Mahara	1	Dallekh	M	49	10	Health sector/Agriculture
Jay lal Singh Daral	1	Dallekh	M	55	5	Agriculture
Kalawati Manyal	2	Chauri Gaun	F	24	SLC	Agriculture
Gaur Singh Thagunna	8	Sundamunda	M	49	10	Agriculture
Harak Singh manyal	2	Chauri Gaun	M	55	No	Agriculture
Jayanti Manyal	2	Chauri Gaun	F	28	No	Agriculture

Name	Ward No.	Locality	Gender	Age	Education	Profession
Rama Devi Bohara	2	Chauri Gaun	F	50	No	Agriculture
Karbir Bohara	6	Tilmada Dhar	M	60	No	Agriculture
Pana Devi Bohara	4	Mallo Gaun	F	65	No	Agriculture
Gaur Singh Dhami	7	Jukepani	M	68	No	Agriculture
Saguni Thagunna	7	Deularo	F	35	5	Agriculture
Dhawal Singh Thagunna	5	Khar	M	50	I.Ed.	Teaching/Agriculture
Mathura Sonara	3	Chaur	F	40	No	Agriculture
Mana Thagunna	4	Tallo Gaun	F	21	No	Agriculture
Khadak Singh Bohara	6	Pari Khet	M	35	I.Ed	Teaching/Agriculture
Santa Devi Manyal	3	Godhani	F	35	No	Agriculture/Business
Daljit Singh Manyal	3	Dallekh godan	M	65	No	Agriculture
Ganga Devi Manyal	1	Dallekh	F	NA	No	Agriculture
Kalasi Devi Thagunna	8	Sundamunda	F	52	No	Agriculture

Annex 3: **List of pteridophyte taxa recorded from Khar VDC**

Family	Species	Distribution
Aspleniaceae	*Asplenium dalhousieae* ["dalhousiae"] Hook.	Native to N America, Mexico; found Asia in the Himalaya
Blechnaceae	*Woodwardia unigemmata* (Makino) Nakai	S Asia, Philippines, Vietnam
Davalliaceae	*Katoella pulchra* (D.Don) Fraser-Jenk., Kandel & Pariyar	
Dennstaedtiaceae	*Dennstaedtia appendiculata* (Wall. ex Hook.) J.Sm.	Bhutan, N India, Nepal
Dryopteridaceae	*Cyrtomium anomophyllum* (Zenker) Fraser-Jenk.	Bhutan, India, Japan, Nepal, Pakistan
Dryopteridaceae	*Dryopteris carolihopei* Fraser-Jenk.	S Asia, Myanmar
Dryopteridaceae	*Dryopteris nigropaleacea* (Fraser-Jenk.) Fraser-Jenk.	
Dryopteridaceae	*Hypodematium crenatum* (Forssk.) Kuhn & Decken subsp. *loyalii* Fraser-Jenk	Japan, Malaysia, Myanmar, Philippines; Africa, SW and subtropical regions of Asia
Dryopteridaceae	*Polystichum obliquum* (D.Don) T.Moore	
Dryopteridaceae	*Polystichum squarrosum* (D.Don) Fée	S Asia
Equisetaceae	*Equisetum arvense* L. subsp. diffusum (D.Don) Fraser-Jenk.	Native to N America, Eurasia s to Himalaya, China, Korea, Japan
Lycopodiaceae	*Huperzia hamiltonii* (Spreng.) Trevis.	S Asia, N Myanmar
Lycopodiaceae	*Huperzia pulcherrima* (Wall. ex Hook. & Grev.) Pic. Serm.	Africa, Tropical America
Oleandraceae	*Oleandra wallichii* (Hook.) C.Presl	S Asia, Thailand, Vietnam
Ophioglossaceae	*Botrychium lanuginosum* Wall. ex Hook. & Grev.	S Asia, Papua New Guinea, Philippines, Thailand, Vietnam
Ophioglossaceae	*Botrychium ternatum* (Thunb.) Sw.	S and E Asia
Polypoidaceae	*Goniophlebium argutum* (Wall. ex Hook.) Bedd.	
Polypoidaceae	*Lepisorus scolopendrium* (Ching) Mehra & Bir	S Asia
Polypoidaceae	*Loxogramme porcata* M.G.Price	S Asia, Myanmar, N Thailand
Polypoidaceae	*Microsorum membranaceum* (D.Don) Ching	S Asia, Thailand, Vietnam
Polypoidaceae	*Polypodiodes lachnopus* (Wall. ex Hook.) Ching	S Asia
Polypoidaceae	*Pyrrosia flocculosa* (D.Don) Ching	S Asia, Thailand, Vietnam
Polypoidaceae	*Selliguea oxyloba* (Wall. ex Kunze) Fraser-Jenk.	N India, Myanmar, Nepal, Thailand, Vietnam
Pteridaceae	*Adiantum incisum* Forssk. subsp. Incisum	Tropical Africa, also in S and SW Africa, Yemen, India
Pteridaceae	*Adiantum venustum* D.Don	S Asia
Pteridaceae	*Aleuritopteris albomarginata* (C.B.Clarke) Ching	S Asia
Pteridaceae	*Onychium vermae* Fraser-Jenk. & Khullar	
Pteridaceae	*Pteris cretica* L.	Indigenous to Hawaii (US), Africa, Japan, Europe
Pteridaceae	*Pteris cretica* L. subsp. cretica	
Pteridaceae	*Pteris aspericaulis* Wall. ex J.Agardh	S Asia
Pteridaceae	*Pteris subquinata* Wall. ex J.Agardh	S Asia
Pteridaceae	*Pteris terminalis* Wall. ex J.Agardh	S Asia, China, Philippines, Vietnam, Fiji, Hawaii
Pteridaceae	*Pteris wallichiana* J.Agardh	S Asia, Indonesia, Japan, Kashmir, Laos, Malaysia
Selaginellaceae	*Selaginella subdiaphana* (Wall. ex Hook. & Grev.) Spring	
Thelypteridaceae	*Thelypteris cana* (J.Sm.) Ching	S Asia, China
Thelypteridaceae	*Thelypteris penangiana* (Hook.) C.F.Reed	S Asia, China
Woodsiaceae	*Athyrium schimperi* Moug. ex Fée	Madagascar, Ethiopia
Woodsiaceae	*Athyrium schimperi* Moug. ex Fée subsp. biserrulatum (Christ) Fraser-Jenk.	
Woodsiaceae	*Athyrium strigillosum* (T.Moore ex E.J.Lowe) T.Moore ex Salomon	S Asia, Japan, Myanmar
Woodsiaceae	*Diplazium longifolium* T.Moore	
Woodsiaceae	*Diplazium maximum* (D.Don) C.Chr.	Asia, NE Myanmar

