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Review Article

Invasive alien plant species: a threat to biodiversity and agriculture in Nepal

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Abstract Invasive alien plant species (IAPS) are a significant threat to agriculture, resulting in crop loss and increased production cost. Because of their detrimental effects on floral and faunal organisms and their ecosystems, they pose a significant threat to biodiversity. There are 219 species of alien flowering plants native to Nepal, 26 of which have been reported to be invasive with negative environmental impacts, including agricultural production. Four of them (*Lantana camara* L., *Mikania micrantha* Kunth, *Chromolaena odorata* (L.) King & Robb. and *Eichhornia crassipes* (Mart.) Solms) are among the 100 of the world's worst invasive alien species in agro-ecosystems and range lands. The current status and impacts of invasive alien plant species are discussed in this paper.
Keywords: Invasive alien species, Biodiversity, Ecosystem, Biological species, Impacts

Introduction

Invasive alien plant species (IAPS) is a species that has been deliberately or inadvertently introduced to a place, area, or region where it naturally does not occur. They are endemic to one place or territory that affects biodiversity, ecology, and environments, and human safety and shows a tendency to spread out of control (CBD, 2002; Gaertner *et al*., 2009). The "invasive" label is generally reserved for plants that have been introduced from other regions and spread like wildfire in their new habitats. The main driver of global change is invasive species (Pejchar and Mooney, 2009) which can affect the biological diversity and mechanism of the environment (Clout and Poorter, 2005). A major component of global environmental change has been called biologic invasions (Vitousek, 1990), which was the leading cause of natural biodiversity degradation and depletion (Ricciardi *et al*., 1998), and biodiversity services (Peychar and Mooney, 2009). Besides, the composition and purposes of the goods and services offered by the environment are determined by the introduction of a new species into the environment (Wilcove *et al*., 1998). Such invasive plant species endangering and disrupting the natural environment and affecting agriculture in Nepal (Tiwari *et al*., 2005). In addition, invasive species may significantly reduce agricultural production and jeopardize significant cultural environments, eg. historic gardens (Richburg, 2008). Such disruption is exacerbated by climate change (Kriticos *et al*., 2003; Dukes and Mooney, 2004), deforestation, ecosystem destruction, and human- perturbation (Norbu, 2004). Some invasive species of plants such as *Ageratina adenophora* (Spreng.) King & Robb (Chettri, 1986), *Lantana camara* L., *Chromolaena odorata* (L.) King & Robb. (Norbu, 2004), *Mikania micrantha* Kunth (Sapkota 2012; Rai and Scarborough, 2012), and *Hyptis suaveolens* (L.) Poit. are significant invasive species in the forest of Nepal that invade forest and shrubs land (Tiwari *et al*., 2005).

The main issue of invasive plant species continues to increase at high social, health and environmental level worldwide. The impacts of invasive plant species on developing countries like Nepal are very serious as they depend on resource-based livelihoods such as agriculture, aquaculture, fisheries, and forestry (Matthews and Brandt, 2004). Substantial advancement, economic expansion, and food security could also be attributed to social instability and economic disruption by invasive alien species (GISP, 2009). One of the key sources of environmental and economic disruption and the major factors of biodiversity loss has been a biological invasion (CBD, 1992). Invasive alien species are more widespread along the road and anthropogenic disruptions (Kohli *et al*., 2009). The widespread availability of available capital raises ecosystem susceptibility to invasion (Davis *et al*., 2000). Human actions raise invasive species proliferation pressure (Simberloff, 2009).

Bellard *et al*. (2016) and Downey and Rirchardson (2016) reported alien species were among the main causes of the decline in biodiversity (extermination of populations) and economic damage. In fact, the most significant threats to human loss and habitat destruction in the Island habitats worldwide may also be due to invasive alien species (Donlan *et al*., 2003). Invasive species alter hydrological flows and environments and adjust the composition of soil and its chemical properties (Randall and Marinelli, 1996). Furthermore, invasive alien species can hybridize with native plant relatives and are regarded to be biological pollutants (Westbrooks, 1991). This may result in unintended modifications to plant genetics makeup (Richburg, 2008).

