Invasive alien plants and *Eupatorium*: Biodiversity and livelihood

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Invasive alien species colonize aggressively, threatening native biodiversity. The success of invasive alien plants is due to their opportunistic exploitation of anthropogenic disturbances, the absence of natural enemies, and, frequently, their allelopathic competitive strategies. Invasive species can have a significant impact on development, affecting sustainability of livelihood, food security and essential ecosystem services and dynamics. *Eupatorium adenophorum* Spreng. and *E. odoratum* L. (forest killer, local name banmara) are unpalatable and highly competitive. They have taken hold in scattered sites throughout eastern and central Nepal, currently, they are also rapidly spreading westward. Efforts are being made to control established invasive species, but a better understanding of why species become invasive offers the possibility of taking pre-emptive measures.

Key words: Invasive alien plant species, *Eupatorium*, biological control, livelihood

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Introduction

All of the threats to Nepal's biodiversity are due to the activities of human beings: habitat destruction and over-exploitation are accompanied by introduction of exotic species leading to habitat change and soil degradation (Chaudhary 1998). The wide range of habitats and environmental conditions makes Nepal especially vulnerable to the establishment of invasive species of foreign origin. Potential invasive alien species from most areas of the world may find suitable habitat somewhere in Nepal. In recent years invasive species have gained considerable notoriety as major threats to native species and ecosystem.

Introduction of plants from one place to another may be natural or planned. Accidental and intentional introduction by gardeners, traders and foresters have contributed to the large number of exotic plants in Nepal. Nepal has a long history of introduction of non-native species, especially species proven to be productive elsewhere and offering potential economic benefits to the country. *Tamarindus indica* (tamarind), originally from Africa, is believed to have been first introduced into Turkey in 126 B.C.-220 A.D. (Yan et al. 2001), spreading gradually toward China along the 'Silk Road'; by now it has been thoroughly naturalized in Nepal. In the 19th century, the British were major contributors, bringing economically important plants from almost every continent (Islam 1991). Some of the alien tree species, such as *Tectona grandis* (teak) and *Albizia* spp. (siris), were introduced for their timber potential or for watershed protection. Some now-common fruit trees, including *Litchi chinensis* (litchi), *Ananas comosus* (pineapple), and *Cocos nucifera* (coconut), were also introduced, as were most of the pulses and oil yielding plants (Das 1982). Similarly, vegetables such as *Cucurbita* spp. (cucurbits), *Raphnus sativus* (radish), *Solanum tuberosum* (potato) and *Daucus carota* (carrot), came from other countries and have been welcomed by Nepalese farmers. Likewise, *Eupatorium odoratum, E. adenophorum, Lantana camara* and *Eichhornia crassipes* were first introduced as ornamental plants and they are now well established and dominant in forest, farmland, wetland and wasteland.

In the 20th century, the country's economic development including growth in trade and transportation systems multiplied the avenues of introduction and spread of invasive species. Newcomers such as *Leucaena leucocephala* (ipil ipil), *Eucalyptus camaldulensis* (masala), *Acacia auriculoformis* (watal), *Cassia occidentalis* (chakor) and *Samania saman*, are becoming plantation favorites. In the hills and even in the Terai, fields are sown with the woody legume species *L. leucocephala* in order to rehabilitate soils left bare by intensive deforestation. In recent decades, however, there has been a growing awareness of the significant impact of such transformations of indigenous ecosystems.

Biological invasion worldwide threatens biodiversity, ecosystem dynamics, resource availability, national economy and human health (Ricciardi et al. 2000). It is a pervasive and costly environmental problem (Larson et al. 2001). Over the past half century it has become the focus of intense management and research activities worldwide (Kennedy et al. 2002). The Convention on Biological Diversity (CBD), to which Nepal and 177 other countries are party, calls on governments to prevent the introduction, control or eradication of those alien species that threaten ecosystems, habitats or species (Article 8). However, approaches taken to combat this phenomenon and even the data on which they should be based are clearly inadequate to deal with the onslaught of invasive species in Nepal. Participatory biodiversity conservation programme and an inventory of alien species are being run by International Union for Nature Conservation Nepal (IUCN/Nepal). However, accurate predictions of community susceptibility to invasion remain elusive. No story of the ecosystem of Nepal will be complete or comprehensive without taking into account the role played by the well-established *Eupatorium* species (local name banmara, or "forest killer"). This study is an attempt to ➡