Annex 4: **List of dicot taxa recorded from Khar VDC**

Family	Species	Distribution
Acanthaceae	*Barleria cristata* L.	Nepal, E India, Myanmar, SE Asia
Acanthaceae	*Diclipterabupleuroides* Nees	Afghanistan, Himalaya, Thailand, SE Asia, W China
Amaranthaceae	*Achyranthus aspara* L.*	Pantropical
Amaranthaceae	*Amaranthus spinosus* L.* #	Native of tropical America
Amaranthaceae	*Cyathula tomentosa* (Roth) Moq	Himalaya to W China
Anacardiaceae	*Rhus javanica* L.	Himalaya, Sri Lanka, Korea, Japan
Anacardiaceae	*Pistacia chinensis* JL Stewart	Afghanistan, Pakistan, Himalaya
Apiaceae	*Selinum wallichii* Franch.	Himalaya, NE India, China
Araliaceae	*Hedera nepalensis* K. Koch	Afghanistan, Himalaya, NE India, N Myanmar, China
Asteraceae	*Ageratina adenophora* L.* #	Native of Mexico, naturalized in rest of the world
Asteraceae	*Ageratum conyzoides* L.* #	Native of Central and South America
Asteraceae	*Ageratum houstonianum* Mil.* #	Native of Mexico and Central America
Asteraceae	*Anaphalis adnata* Wall. ex DC	Himalaya, Myanmar, China, Philippines
Asteraceae	*Anaphhalis busua* (Buch-Ham ex D Don)DC	Himalaya, NE India, Myanmar
Asteraceae	*Anaphalis triplinervis* DC	Himalaya
Asteraceae	*Aster sikkimensis* DC	Himalaya
Asteraceae	*Bidens bipinnata* L.	Native to S America and/or E Asia, naturalized elsewhere
Asteraceae	*Bidens pilosa* L.* #	Native of tropical America
Asteraceae	*Cirsium falconeri* (Hook.f.) Petr	Afghanistan, Pakistan, Himalaya
Asteraceae	*Erigeron karvinskianus* DC* #	Native of Mexico and Central America
Asteraceae	*Fraxinus floribunda* Wall.	India, Himalaya
Asteraceae	*Galinsoga quadriradiata* Ruiz & Pav.*#	Native of Mexico
Asteraceae	*Inula cappa* (Buch-Ham ex D Don) DC	Himalaya, NE India, China, Java, Thailand
Asteraceae	*Myriactis nepalensis* Less.	Caucasus, Iran, Turkestan, Afghanistan, himalaya, Indonesia
Asteraceae	*Pseudonaphalium affine* (D Don) Anderb	C Asia, Africa, Indonesia, Europe
Asteraceae	*Sigesbekia orientalis* L.	Africa, Himalaya, Malaysia, China, Oceania, Australia, Japan
Asteraceae	*Synotis capa* (Buch-Ham. ex D. Don) C. Jeffrey & Y.L. Chen	
Asteraceae	*Xanthium strumarium* L.* #	Native of Americas
Begoniaceae	*Begonia picta* Sm.	Himalaya, NE India
Berberidaceae	*Berberis asiatica* Roxb. ex DC.	Himalaya, China, NE India
Berberidaceae	*Berberis aristata* DC.	Himalaya
Berberidaceae	*Holboillia latifolia* Wall.	Himalaya, Myanmar, China
Betulaceae	*Alnus nepalensis* D. Don	Himalaya, NE India, Myanmar, SE China, W China
Betulaceae	*Betula alnoides* Buch.-Ham. ex D. Don	Himalaya, NE India, Myanmar, W and C China
Boraginaceae	*Cynoglossum zeylanicum* (Vahl ex Hornem.) Thunb ex Lehm	Afghanistan, Himalaya, Sri Lanka, China, Japan, Malaysia
Boraginaceae	*Hackeliaun cinata* Benth	Himalaya, NE India, China
Brassicaceae	*Cardamin escutata* With.*	Temperate Eurasia, Eastern Canada
Buxaceae	*Sarcococca hookeriana* Bail	Himalaya, NE India, W China
Campanulaceae	*Campanula pallida* Wall.	Afghanistan, Himalaya, India, Myanmar, SE Asia, W China
Campanulaceae	*Cynanthus lobatus* Wall ex Benth	Bhutan, India, China, Myanmar
Caryophyllaceae	*Stellaria vestita* Kurz.	Himalaya, W China, “Taiwan, China”, Malaysia
Convolvulaceae	*Dinetus grandiflorus* (Wall.)Staples	Pakistan, Himalaya, China
Coriariaceae	*Coriaria nepalensis* Wall.	China, Myanmar, Pakistan, Bhutan
Daphniphyllaceae	*Daphniphyllum himalense* Benth	Himalaya, Myanmar, China

Family	Species	Distribution
Dipsacaceae	*Dipsacus intermis* Wallich	Afghanistan, Himalaya
Ericaceae	*Lyonia ovalifolia* (Wall.) Drude	Himalaya, NE India, Myanmar, China, Malay Peninsula
Ericaceae	*Rhododendron arboreum* Sm.	China, NE India, Myanmar
Euphorbiaceae	*Euphorbia hirta* L.*	Pantropical
Euphorbiaceae	*Phyllanthus urinaria* L.*	Pantropical
Fabaceae	*Caesalpinia decapetala* L.	Himalaya, Sri Lanka, SE Asia, China, Japan, Malaysia
Fabaceae	*Crotalaria albida* Heyne ex Roth	Himalaya, India, SE Asia, "Taiwan, China", Malaysia
Fabaceae	*Crotalaria sessiliflora* L.	China, Malaysia, Japan
Fabaceae	*Desmodium concinnum* DC	Himalaya, Myanmar, China
Fabaceae	*Desmodium heterocarpon*	Himalaya, Pacific Islands, Australia
Fabaceae	*Desmodium oblongum* Wall ex Benth	China, India, Myanmar, Thailand
Fabaceae	*Lespedeza gerardiana* Grah.	Himalaya
Fabaceae	*Parochetus communis* Buch-Ham ex D Don	Africa, Himalaya, Malaysia, China
Fabaceae	*Smithia ciliata* Royle	Himalaya, NE India, SE Asia, China, Japan
Fabaceae	*Uraria lagopus* DC.	Himalaya, NE India
Fabaceae	*Vicia angusitifolia* L.	Europe, Africa, Asia, Naturalized in Australia
Fabaceae	*Zornia gibbosa* Span.	Himalaya, China, Australia
Fagaceae	*Quercus leucotrichophora* A. Camus	Himalaya, Myanmar, SE Asia
Fagaceae	*Quercus lanata* Sm.	Himalaya, Myanmar, SE Asia
Fagaceae	*Quercus semecarpifolia* Sm.	Afghanistan, Pakistan, Myanmar, W and S China
Gentianaceae	*Swertia anguistofolia* Buch-Ham ex D Don	Himalaya, N India, Myanmar, S China
Gentianaceae	*Swertia chirayita* (Roxb. ex Fleming) H. Karst	Himalaya
Gentianaceae	*Swertia cordata* (Wallich ex G. Don) C.B. Clarke	Pakistan, Himalaya, NE India, Myanmar, China
Gentianaceae	*Swertia nervosa* (G. Don.) C.B.Clarke	Himalaya, W China
Geraniaceae	*Chirita urticifolia* Buch-Ham ex D Don	NE India, N Myanmar, W China
Geraniaceae	*Geranium procurrens G.*	Himalaya, Nand NE India
Gesneriaceae	*Rhyncho glossumobliquum* Blume	Himalaya, India, Sri Lanka, Myanmar, W and S China, Malaysia
Hippocastanaceae	*Aesculus indica* (Cambess.) Hook.	Afghanistan, Himalaya (Kashmir to Nepal)
Hydrangeaceae	*Dichora febrifuga* Lour.	Himalaya, Myanmar, China, Malaysia
Hypericaceae	*Hypericum uralum* Buch.-Ham. ex D. Don.	Himalaya, Sumatrra, Thailand
Juglandaceae	*Juglans regia* DC.	Himalaya, China
Lamiaceae	*Elsholtzia ciliata* (Thunb)Hyland.	C Europe, N Asia, Himalaya, China, Japan
Lamiaceae	*Elsholtzia eriostachya* Benth.	Himalaya, India, China
Lamiaceae	*Elsholtzia fruticosa* (D. Don) Rehder	Himalaya, India, Myanmar, China
Lamiaceae	*Elsholtzia pilosa* Benth	Himalaya
Lamiaceae	*Isodon angustifolius*(Dunn)Kudo	Himalaya, China (Yunnan)
Lamiaceae	*Isodon lopanthoides* Benth	Himalaya, Myanmar, China
Lamiaceae	*Leucoseptrum cannum* Sm.	Himalaya, NE India, Myanmar, China
Lamiaceae	*Micromeria biflora* (Buch-Ham ex D. Don) Benth	Aghanistan, Himalaya, Myanmar
Lamiaceae	*Nepeta laevigata* (D Don) Hand-Mazz	Himalaya, Afghanistan, Turkestan
Lamiaceae	*Nepeta lamiopsis* Benth ex Hook	Himalaya, India, China
Lamiaceae	*Origanum vulgare* L.	Europe, Asia, and N America
Lamiaceae	*Prunella vulgaris* L.*	Europe and Temperate Asia
Lamiaceae	*Salvia campanulata* Wall ex Benth.	Himalaya, India, China
Lamiaceae	*Scutellaria repens* Buch-Ham. ex D. Don	Himalaya, Myanmar
Lauraceae	*Neolitsea pallens* (D. Don)Momiy.	Pakistan, China, Kashmir