Invasive alien plants performance is attributable to the existence of novel weapons such as allelopathic traits (Rai and Tripathi, 1982) and its evolution with improved competition (Callaway and Ridenour, 2004). The latest work reveals empirical similarities between the success of exotic human invasions and the success of exotic plant invasions-use of advanced arms (Callaway and Ridenour, 2004). Naturalized species are more invasive and free of natural rivals - Enemy release hypothesis (ERH) (Torchin *et al*., 2003; Eschtruth and Battles, 2009). Biotic resistance hypothesis (BRH) is the most plausible for biological invasions in abundant and dense woodland with monospecific stands (Pimm, 1984; Norbu, 2004). Invasive plants prosper from high rates of nitrogen (Brooks, 2003).

Anthropogenic practices had the greatest impact in raising the invasion of plant organisms, e.g. *Chromolaena odorata* in the decreased understory biomass and canopy exposure induced by human intervention (Joshi, 2001; Norbu, 2004). With the globalization of the commerce and human activities in all continents and climatic regions (Seebens *et al*., 2017), even in the high mountains and Polar Regions, the number of alien organisms has increased without any saturation indication (Pauchard *et al*., 2016). Recent trends have seen a significant increase in the pace and threat associated with the introduction of alien species as human population development and environmental improvements have steadily increased (Pimentel *et al*., 2000). The degree of invasion has been observed to be lowered slowly from near- study areas as human intervention is progressively decreased (Karki, 2009). The scale of biological invasion has gradually risen across many of the ecosystems and environments, as human movement and global commerce, have intensified. The adverse effects of alien organisms are exacerbated by current climate change, as the extent and severity of the biological invasion is expected to rise (Simberloff, 2000).

Most alien species effectively naturalize and disrupt native species and homogenization of ecosystem, alteration in hydrological characteristics, gene pools degradable by native species hybridization (Richburg, 2008), leading to a loss in biodiversity (Miththapala, 2007; Gaertner *et al*., 2009; Hui *et al*., 2011). A category of naturalized organisms dispersed so rapidly and widely that they had significant adverse effects on introduced ecosystems, biodiversity, the environment, human health and the economy called invasive alien organisms (Pysek *et al*., 2004). The biological invasion was therefore recognized as the second leading source of biodiversity destruction in tandem with the depletion of the ecosystem as a whole (Glowka *et al*., 1994).

All exotic species, though, are not invasive. A species must be naturalized to avoid aggressive and distributed throughout its territory. Just one percent of all introduced organisms are projected to be invasive (Keam *et al*., 2009). If the ecosystem in which it invades is disrupted, introduced species can be at significantly higher risk to native ecosystems and species diversity (Moore, 2000; Wilcove *et al*., 1998). Besides, the composition and roles of the goods and services offered by the environment are affected by the introduction of a new species in the ecosystem (Wilcove *et al*., 1998). Invasive species intrusion of alien plants has influenced native species by trade, predation, hybridization, pathogens and disturbances of local habitats and ecosystem processes and may re-emerge after the elimination of the invasive species (Andreu and Vila, 2011), in virtually any environment on earth and triggered hundreds of extinctions (McNeely *et al*., 2001). While it is possible to increase the number of species in a particular site in the short term with the introduction of an alien species, this would lead to a reduction in the diversity of species dif the native species were reduced or eventually displaced from a particular site or region (Begon *et al*., 1990). In this paper, we highlighted a brief overview of the diversity, current status, impacts, benefits, and management of invasive alien plant species found in Nepal.

Species attributes of IAPS

Invasive plant species exhibit rapid vegetative development, ample seed production potential, higher germination rate, long-lived seeds, rapid sexual and reproductive maturation, and a high ability to develop a wide range of phenotypic plasticity (ability to physically adapt to new environments) and survival potential for a variety of food types and environmental factors (Tiwari *et al*., 2005). Invasive species may significantly change their ecosystem by releasing chemical compounds, abiotic factors, or herbivorous behaviors that may have a positive or negative impact on other organisms. Certain species, including *Kalanchoe daigremontana* Raym.-Hamet & H. Perrier, develop allelopathic substances, inhibiting competitive organisms and disrupting other processes of soil such as carbon and mineralization of nitrogen (Herrera *et al*., 2018). Additional species such as *Stapelia gigantea* N.E. Br. tends to attract seedlings of certain plants from

arid habitats by maintaining optimal microclimate conditions and suppressing herbivory in early growth phases (Huenneke, 1990).