BOX 1. Recommended terminology in plant invasion ecology

Native plants	Plant species or subspecies or lower taxa, occurring within their natural range (past or present) and dispersal potential (i.e. within the range they occupy naturally or could occupy without direct or indirect introduction by humans)
Alien plants	Plant taxa in a given area whose presence there is due to intentional or accidental introduction as a result of human activity (Syn.: exotic plants, non-native, non-indigenous plants)
Casual alien plants	Alien plants that may flourish and even reproduce occasionally in an area, but which do not form self-replacing populations and which rely on repeated introduction for their persistence
Naturalized plants	Alien plants that reproduce consistently (casual alien plants) and sustain populations over many life cycles without direct intervention by humans. They often recruit offspring freely, usually close to adult plants, and do not necessarily invade natural or human-made ecosystems
Invasive plants	Naturalized plants that produce reproductive offspring, often in very large numbers, at considerable distances from parent plants (approximate scales: > 100 m; < 50 years for taxa spreading by seeds and other propagules; >6 m/3 years for taxa spreading by roots, rhizomes, stolons, or creeping stems), and thus have the potential to spread over a considerable area
Invasive alien plants	Plants become established in natural or seminatural ecosystems or habitats and are agents of change, threatening native biological diversity
Weeds	Plants (not necessarily alien) that grow in sites where they are not wanted and which usually have detectable economic or environmental effects. Environmental weeds are alien plant taxa that invade natural vegetation, usually adversely affecting native biodiversity

Sources: De Candolle (1855), Humphries et al. (1991), Randall (1997), Richardson (1998), IUCN/SSC (2000), Richardson et al. (2000)

review available information on invasive species and to recommend solutions.

Invasive species

The term 'invasive species' denotes plants and animals that: (i) have been introduced into ecosystems where they are not native by either intentional or unintentional human activity, (ii) have established self-reproducing populations, and (iii) have caused significant changes in pre-existing natural or artificial ecosystems (Richardson 1998) **(Box 1)**.

Eupatorium species have a remarkable range of altitudinal distribution (800 to 2000 m asl) in Nepal (Sharma and KC 1977), which overlaps with human settlements (Shrestha 1989). It has been sporadically spreading and now it is reported from 305 to 2500 m in abandoned slopes after slash and burn cultivation (Joshi 1983), fallow lands and disturbed forests with severe human interference. It is represented by six species in Nepal (Press et al. 2000) viz. *E. acuminatum, E. adenophorum, E. cannabinum, E. capillifolium, E. chinense* and *E. odoratum* out of which two (*E. adenophorum* and *E. odoratum*) are highly undesirable (Singh 1979). *E. odoratum* and *E. adenophorum* are aggressively colonizing abandoned slopes in the tropical to lower temperate zones, respectively (NBLP 2001). *E. adenophorum* was introduced in India after 1498 (Biswas 1934) and it is likely that it was introduced into Nepal from India through eastern border (Banerji 1958) probably before 1950. It is now widespread in eastern and central part of Nepal.

Mode of invasion

Biological invasion is a natural process. Nevertheless, the growing human population and improved worldwide transport have led to a skyrocketing incidence and scale of invasions by non-indigenous species (Ewel et al. 1999). Their introduction relies on mutualism in their new habitats to overcome barriers to establishment and naturalization (Richardson et al. 2000). Parasitism is significantly reduced in organisms in the introduced range, a fact that supports the 'enemy release hypothesis' (ERH) - the idea that species are more likely to become invasive when they are released from control by their natural enemies (Torchin et al. 2003). The biotic resistance hypothesis (BRH) argues that diverse communities are highly competitive and readily resist invasion because interactions with native species, including natural enemies, limit invaders' impacts (Darwin 1859, Maron and Vila 2001). As a result, deep forest, which is less diverse than the forest margin, is vulnerable to ecological invasion (Pimm 1984). Distribution of invasive plants directly correlates with human disturbances, which can be easily seen in forest fringe areas. In general, increasing the frequency, intensity, spatial patterns, or scale of disturbances will likely lead to faster replacement of native species by exotic species (Yan et al. 2001). Massive invasion and spread is also typically allelopathic (Rai and Tripathi 1982, Chettri 1986).

Intentional introduction has been performed by various institutions for economic development, recreation uses, ecosystem betterment, highway beautification and creation of wildlife habitat. It may also take place due to import without quarantine of biological inputs, seeds and saplings, implements and fertilizers from foreign countries. Plants introduced for commercial and ecological purposes include *Eucalyptus* species, *Grevillea robusta* and *Leucaena leucocephala*. Some of the most invasive and widespread unintentional introductions include the *Amaranthus* spp. (amaranth), *Solidago* spp. (gold enrod), *Eupatorium* spp. (crofton weed), *Lantana camara*, and *Cestrum* spp. **(Table 1)**.

Impacts: boon or bane?

Introductions of non-native species can be both boon and bane to society. The relative magnitudes of costs and benefits vary both in space and over time. Although an introduction may meet a desired objective in one area, at one time, or for some sectors, unwanted and unplanned effects may also occur.