Family	Species	Distribution
Linderniaceae	*Lindernia antipoda* (L.) Alston	Tropical and Temperate Asia, Australia, Polynesia
Linderniaceae	*Lindernia ciliata* (Colsm.) Pennell	Himalaya, Myanmar, "Taiwan, China", Japan, Australia
Linderniaceae	*Lindernia crustacea* (L.) F. Muell.	Tropical America, Himalaya, Japan, Malaysia, Polynesia, america
Lobeliaceae	*Lobelia seguinii* H. Lev. &Vaniot	Himalaya, Myanmar, W China
Malvaceae	*Urena lobata* L.*	Pantropical
Melastomaceae	*Osbekia stellata* Buch-Ham. ex D. Don	Himalaya
Menispermaceae	*Cissampelos pareira* L.*	Pantropical
Moraceae	*Streblus asper* Lour	China, Sri Lanka, Malaysia
Myrsinaceae	*Maesa montana* A DC	Tropical Himalaya(Nepal, Sikkim), E and W China
Oleaceae	*Chionanthus ramiflorus* Roxb.	Tropical Himalaya, India, Myamar, "Taiwan, China"
Oleaceae	*Fraxinus floribunda* Wall.	Himalaya, NE India, east to west China
Oleaceae	*Jasminum dispersum* Wall.	NE India, N Thailand, W China
Oleaceae	*Jasminum humile* L.	C Asia, Himalaya, Myanmar, W China
Onagraceae	*Oenothera rosea* L'Herit ex Ait.*	Native to Peru, Naturalized in Himalaya, Europe, Myanmar
Oxalidaceae	*Oxalis corniculata* L.	Cosmopolitan
Plantaginaceae	*Plantago major* L.	Europe, W Asia, Introduced elsewhere
Polygalaceae	*Polygala abyssinica* R.Br. Ex Fresen	Africa, Afghanistan, Himalaya
Polygalaceae	*Polygala furcata* Royle	Himalaya, Myanmar, W China
Polygonaceae	*Aconogon ummolle* (D. Don) H. Hara	Himalaya, NE India, eastto W China
Polygonaceae	*Fagopyrum dibotrys* (D Don) H Hara	Himalaya
Polygonaceae	*Oxyria dignya* (L.) Hill.	Europe, W and C Asia, Siberia, Japan, Himalaya
Polygonaceae	*Persicaria capitata* (Buch-Ham ex D Don) H Gross	Himalaya, W China
Polygonaceae	*Persicaria chinensis* H Hara	Himalaya, Japan, Malaysia
Polygonaceae	*Persicaria nepalensis* (Meisn) H Gross	Tropical America, Himalaya, Japan, Malaysia
Polygonaceae	*Polygonum recumbens* Royle ex Bab.	Himalaya (Kashmir to Nepal)
Polygonaceae	*Rumex hastatus* D.Don.	Afghanistan, Himalaya, W China
Primulaceae	*Lysimachia coangestiflora* Hemsl.	Himalaya, Myanmar, China
Primulaceae	*Lysimachia ferruginea* Edgew	Himalaya, N Myanmar
Primulaceae	*Primula edgeworthii* Hook.	Himalaya
Ranunculaceae	*Anemone vitifolia* Buch.-Ham. ex DC.	Himalaya, NE India, N Myanmar, W China
Ranunculaceae	*Clematis buchananiana* DC.	Himalaya, W China
Ranunculaceae	*Clematis montana* Buch-Ham ex DC.	Aghanistan, Himalaya, China
Ranunculaceae	*Ranunculus diffusus* DC.	Himalaya, N Myanmar, China
Ranunculaceae	*Thalictrum foliolosum* DC.	Himalaya, N Myanmar, China
Rosaceae	*Cotoneaster frigidus* Wall. ex Lindl	Himalaya, China
Rosaceae	*Cotoneaster microphyllus* Wall. ex Lindl.	Nepal, China
Rosaceae	*Fragaria indica* Andrews	Afghanistan, Himalaya, E to China, Japan and Malaysia
Rosaceae	*Potentilla nepalensis* Hook.	Himalaya (Kashmir to Nepal)
Rosaceae	*Prinsepia utilis* Royle	Himalaya, NE India, W China
Rosaceae	*Prunus persica* (L.) Batsch	China, widely cultivated in Europe and Asia
Rosaceae	*Pyracantha crenulata* (D. Don) M.Roem.	Himalaya, Myanmar, China
Rosaceae	*Pyrus pashia* Buch.-Ham. ex D. Don	Himalaya, NE India, Myanmar, W China
Rosaceae	*Rosa brunonii* Lindl.	Himalaya, Myanmar, W China
Rosaceae	*Rubu sellipticus* Sm.	Himalaya, Sri Lanka, east to W China, Philippines
Rosaceae	*Rubus foliolosus* D.Don	Himalaya, NW India, W China
Rosaceae	*Rubus paniculatus* Sm.	Himalaya, NE India
Rubiaceae	*Galium asperifolium* Wall	Afghanistan, India, Thailand

Family	Species	Distribution
Rubiaceae	*Galium elegans* Wall.ex Roxb.	Himalaya, India, Myanmar, Thailand, "Taiwan, China"
Rubiaceae	*Rubia manjith* Roxb. ex Fleming	Himalaya, NE India
Rubiaceae	*Spermadictyon suaveolens* Roxb.	Himalaya (Kashmir to Bhutan), India
Rutaceae	*Boenninghausenia albiflora* (Hook.) Rechenb.ex Meissn.	Himalaya, "Taiwan, China", Malaysia
Rutaceae	*Zanthoxylum armatum* DC.	Himalaya, India, China, "Taiwan, China", Philippines, Lesser Sunda Islands
Sambucaceae	*Viburnum cotinifolium* D Don	Afghanistan, Himalaya
Sambucaceae	*Viburnum erubescens* Wall. ex DC.	Himalaya, W and C China, N Myanmar
Santalaceae	*Osyris quadripartita* Sazmann ex Decaisne	Africa, Himalaya, Sri Lanka, China, SE Asia
Saxiragaceae	*Astilberi vularis* Buch-Ham. ex D Don	Himalaya, Thailand, W China
Saxiragaceae	*Bergenia ciliata* (Haw) Sternb.	Himalaya (Kashmir to Nepal)
Scrophulariaceae	*Hemiphragma heterophyllum* Wall.	Himalaya, China, Myanmar, "Taiwan, China", Philippines
Scrophulariaceae	*Lindenbergia muraria* (Roxburgh ex D. Don) Bruhl.	Himalaya, Afghanistan, Myanmar, east to W China
Scrophulariaceae	*Verbascum thapsus* L.	Himalaya, W and C China
Solanaceae	*Solanum americanum*Mill.*	Cosmopolitan
Thymelaeaceae	*Daphne bholua* Buch-Ham. ex D. Don	Himalaya, NE India, W China
Thymelaeaceae	*Wikstroemia canescens* Meisn	Afghanistan, Himalaya, Sri Lanka, China
Ulmaceae	*Ulmus wallichiana* Planch	Himalaya, India
Umbelliferae	*Centella asiatica* (L.) Urb.	Nepal, widespread in tropical regions of the world
Urticaceae	*Boehmeria macrophylla* Hornem.	Himalaya, Myanmar, SE Asia, W China
Urticaceae	*Chamabainia cuspidata* Wight	India, Sri Lanka, Myanmar, "Taiwan, China", Java
Urticaceae	*Debregeasia salicifolia* (D.Don)Rendle	Abyssinia, Iran, Afghanistan, Himalaya
Urticaceae	*Elatostema monandrum* (Buch-Ham ex D Don) H Hara	Himalaya, W China
Urticaceae	*Girardinia diversifolia* (Link) Friis	Himalaya, Sri Lanka, Malaysia, Myanmar, east to C China
Urticaceae	*Gonostegia hirta* (Blume) Miq	Himalaya, Myanmar, China, Japan, Malaysia
Urticaceae	*Lecanthus peduncularis* (Royle) Wedd.	Africa, Himalaya, Myanmar, SE Asia, "Taiwan, China", Java
Urticaceae	*Pilea scripta* Wedd.	Himalaya, NE India, Myanmar, W China
Urticaceae	*Pouzolzia zeylanica* (L.) Benn	Himalaya, E China, S Japan, Malaysia, Japan
Urticaceae	*Urtica dioca* L.	Europe, N Africa, W Siberia, C Asia, Himalaya, W China

Annex 5: **List of monocot taxa reported from Khar VDC**

Family	Species	Distribution
Araceae	*Aresaema flavum*	Afghanistan, Himalaya (Kashmir to Bhutan), W China
Asparagaceae	*Asparagus racemosus* Willd.	Himalaya, Australia, Malaysia, Africa
Cyperaceae	*Carex filicina* Nees.	Himalaya, E India, east to "Taiwan, China", south to Malaysia
Cyperaceae	*Cyperus aristatus* Rottb.	Pantropical
Cyperaceae	*Eriophorum comosum* (Wall.) Clarke	Afghanistan, Himalaya, N Myanmar, China
Cyperaceae	*Fimbristylis dichotoma* (L.) Vahl	Tropical to temperate zones of the all world
Liliaceae	*Ophiopogon intermedius* D. Don	Himalaya, Thailand, W China
Liliaceae	*Smilicina oleracea* (Baker) Hook.f.	Himalaya, N Myanmar, W China
Orchidaceae	*Goodyera biflora* (L.) R. Br.	Nepal, China
Orchidaceae	*Habenaria pectinata* D.Don	Himalaya, China
Poaceae	*Agrostis pilosula* Trin.	Himalaya (Kashmir to Sikkim), India
Poaceae	*Apluda mutica* L.	Himalaya, India, SE Asia, Australia
Poaceae	*Arthraxon lanceolatus* (Roxb.) Hochst.	Ethiopia, Nepal, India, China
Poaceae	*Arundinella nepalensis* Trin.	Himalaya, SE Asia, China
Poaceae	*Bothriochloa intermedia* (R.Br.) A. Camus.	Himalaya, India, Australia
Poaceae	*Brachypodium pinnatum* (L.) P. Beauv.	Europe, Temperate Asia, introduced elsewhere
Poaceae	*Capillipedium assimile* Stapf	Himalaya, SE Asia, Myanmar, Malaysia
Poaceae	*Cymbopogon distans* (Steud.) W. Watson	Himalaya, Sri Lanka
Poaceae	*Cymbopogon pendulus*(Nees ex Steudel) Will. Watson	Nepal, NW India
Poaceae	*Cynodon dactylon* (L.) Pers.*	Widely distributed in warm countries
Poaceae	*Chrysopogon gryllus* (L.) Trin.	S Europe, N Africa, temperate Himalaya
Poaceae	*Digitaria ciliaris* (Retz.) Koeler	Tropics of Old World
Poaceae	*Eleusine indica* (L.) Gaertn.	Tropical and subtropical regions
Poaceae	*Eragrostis nigra* Nees ex Steud.	S Asia, Myanmar, China
Poaceae	*Eragrostis tenella* (Linn.) P.Beauv. ex Roem. & Schult.	Tropics of Old World, introduced into America
Poaceae	*Eragrostis unioloides* (Retzius) Nees ex Steudel.	Africa, Nepal, India, SE Asia
Poaceae	*Eulalia mollis* (Griseb.) Kuntze	Himalaya
Poaceae	*Hackelochloa granularis* (L.) Kuntze*	Throughout the tropics
Poaceae	*Heteropogon contortus* (L.) Roem. & Schult.*	Widely distributed in tropics
Poaceae	*Imperata cylindrica* (L) P. Beauv	Mediterranean
Poaceae	*Miscanthus nepalensis* (Trin.) Hack.	Himalaya, NE India, Myanmar, W China
Poaceae	*Oplismenus compositus* (L.) P. Beauv.	Tropics of Old World and New World
Poaceae	*Paspalidium flavilum* (Retz.) A.Camus	Tropical Asia
Poaceae	*Pennisetum orientale* Rich.	N Africa, Iran, Arabia, Iraq, Himalaya
Poaceae	*Pogonatherum crinitum* (Thunb.) Kunth	Himalaya, Myanmar, Thailand, SE Asia, "Taiwan, China", Malaysia
Poaceae	*Saccharum rufipilum* Steud.	Nepal, N India, W China
Poaceae	*Sacciolepis indica* (L.) Chase	Himalaya, Australia, introduced in Africa and Americas
Poaceae	*Setaria pallidefusca* (Schumauch.) Stapf & Hubbard.	Tropics of Old World
Poaceae	*Sporobolus fertilis* (Steud.) Clayton.	Himalaya, Myanmar, China, Japan, Malaysia
Poaceae	*Sporobolus piliferus* (Trin.) Kunth	E Africa, Himalaya, India, Sri Lanka
Poaceae	*Themeda hookeri* Stapf.	Himalaya, W China
Smilacaceae	*Smilax aspera* L.	From Mediterranean and E Africa to India and Sri Lanka