Current status of IAPS in Nepal

There are at least 219 alien species of flowering plants that are naturalized in Nepal. Among them 26 species, mostly native of tropical Americas, have been reported to be invasive with negative impacts on the environment including agriculture production (Shrestha *et al*., 2017). In addition to them, four naturalized species *Ageratum conyzoides* L., *Erigeron karvinskianus* DC., *Galinsoga quadriradiata* Ruiz & Pav. and *Spermacoce alata* Aubl. (Syn. *Borreria alata*) have been also found to be invasive in agro-ecosystems and range lands. Among 26 IAPS, four species (*Chromolaena odorata, Eichhornia crassipes, Lantana camara* and *Mikania micrantha*) are included in world's 100 worst invasive species (GoN, 2019). An assessment of invasive alien plant species (IAPS) was undertaken for the first time by IUCN Nepal during 2002 - 2003 in Nepal (GoN, 2019). Nepal's ecosystem is vulnerable to alien plant species because it disrupts various habitats and environmental factors (Kunwar, 2003; Tiwari *et al*., 2005).

In eastern and central Nepal, the number of naturalized species and invasive plant species is higher than in western Nepal (Bhattarai *et al*., 2014). At least some alien species inhabited the east of Nepal first and spread gradually to the west. For example, *Chromolaena odorata* and *Mikania micrantha* is absent can only be identified in a few areas in western Nepal (Poudel 2016), both are primary invasive weeds areas for eastern and central Nepal (Tiwari *et al*., 2005). A large number of alien organisms are also known for the middle mountain area with a subtropical to a temperate climate. There have only been a few alien species (eg *Ageratina adenophora* and *Galinsoga quadriradiata*) recorded from the high mountains and until now the High Himal area is free of invasive alien plant species (Shrestha *et al*., 2016). By 1972 in the eastern part of Nepal (districts of Ilam, Terhathum and Dhankuta), *Procecidochares utilis* entered Nepal gradually from India and became an established population (Sharma and Chhetri, 1977).

This is not unexpected, because over $3/4^{th}$ of the native-born plant species (including alien species) in Nepal come from the world's subtropical and tropical areas (Tiwari *et al*., 2005; Bhattarai *et al*., 2014). In seven tropical and subtropical regions of Nepal with high species resources between 700 and 1500 masl, alien plants are most widespread (Bhuju *et al*., 2013). Many exotic plants exhibit invasive character as the exotic countries are exempt from natural enemies and rivalry, e.g. from tropical America to Nepal, because of which invasive organisms may expand quickly and propagate (May, 2007). In Nepal, most alien species come from tropical America (Tiwari *et al*., 2005). Not all incorporated is invasive but is likely to be invasive by invasion (Tiwari *et al*., 2005; Siwakoti, 2012), by the implementation, set-up, and distribution (Keam *et al*., 2009). Invasive alien species amount is also high in the southern lowlands (Tarai and Siwalik) of tropical to subtropical climate, while most alien organisms are from tropical America (Tiwari *et al*., 2005). The types of IAPS was given in Table 1. The common IAPS found in Nepal was given in Table 2.

Table 1: Types of invasive alien plant species based on land use

Land use types	Invasive alien plant species
Agroecosystems	*Ageratum houstonianum, A. conyzoides, Mimosa pudica, Oxalis latifolia, Parthenium hysterophorus, Spergula arvensis, Alternanthera philoxeroides, Argemone mexicana, Erigeron karvinskianus, Galinsoga quadriradiata*
Wetlands	*Alternanthera philoxeroides, Myriophyllum aquaticum, Pistia stratiotes, Eichhornia crassipes, Ipomoea carnea spp. fistulosa, Leersia hexanda*
Grasslands and residential areas	*Amaranthus spinosus, Bidens pilosa, Xanthium strumarium, Parthenium hysterophorus, Senna tora, S. occidentalis, Spermacoce alata*
Forests and shrub lands	*Mikania micrantha, Ageratina adenophora, Chromolaena odorata, Hyptis suaveolens, Lantana camara*

(Table adapted by Shrestha *et al*. (2017)

Table 2: List of invasive alien plant species (IAPS) of Nepal having negative impacts to the environment and agriculture production

SN	Common name	Local name	Scientific Name	Family
1	Bushmint	TulsiJhar	*Hyptis suaveolens* (L.)	Lamiaceae
2	Bush morning Glory	Besaram	*Ipomoea carnea* ssp. f*istulosa* (Mart. ex Choisy) D.F. Austin	Convolvulaceae
3	Corn spurry	Thangnejhar	*Spergula arvensis* L.	Caryophyllaceae
4	Crofton weed	Kalo Banmara	*Ageratina adenophora L.*	Asteraceae
5	Karwinsky's Fleabane	Phule Jhar	*Erigeron karvinskianus* DC.	Asteraceae
6	Parthenium	Patijhar	*Parthenium hysterophorous* L.	Asteraceae
7	Rough cockle Bur	Bhede kuro	*Xanthium strumarium* L.	Asteraceace
8	Sensitive plant	Lajjawati	*Mimosa pudica* L.	Mimosaceae
9	Shaggy Soldier	Jhuse Chitlange	*Galinsoga quadriradiata* Ruiz & Pav.	Asteraceae
10	Siam weed	Seto Banmara	*Chromolaena odorata* (L.), R.M.King and H. Roxb.	Asteraceae
11	Sickle pod senna	Tapre	*Senna tora* (L.) Roxb.	Caesalpiniaceae
12	Southern Cut grass	Karaute ghans, Navo dhan	*Leersia hexandra* Sw.	Poaceae
13	Spiny pigweed	Kandelude	*Amaranthus spinosus* L.	Amaranthaceae
14	Water hyacinth	Jalkumbhi	*Eichhornia crassipes* (Mart.) Solms	Pontederiaceae
15	Water lettuce	Kumbhika Panibanda	*Pistia stratiotes* L.	Araceae
16	Alligator weed	Jala jambhu, Patpate	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae
17	Billygoat	Raunne/Gandhe	*Ageratum conyzoides* (L.)	Asteraceae
18	Black jack/Hairy beggar-tick	Kalokuro	*Bidens pilosa* L.	Asteraceae
19	Blue Billygoat Weed	Nilogandhe	*Ageratum houstonianum* Mill.	Asteraceae
20	Broadleaf bottonweed	AluPate Jhar	*Spermacoce alata* Aubl.	Rubiaceae
21	Lantana	Kirne kanda	*Lantana camara* L.	Verbenaceae
22	Mexican poppy	Thakal	*Argemone mexicana* L.	Papaveraceae
23	Purple wood sorel	Chari amito	*Oxalis latifoba* Kunth	Oxalidaceae
24	Mile-a-minute weed	Lahare banmara	*Mikania micrantha* Kunth	Asteraceae
25	Parrot's feather	-	*Myriophyllum aquaticum* (Vell.) Verdc.	Holaragaceae
26	Corn spurry	Thangejhar	*Spergula arvensis* L.	Caryophyllaceae

(Source: Shrestha, 2017; GoN, 2019)

***Mikenia micrantha* and its impacts**

Mikania micrantha, a rapidly developing, perennial creeping vine from Central and South America, colonizes agricultural land and is vandalistic in the humid rainforest zones of Asia and particularly Southeast Asia (Choudhary, 1972; Holmes *et al*., 2009; Parker, 1972). *Mikania micrantha*, commonly referred to as mile-a-minute, stretches through woodland patches and grassland in the CNP buffer zone (Poudel *et al*., 2005; Sapkota, 2007). A research carried out in Chitwan National Park central region and community-buffer forest region found *M. mikrantha* to severely overwhelm riparian locations, forest edges and sparsely treed, shrub lined grasslands, as well as lower canopy areas of both natural and planted forest (Sapkota, 2007). The results on the native plant species in the Buffer zone of CNP in Nepal has been well documented by *Mikania micrantha* colonization (Rai *et al*., 2012a; Sapkota, 2007). In the Koshi Tappu Wildlife Reserve, one of the major Ramsar sites in Nepal and IBA (Baral and Inskipp, 2005), the influence of mikania weeds on Nepal's wetlands habitats is most evident. *Mikania micrantha* is regarded as an intermediary host for liver fluke and hence it is suffered from animals grazing around it (Tiwari *et al*., 2005). Invasive weeds are much more nuanced than the adverse environmental effects on agricultural areas. In rural areas, more than two-thirds of the populace lives and cultivates livelihoods. The conservation of forest resources and daily living services is very critical (Adhikari *et al*., 2004; Pandit and Bevilacqua, 2011).