Annex 6: **Photographs of the invasive alien plant species recorded in KSL-Nepal**

Ageratina adenophora

Ageratum conyzoides

Ageratum houstonianum

Amaranthus spinosus

Bidens pilosa

Erigeron karvinskianus


Galinsoga quadriradiata


Ipomoea carnea ssp. *fistulosa*


Lantana camara


Oxalis latifolia


Parthenium hysterophorus

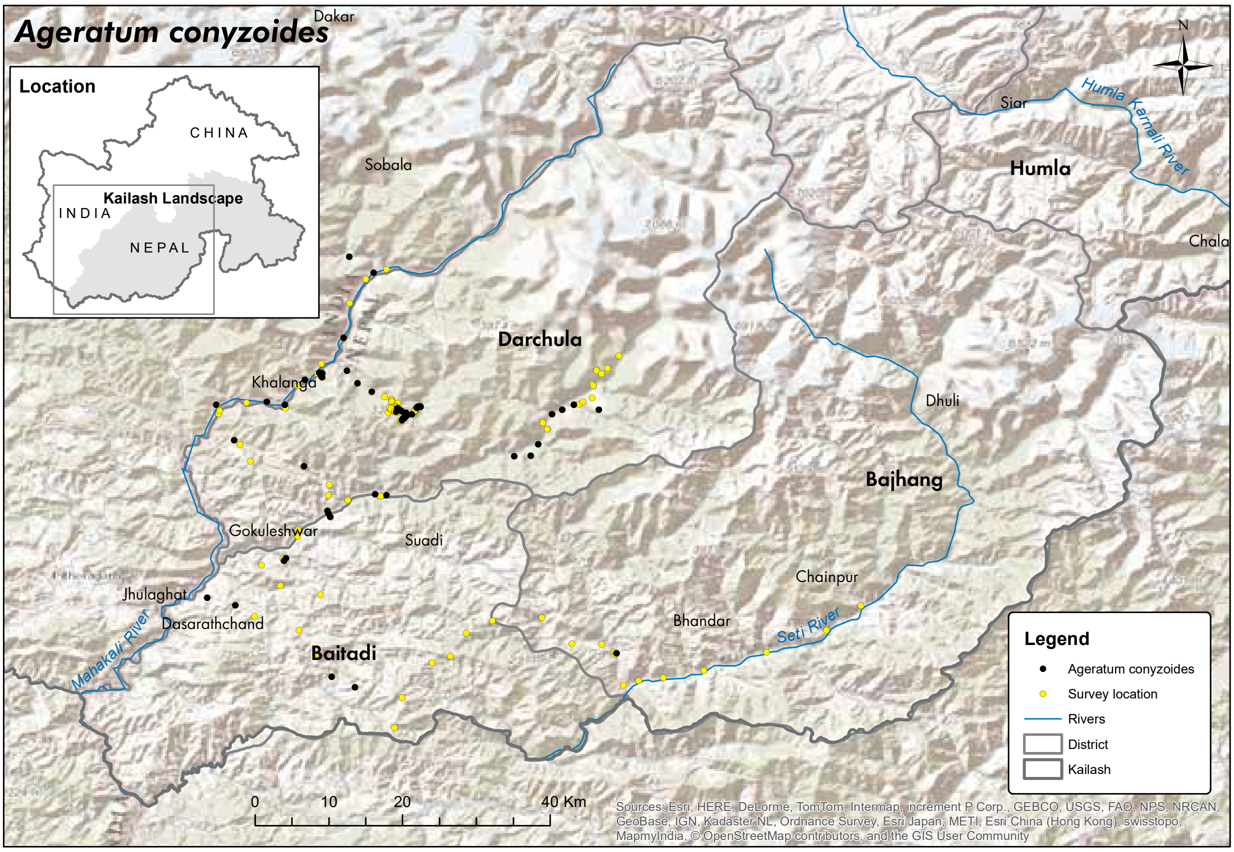

Pistia stratioites

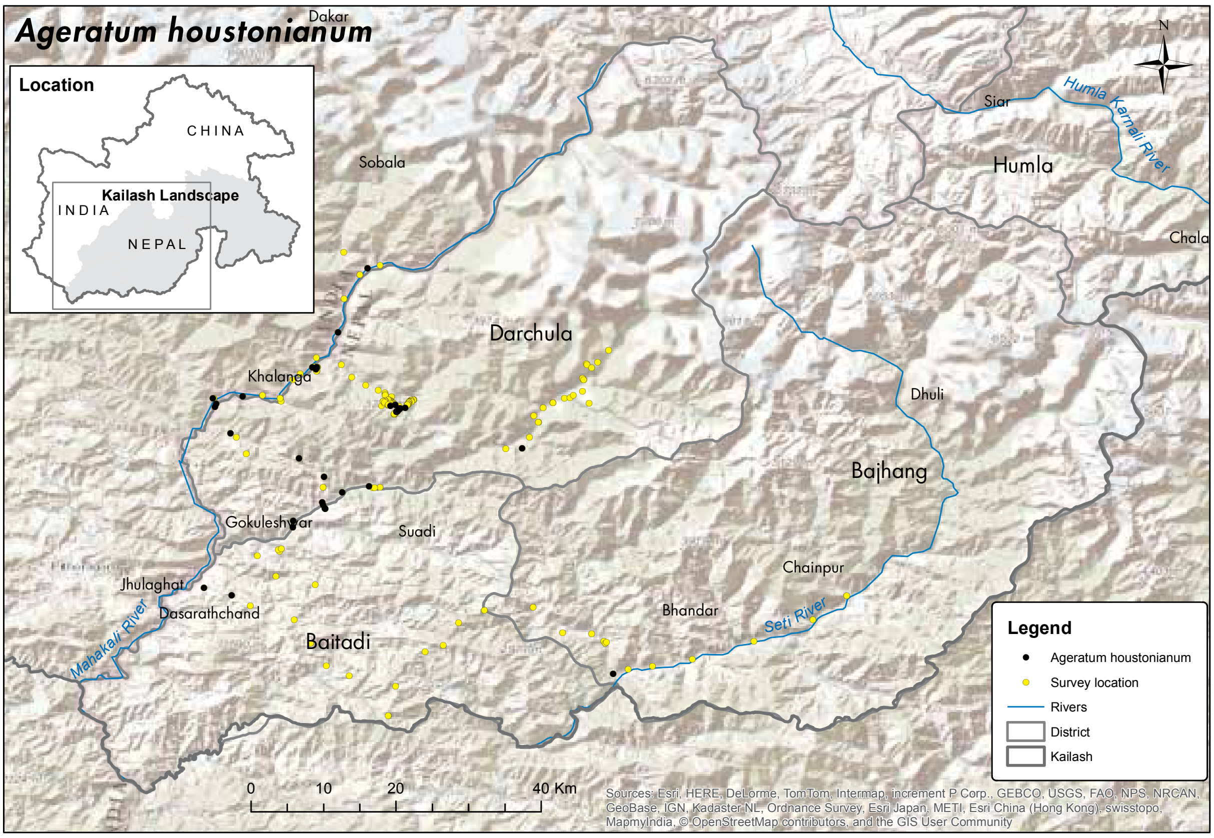
Senna occidentalis

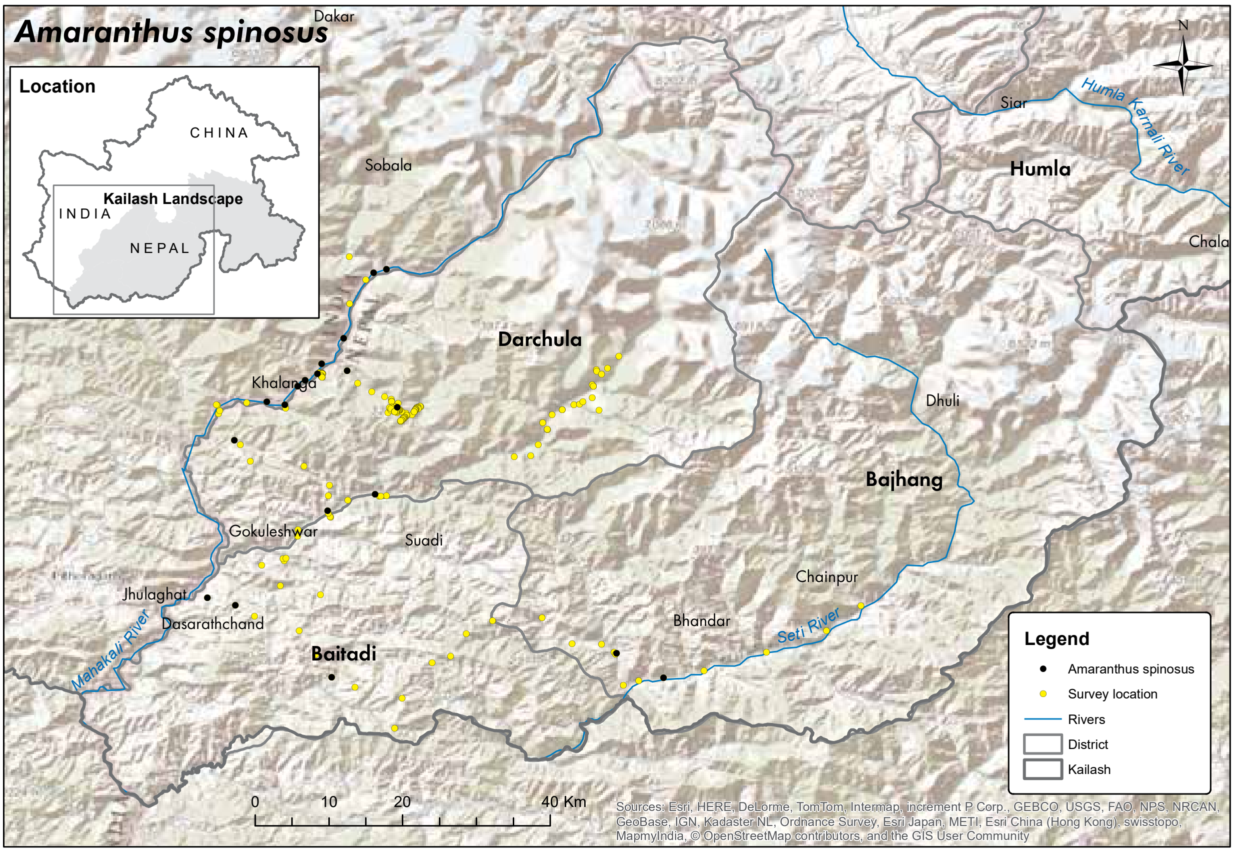
Senna tora

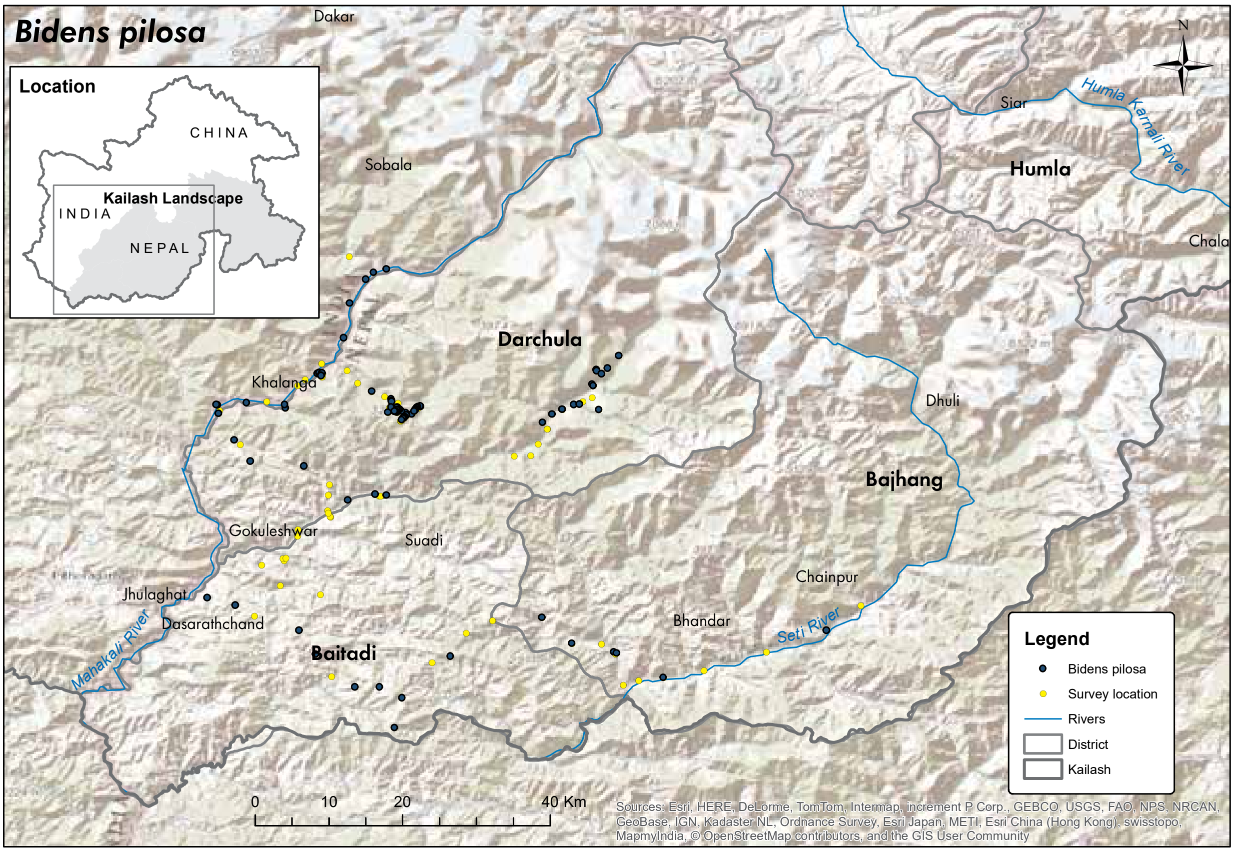
Xanthium strumarium

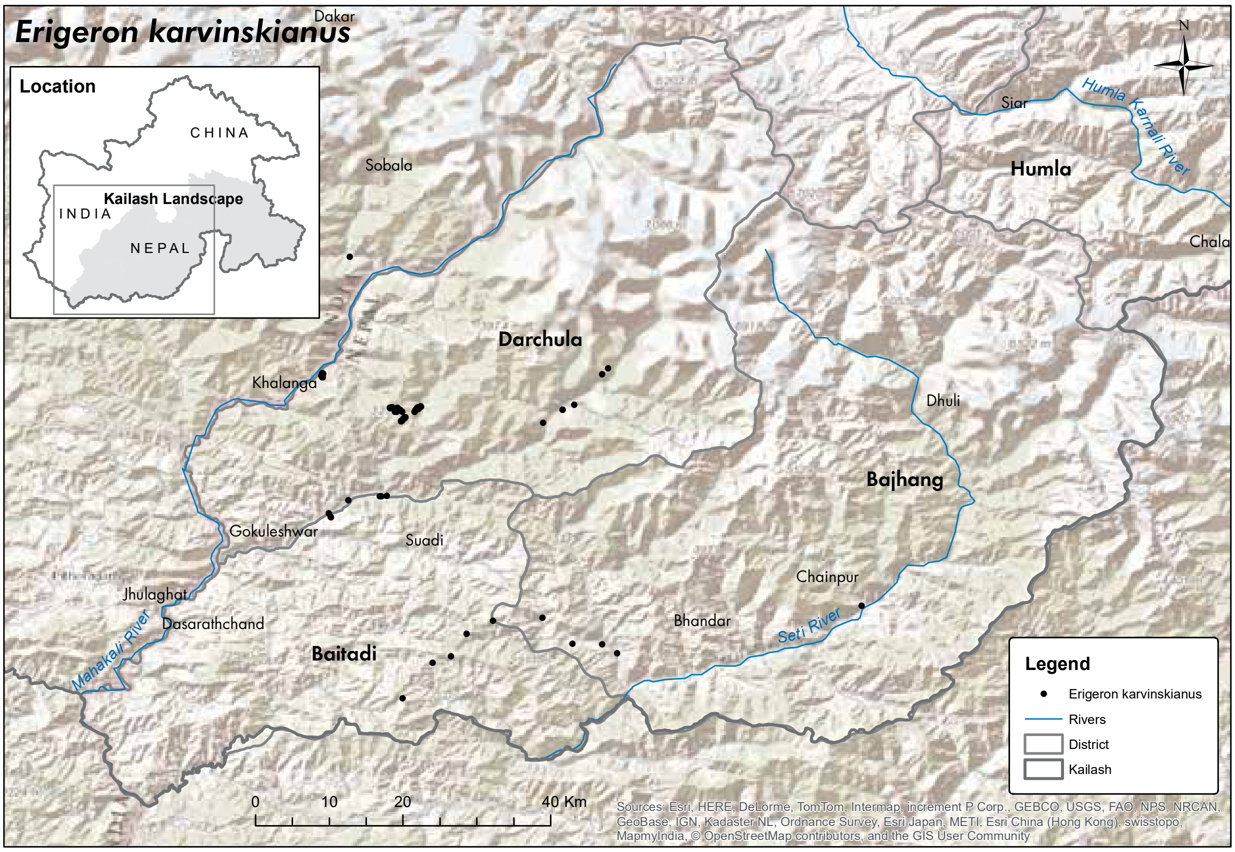
Annex 7: **Distribtion of the invasive alien plant species in KSL- Nepal**

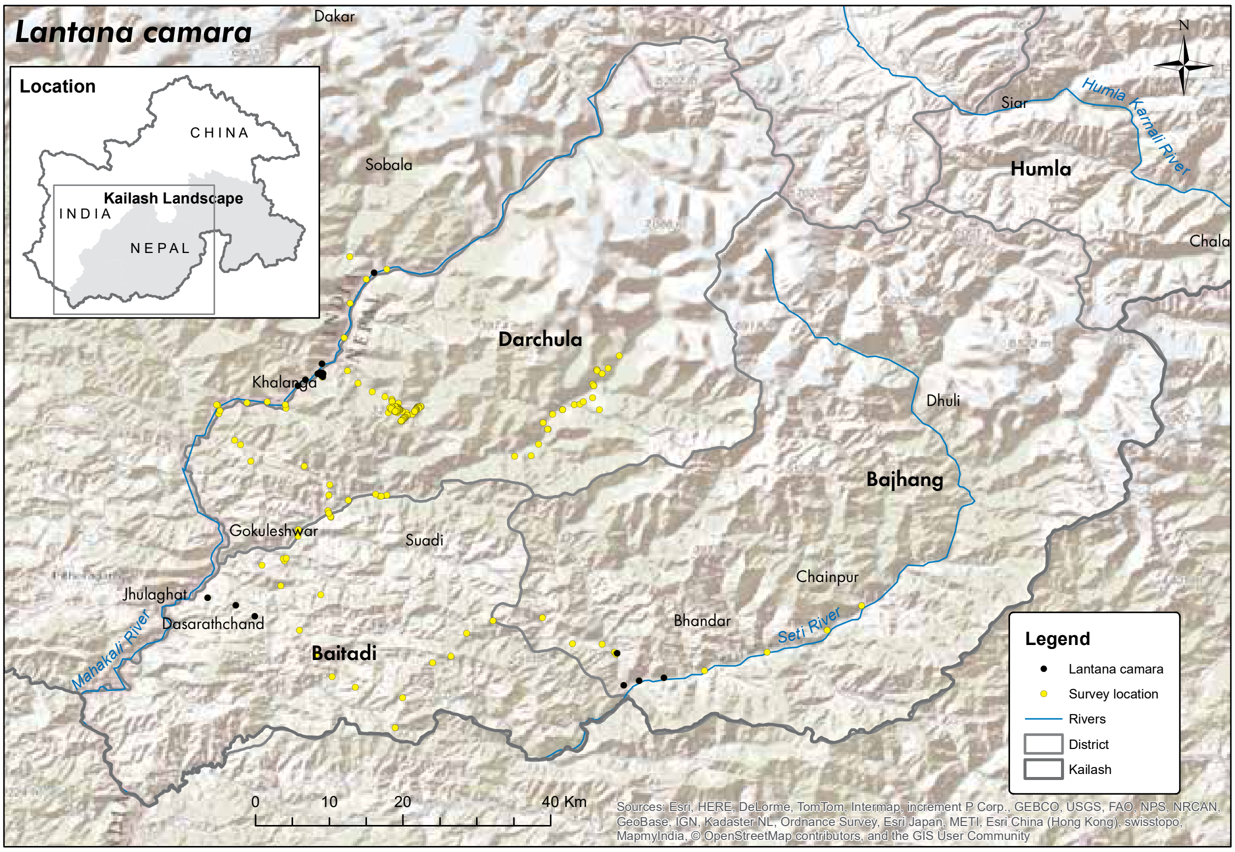


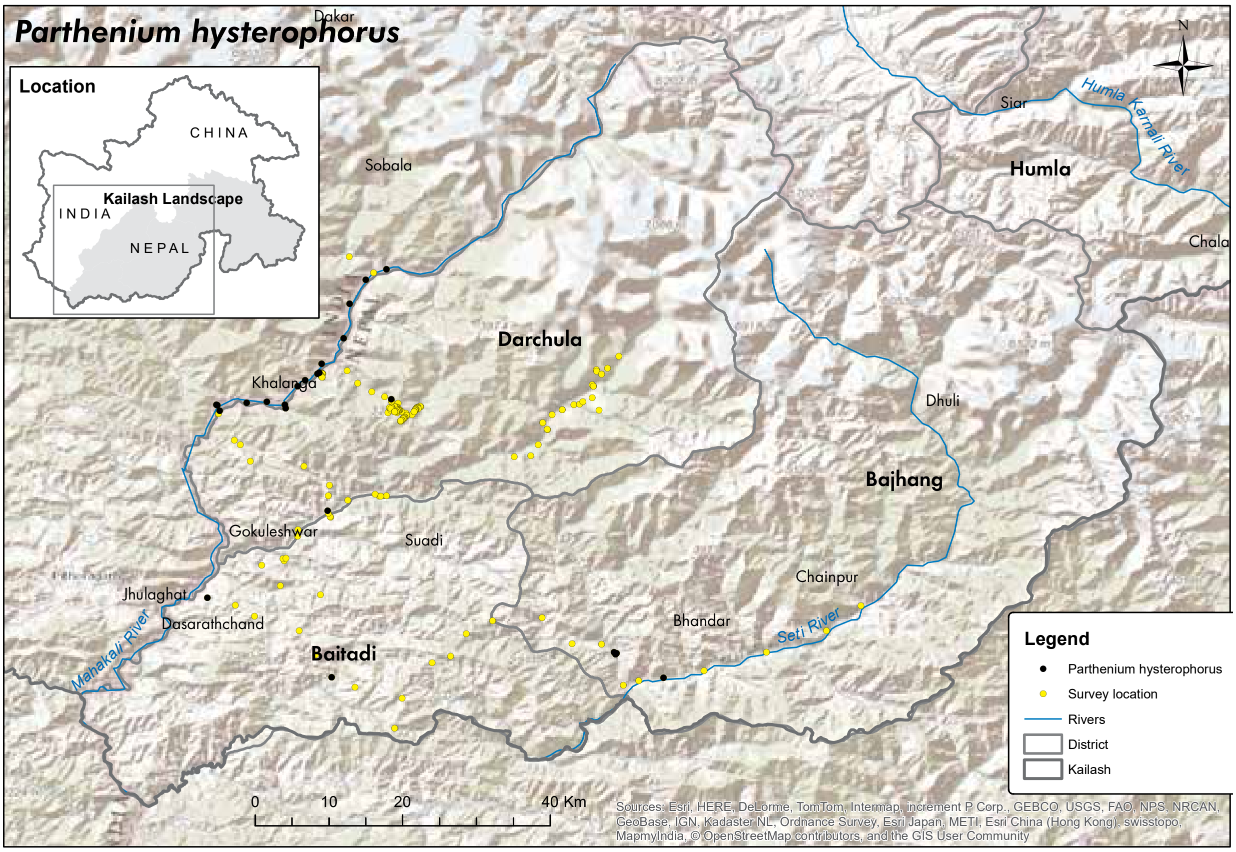


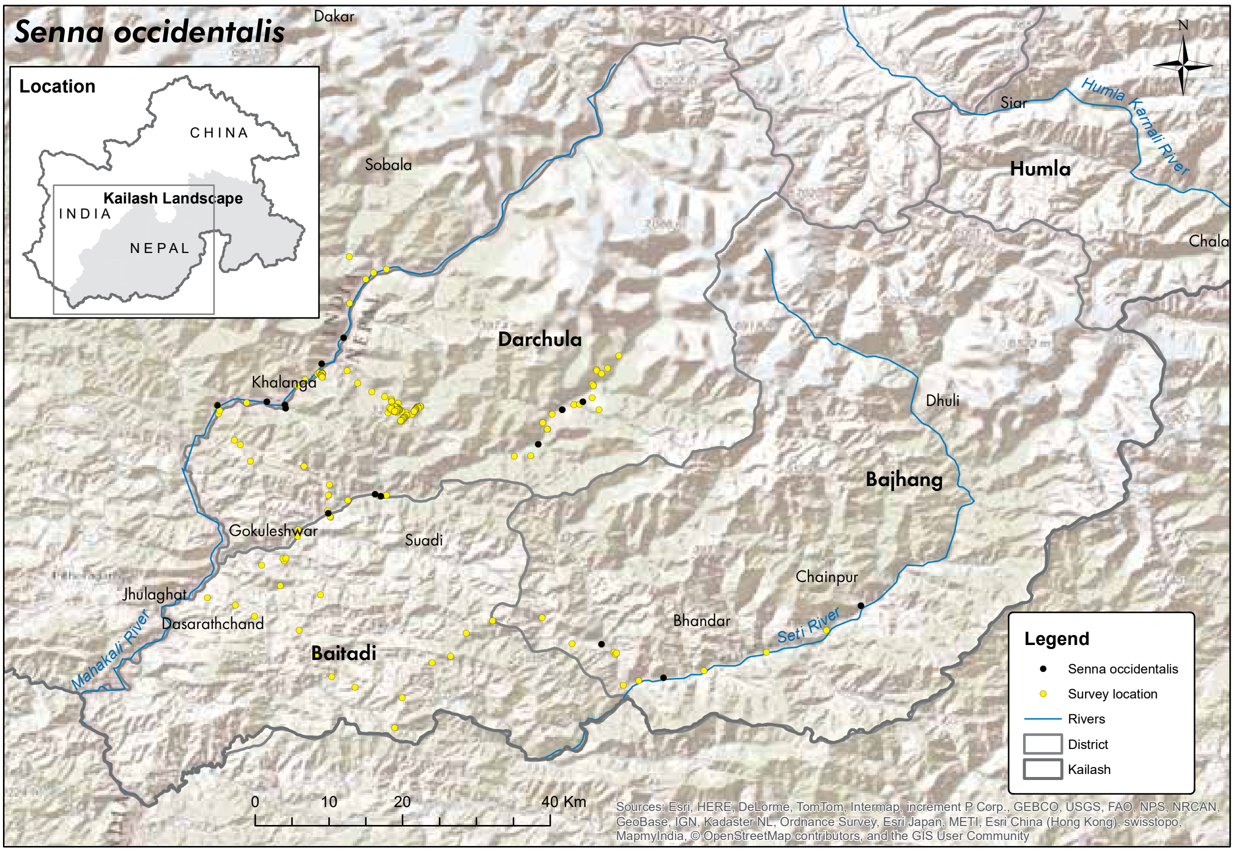

Amaranthus spinosus
Location
CHINA
Kailash Landscape
INDIA
NEPAL
Dakar
Sobala
Siar
Humla Karnali River
Humla
Chala
Darchula
Khalanga
Dhuli
Bajhang
Gokuleshwar
Suadi
Chainpur
Jhulaghat
Dasarathchand
Mahakali River
Bhandar
Seti River
Baitadi
Legend
Amaranthus spinosus
Survey location
Rivers
District
Kailash
0 10 20 40 Km