Study and case studies have shown that the influence of alien species varies from habitat

degradation of endangered species to adverse effects on rural communities (Rai *et al*., 2012). By the native forage abundance and bio-mass, *M. micrantha* was harmful to rhino-food supply (Subedi *et al*., 2014). In the developing world, this is especially serious where a multitude of challenges threatens their livelihoods are exacerbated (Sapkota, 2007). The distribution of plants and the surface chemistry of grasslands have been greatly changed by another alien group *Parthenium hysterophorus* (Timsina *et al*., 2011). *M. micrantha* has appeared in the tropical and sub-tropical areas of Nepal as the most extreme weeds of the non-native species that have started to exhibit invasive characteristics (Tiwari *et al*., 2005; Rai *et al*., 2012; Murphy *et al*., 2013). It has been identified as one of the world's 100 worst invasive alien species (Lowe *et al*., 2001), and the second most damaging weed in South Pacific (Waterhouse and Norris, 1987). It has been documented as the worst in the world (Tiwari *et al*., 2005).

Impacts of IAPS in biodiversity and agriculture

Invasive species is the second largest reason for biodiversity loss after habitat defragmentation (Gaertner *et al*., 2009). Invasive species threaten biodiversity by causing disease, acting as predators or parasites, acting as competitors, altering habitat, or hybridizing with local species. Besides replacing the native species, invasive plants also change the ecology of a given habitat by changing the nutrient cycle and soil pH (Drenovsky *et al*., 2007). Invasive plants can significantly alternative biodiversity including plants, insect and microbial communities. Species extinction, habitat transition (for example, nitrogen cycle, hydrology, fire regime) and development are biological and evolutionary consequences, For example, approximately 42 % of the species reported under threats endangered are predominantly at risk from alien species (Pimentel *et al*., 2000). Invasive alien species are one of the crucial driving forces of inland waters biodiversity destruction (MEA, 2005). Comprehensive research and analysis to expose the status and impacts of invasive species in Nepal are mandated in some of the alarming impacts on the natural grasslands of national parks and conservation zones of invasive species such as *Eichhornia crassipes* and *Mikania micrantha* (Tiwari *et al*., 2005) wetlands.

Invasive plants can have a wide range of impacts on agriculture. They may act as new or additional hosts for new or existing crop diseases and pests, may cause crop yield reductions and may require increased use of pesticides to control them. This increases costs for farmers and reduces crop values. Invasive plants, which invade agricultural land, severely reduce productivity and land values. The invasion of pastures leads to loss of forages and forage value. Farmers have suffered major declines in crop yields and seed production in agro-ecosystems due to the invasion of many alien organisms. The development of *Ageratum conyzoides* in agricultural crops, particularly the ginger, millet, rice, and corn, has declined (Bhusal, 2009) and their productivity has also declined. (Oerke *et al*., 1994) officially confirmed that there was a 13% decline in agriculture production. *Amaranthus spinosus* which competes with crops for nutrients is a widespread agricultural weed (Tiwari *et al*., 2005). The research reported about 8000 species of plant exchanged or non-traded, and some 2500 of these are considered to be potentially hazardous, are thought to be agricultural weeds (Yaduraj *et al*., 2000). Among all taxa, which are estimated to be five times faster than that of terrestrial plant species in North America, at rates comparable to tropical forests (Ricciaardi and Rasmussen, 1999), around 20% of the world's aquatic plant species, in accordance with the rest of the leading species, are at risk of extinction because of plant species in addition to other significant drivers of loss in biodiversity (Moyle and Leidy, 1992). The invasion of Nepal's wetlands is concentrated on the exotic aquatic plant, such as *Eichhornia crassipes* (water hyacinth), *Alternanthera philoxeroides*, *Ipomoea spp*, *Myriophyllum aquaticum*, Pistia, *Leersia hexandra* and stratiotes (HMGN/MFSC 2002; Poudel *et al*., 2005 and Sikawoti, 2007).