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

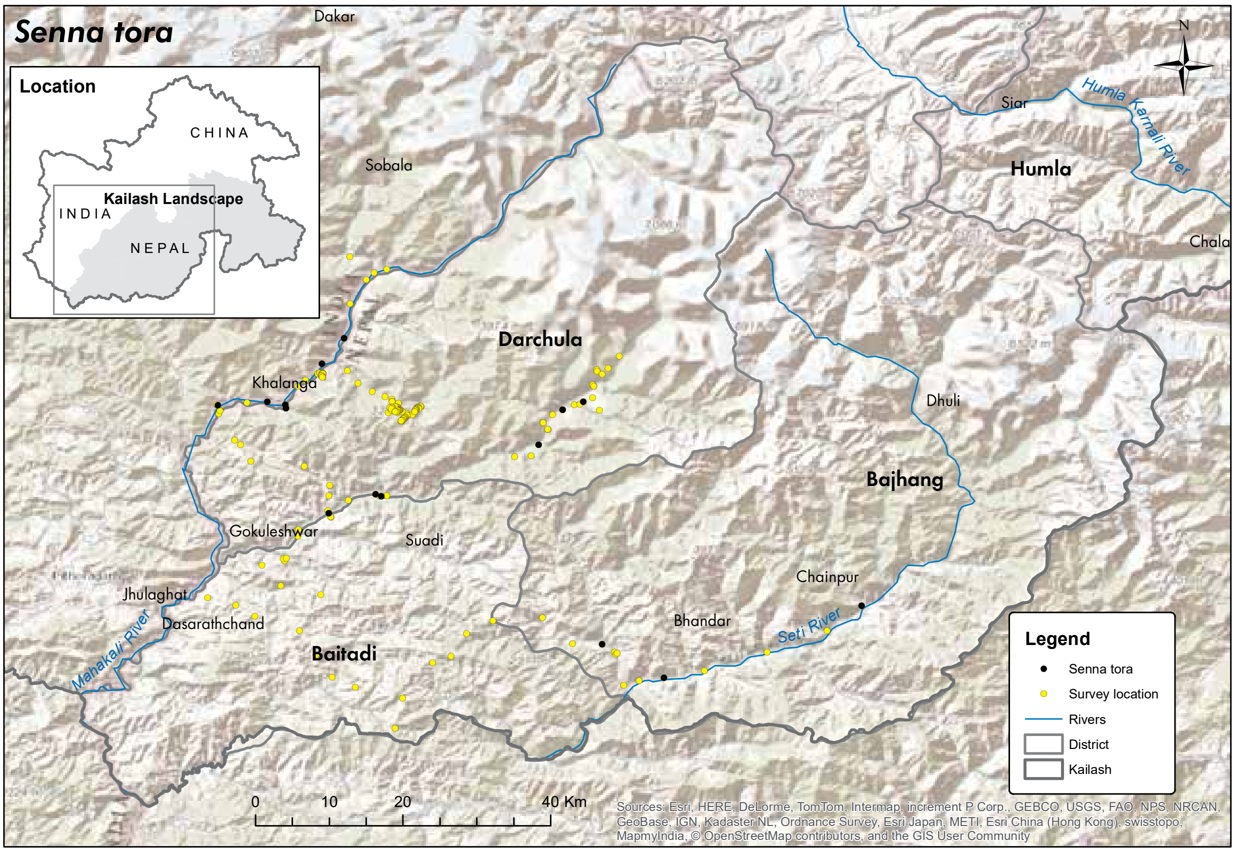

Bidens pilosa
Location
CHINA
Kailash Landscape
INDIA
NEPAL
Dakar
Sobala
Siar
Humla Karnali River
Humla
Chala
Darchula
Khalanga
Dhuli
Bajhang
Gokuleshwar
Suadi
Chainpur
Jhulaghat
Dasarathchand
Mahakali River
Bhandar
Seti River
Baitadi
Legend
Bidens pilosa
Survey location
Rivers
District
Kailash
0 10 20 40 Km
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