Invasive alien plant species may be repositories of pathogens or carriers of diseases that are spread across bodies, such as avian influenza A (H5N1) and humans and animals affecting both warm and tropical countries (Tiwari *et al*., 2005) illustrate a lethal modern pathogen. *Ageratum conyzoides* are allergic and create an unpleasant scent, sometimes contributing to sneezing, diarrhea, headache and fever. In comparison, other invasive alien plant species are poisonous to domestic animals, such as *Xanthium strumarium*, *Ipomoea carnea, Lantana camera, Ageratum houstonianum* etc. (Tiwari *et al*., 2005). *Ageratum houstonianum* is poisonous to grazing livestock, triggering liver lesions (Sanchez and Durand, 2004) cattle will often die when they are fed. In Mozambique, goats have been confirmed to have *IIpomoea carnea* induced lysosomal storage diseases, animals have stung, and head tumors that may trigger death (Tiwari *et al*., 2005). *Xanthium strumarium* burs are hazardous substances, Carboxyatractyloside which can kill animals, cattle, sheep and swine (Parsons and Cuthbgertsonet, 1992). *Lantana camara* creates impacts on the food web level and limits the suitability of wildlife environments in the forest (Prasad, 2007). *Parthenium hysterophorus* has widened its range to cover threatened mammal populations from urban areas and grasslands to woodland eco-systems (Shrestha, 2015) and raised its resources to the hardwood forests (Bhusal *et al*., 2014). Large coverage of *Chromolaena odorata* diseases could

also lead to invasion (Rejmanek 1995). It may be attributed to limited seed quantity, robust development, fast growth, low nuclear DNAs, strong competition capacity for nutrition.

Harmful allelopathic implications of *Argemone maxicana* have been recorded for 11 germinations and cultivated seedling of crops has documented *Cassia occidentalis*, *Bidens pilosa* reduces soil fertility, *Xanthium strumarium* common in wheat field decreases productivity in soil (Tiwari *et al*., 2005). The seedling development of *Lectuca sativa* and *Amaranthus mangostanus* has been significantly affected by *Xanthium strumarium* pigment named xanthinosin (Shao *et al*., 2012). *Parthenium hysterophorus*, which triggers allergic disorders including skin issues, hay fever, asthma, is an extremely noxious weed (McFadyen, 1995; Cheney 1998). *Argemone mexicana* seed is reminiscent of mustard (*Brassica compestris*) and *Argemone maxicana* seed produces non-edible toxic oils which trigger death dropsy when cooking oil (Tiwari *et al*., 2005). *Cassia occidentalis* also recently reported toxic in seed, fruit leaves, and roots. Also, 10 cause dark brown urine, diarrhea, etc. *Ipomoea carnea* causes vomiting and diarrhea and the smell of *Hyptis suaveolens* might cause headache (Tiwari *et al*., 2005).

Benefits from IAPS

Anti-helminthic, antimicrobial, anti-malaria, anti-ulcerogenic properties and protozooicidic properties have been documented to be found in *Bidens pilosa* (Lewu and Afolayan, 2009). Also, in the North West of South Africa (Lubbe *et al*., 2007) found the traditional medicinal use of *A. achroleuca*. For the treatment of hypertension, *E. japonica* is registered. Emetic, expectorant, diuretic, laxative, Purgative, topical emollient, and diaphoretic have been identified as *Sambacus canadensis* (Charlebois, 2007). Future herbivores management attempts have been told of the release of Blackberry *Rubus niveus* levels from grazing pressure following goat eradication in the Galapagos area (Carrion *et al*., 2011). *Lantana camera* containing ß-caryophyllene, geranyl acetate, terpinyl acetate bornyl acetate and limonene remarkably inhibited the growth of plant pathogenic fungus like *Stemphylium botryosum* of lentil (Subedi *et al*., 2015) and *Excerohilum turcicum* of maize (Subedi *et al*., 2019).

Throughout the UK countryside, common pheasants *Phasianus colchicus* is a source of hunters delight. The species was imported to the United Kingdom from China as a form of game from the 18th century (Scotland Statistical Accounts, 1791–1799). Many pheasants are now raised and published annually on UK sporting estates (Robertson, 1996). Originally imported to the UK as an ornamental herb, *Rhododendron ponticum* is ideal for gardeners as it promises simple maintenance, always green nature and colorful flowers. Introduced in Europe, North America (Pimentel *et al*., 2005), the introduction of the water hyacinth *Eichhornia crassipes* and purple loosestrife *Lythrum salicaria* and improves structurally in tropical environments. In Pokhara valley, the biomass of invasive species.