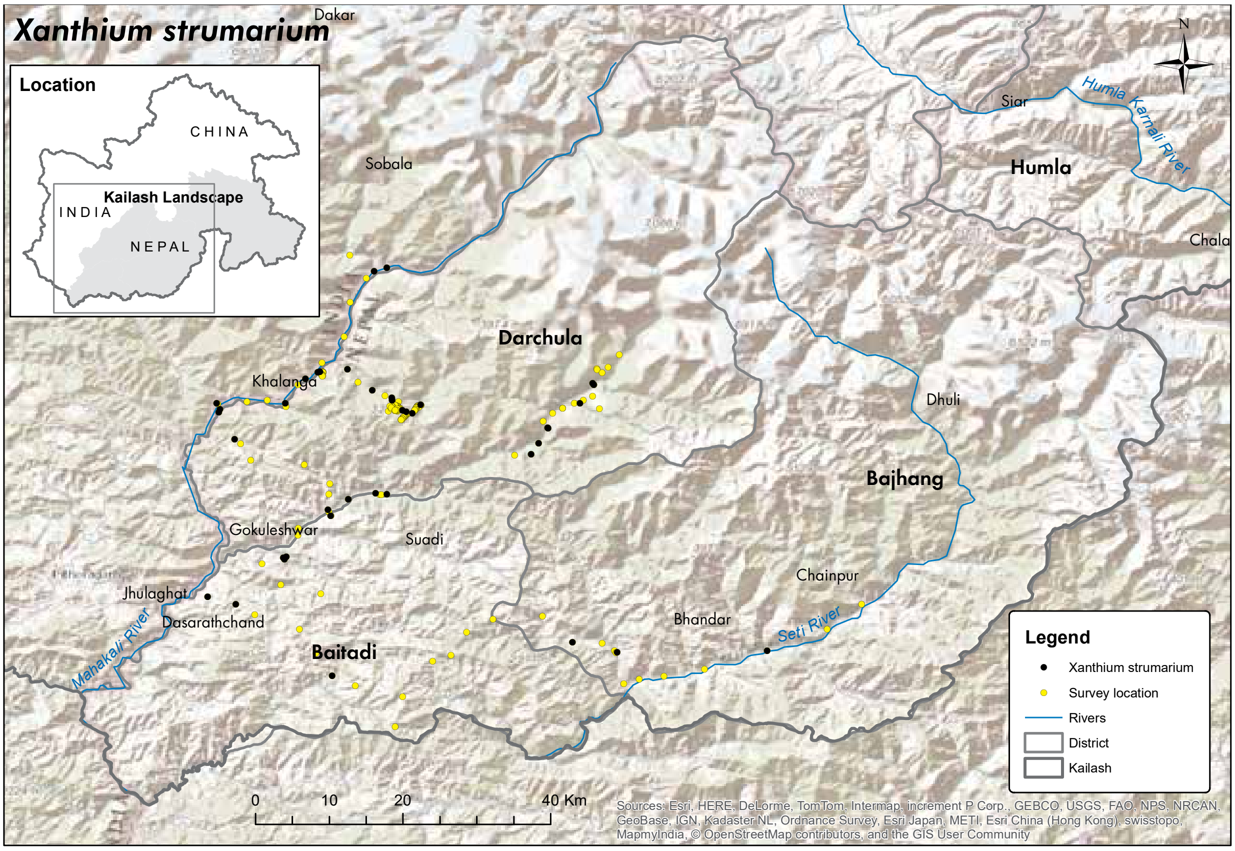

Erigeron karvinskianus
Location
CHINA
Kailash Landscape
INDIA
NEPAL
Dakar
Sobala
Siar
Humla
Humla Karnali River
Chala
Darchula
Khalanga
Dhuli
Bajhang
Gokuleshwar
Suadi
Chainpur
Jhulaghat
Dasarathchand
Bhandar
Seti River
Mahakali River
Baitadi
Legend
Erigeron karvinskianus
Rivers
District
Kailash
0 10 20 40 Km
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

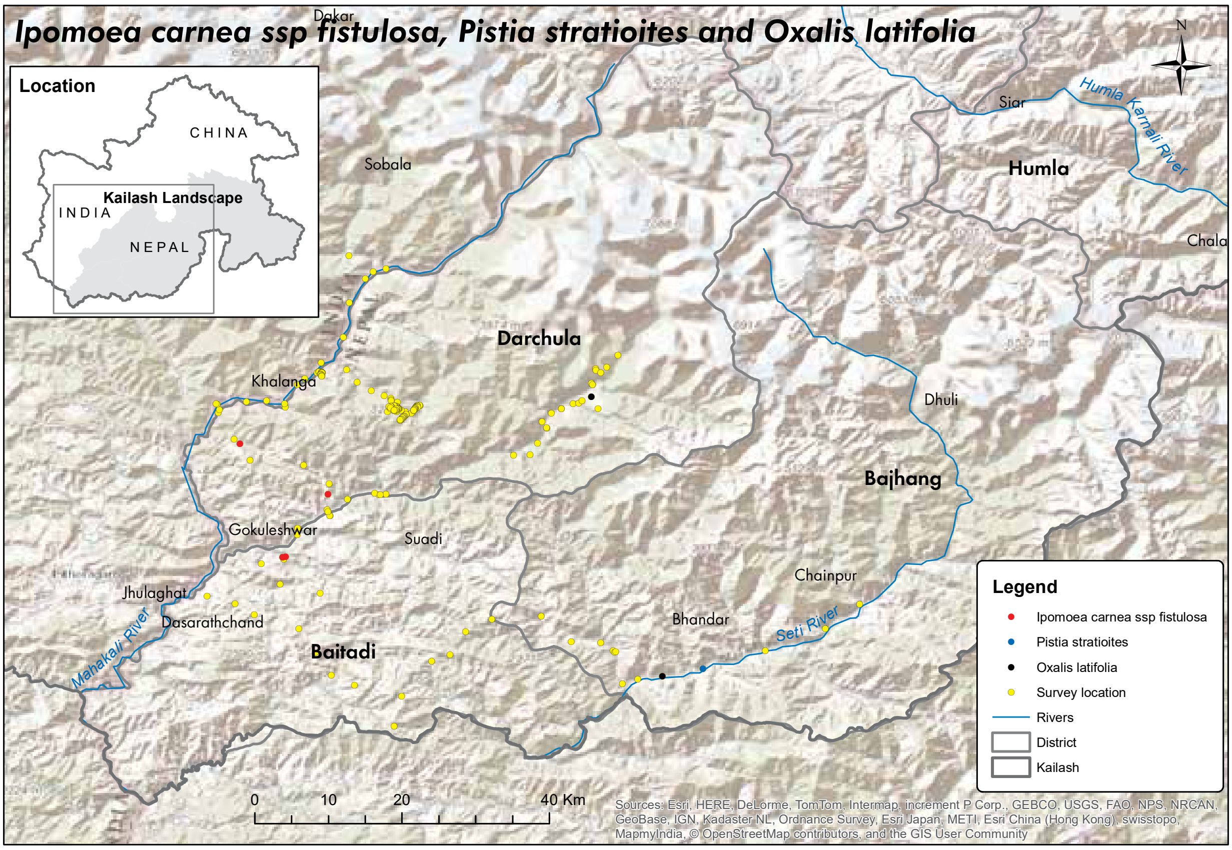

Lantana camara
Location
CHINA
Kailash Landscape
INDIA
NEPAL
Dakar
Sobala
Siar
Humla
Humla Karnali River
Chala
Darchula
Khalanga
Dhuli
Bajhang
Gokuleshwar
Suadi
Chainpur
Jhulaghat
Dasarathchand
Bhandar
Seti River
Mahakali River
Baitadi
Legend
Lantana camara
Survey location
Rivers
District
Kailash
0 10 20 40 Km
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community


Parthenium hysterophorus
Location
CHINA
Kailash Landscape
INDIA
NEPAL
Dakar
Sobala
Siar
Humla Karnali River
Humla
Chala
Darchula
Khalanga
Dhuli
Bajhang
Gokuleshwar
Suadi
Chainpur
Jhulaghat
Dasarathchand
Mahakali River
Baitadi
Bhandar
Seti River
Legend
Parthenium hysterophorus
Survey location
Rivers
District
Kailash
0
10
20
40 Km
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community


Senna occidentalis
Location
CHINA
Kailash Landscape
INDIA
NEPAL
Dakar
Sobala
Siar
Humla Karnali River
Humla
Chala
Darchula
Khalanga
Dhuli
Bajhang
Gokuleshwar
Suadi
Chainpur
Jhulaghat
Dasarathchand
Mahakali River
Baitadi
Bhandar
Seti River
Legend
Senna occidentalis
Survey location
Rivers
District
Kailash
0
10
20
40 Km
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community


Senna tora
Location
CHINA
Kailash Landscape
INDIA
NEPAL
Dakar
Sobala
Siar
Humla
Humla Karnali River
Chala
Darchula
Khalanga
Dhuli
Bajhang
Gokuleshwar
Suadi
Jhulaghat
Dasarathchand
Mahakali River
Baitadi
Chainpur
Bhandar
Seti River
Legend
Senna tora
Survey location
Rivers
District
Kailash
0
10
20
40 Km
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community


Xanthium strumarium
Location
CHINA
Kailash Landscape
INDIA
NEPAL
Dakar
Sobala
Siar
Humla
Humla Karnali River
Chala
Darchula
Khalanga
Dhuli
Bajhang
Gokuleshwar
Suadi
Jhulaghat
Dasarathchand
Mahakali River
Baitadi
Chainpur
Bhandar
Seti River
Legend
Xanthium strumarium
Survey location
Rivers
District
Kailash
0
10
20
40 Km
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Ipomoea carnea ssp fistulosa, Pistia stratioites and Oxalis latifolia
Location
CHINA
Kailash Landscape
INDIA
NEPAL
Dakar
Sobala
Siar
Humla Karnali River
Humla
Chala
Darchula
Khalanga
Dhuli
Bajhang
Gokuleshwar
Suadi
Chainpur
Jhulaghat
Mahakali River
Dasarathchand
Baitadi
Bhandar
Seti River
Legend
Ipomoea carnea ssp fistulosa
Pistia stratioites
Oxalis latifolia
Survey location
Rivers
District
Kailash
0
10
20
40 Km
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu, Nepal
T +977 1 5275222 **F** +977 1 5275238
E info@icimod.org **W** www.icimod.org

german cooperation
DEUTSCHE ZUSAMMENARBEIT

UKaid
from the British people