Management of IAPS

Invasive alien plant species are perceived to be one of the major challenges for the earth's natural habitats and, after deforestation, is seen as a second biggest danger to the survival of biodiversity (Tiwari *et al*., 2005). According to Rejmanek (2005), effective management of biological invasion should follow three main steps from prevention, early detection and eradication and control backed up by integrated management. Due to the increasing issue of invasive species across Nepal and around the world, the National Trust for Nature Conservation (Thapa *et al*., 2014) conducted an international workshop on invasive species in Chitwan National Park, in March 2014. Furthermore, the country has established many sectorial legislation (Plant Protection Act, 1972; Aquatic Life Protection Act, 1961; Seed Act, 1988; Water resource act, 1992; The Forest Act, 1993, The National Parks Agro biodiversity Policy 2008, revised 2013 Wildlife Conservation Act, 1973 and Local Self Governance Act, 1999) to regulate and eliminate native or invasive alien species of germs, pests and weeds in crops (MFSC/CSUWN, 2011). An Integrated Pest Management (IPM) control approach (Wittenberg and Cock, 2001) also is the most effective.

In order to remove *E. crassipes* and *Pistia stratioites* from the Tikauli lakes (part of the Bishajari lakes system, Chitwan), the Hario Ban program was implemented by WWF Nepal where the project is now being carried out (WWF Nepal, 2013). To deter spread of plant pests, 111 countries have signed the International Plant Protection Convention (IPCC) since 1952 and World Trade Organization (WTO), (McNeely *et al*., 2001) accepts its requirements. In addition, current biological management methods will complement suppressive plants (Adkins and Shabbir, 2014) and re-vegetation of deteriorated sites with competitive native forage grasses (Wan *et al*., 2010), for successful handling of invasive species. In Nepal, these two invasive alien organisms are biological surveillance agents: Winter rust *Puccinia abrupta var.*

partheniicola (Jackson) Parmelee for *Parthenium hysterophorus* (Shrestha *et al*., 2015) and leaf eating beetle *Zygogramma bicolorata* Pallister, leaf spot fungi *Passalora ageratinae Crous* and stem galling fly *Procecidochares utilis Stone* and A.R Wood for *Ageratina adenophora* (Winston *et al*., 2014).

Long-term solution to combating unwanted alien species is biological management and it is only successful to delay the cycle of invasion (Sun *et al*., 2004). In 1987, fungi were found to act as successful as gallfly by *Entyloma compositarum* and *Mycovelosiella lantanae* Chupp and (Wan and Wang 2001). Invasive alien plant species in Nepal tend to be the most effective biological control agent of *Zygogramma bicolorata* , but their population remains low and their efficiencies are unpredictable year by year (Shrestha *et al*., 2015). To monitor *P. hysterophorus* effectively, it seems appropriate to balance the regulation of *Z. bicolorates* with other biological control agents, redistribution by competitive plant and other economic, physical and chemical steps (Adkins and Shabbir, 2014). The immediate steps to monitor invasion and to reduce negative effects and application of herbicides in forest areas should be avoided by mechanical removal of weeds (Sankaran *et al*., 2014). For instance, where tiny satellite populations physically are eliminated to avoid their spread, alien species may be effectively managed during initial stages of growth (Wittenberg and Cock, 2001). It is uncertain if a standard quarantine screening should be carried out prior to its release, as did India when *N. eichhorniae* was released in 1984 (Jayanth, 1988). The concern for biological invasion has not yet been discussed adequately, the recently drawn up National Biodiversity Strategy and Action Plan has thoroughly embraced the invasive alien species challenge with several strategies to handle them

Conclusion

Twenty-six invasive alien plant species with negative impacts on the environment and agricultural production have been reported to date in Nepal. The introduction of such species threatens to agriculture production and biodiversity. *Micania macarantha* including other species is serious weeds in agriculture field and national parks. Due to open borders and less effective quarantine (weed pest) in the Nepal-India border, any exotic species established in India can easily spread into Nepal sooner or later. Preventing the introduction, early detection and reporting of infestation of these species, awareness at the local level are recommended as a strategy for managing these species in Nepal.

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