Socio-economic impacts

Humans depend heavily on non-native species for food, shelter, medicine, ecosystem services, aesthetic enjoyment and cultural identity. Intentionally introduced plants have priority over native species with respect to household economy and national economy. Only nine crops (wheat, maize, rice, potato, barley, cassava, soybean, sugarcane, and oats) which are cultivated far beyond their natural range yield over 70% of the world's food (Sattaur 1989). Similarly, 85% of our industrial forestry plantations are established with species of just three genera (*Eucalyptus, Pinus* and *Tectona*), which are

TABLE 1. Some alien species, which have detrimental impacts on ecosystems

Scientific Name	Origin	Impact on the ecosystem
Ageratum conyzoides (Asteraceae)	Mexico	Weed frequently encountered on cultivated land and wasteland
Amaranthus spp. (Asteraceae)	N. America	Invasive, widely distributed weeds
Cassia occidentalis (Fabaceae)	Trop. America	Common weed of hilly areas; prevents the regeneration of native species
Cestrum diurnum (Solanaceae)	Trop. America	Weed of roadside and wasteland
Chenopodium ambrosioides (Chenopodiaceae)	Trop. America	Weed of roadside
Convolvulus arvensis (Convolvulaceae)	Europe	Common weed of wasteland and fallow land
Conyza spp. (Asteraceae)	N. America	Common weed of farmlands and wastelands
Eichhornia crassipes (Pontederiaceae)	S. America	Probably the world's most widespread and serious invasive aquatic weed
Eucalyptus camaldulensis (Myrtaceae)	Australia	Controversy over water recharge and discharge
Eupatorium adenophorum (Asteraceae)	West Indies	Common weed of waste land; suppressed the regeneration of other species
Eupatorium odoratum (Asteraceae)	Jamaica and Mexico	Common weed of waste land; suppressed the regeneration of other species
Grevillea robusta (Proteaceae)	Australia	Agricultural landscape and roadside invasion
Ipomoea carnea (Convolvulaceae)	America	Common weed in aquatic and marshy habitat
Lantana camara (Verbenaceae)	Trop. America	Common weed of wastelands
Leucaena leucocephala (Fabaceae)	Trop. America	Suppress the regeneration of other species
Ludwigia adscendendens (Onagraceae)	C. America	Common weed of all habitats
Mimosa pudica (Fabaceae)	S. America	Common weed of cultivated and wasteland
Opuntia stricta (Cactaceae)	Caribbean Coastal area	Widespread weed in hot and dry areas
Plantago spp. (Plantaginaceae)	N. America	Common in grassland and along roadside
Solidago sp. (Asteraceae)	N. America	Common in suburbs, along roadside

Sources: De Bach (1964), Das (1982), Islam (1991), Richardson (1998), Hossain and Pasha (2001)

also cultivated as exotics (Evans 1992). Thus, although native species fulfill some human requirements, non-native species play an integral role in the economies and culture of most countries.

Despite the many benefits provided by alien species, deliberate and accidental introduction of these species poses a threat to native biodiversity and rural livelihoods. The impact may be devastating, and may entail reduction of carrying capacity of ecosystem (Banerji 1958), alterations in structure and function of natural ecosystem, human health hazards (Ricciardi et al. 2000), crop failure, species extinction, and reduced water yield from watersheds (Harrington and Wingfield 1998). The distribution and composition of biodiversity and local forest resources is affected directly by the invasive species due to change in host pathogen relationship and species competition. The invaders thereby affect the availability of forest resources, both timber and non-timber forest products. This may cause a change in the local people's utilization patterns of forest resources.

Invasion of *Eupatorium* is an enormous problem. Transitional zones and swamp forest are being invaded by dense monospecific stands of *Eupatorium*, which have little understorey except for *Eupatorium* seedlings. Although the species of *Eupatorium* have pesticidal properties (Chettri 1986) which have been applied in a few areas of Nepal, no commercially viable application has been found. Neither cattle nor goats eat this plant, and areas traditionally used for grazing can no longer be used for this purpose, forcing villagers to walk farther in search of grazing pasturage. The increased time spent on this activity translates into a substantial economic loss. The alternative, trying to control the weed, also involves a burden of labour and financial investment.

Eupatorium spp. growing in fallow land prevents soil erosion. They are used as green manure during spring, when the plant is heavily laden with leaves. Dried *Eupatorium* may be burnt to yield potash rich fertilizer. In some parts of the country, it has been used for cattle bedding material (Shrestha 1989). *Eupatorium* leaves when boiled and taken, cure severe stomachache and the apical leaves when made into paste and slaked with lime and applied on the cuts, stops bleeding (Joseph and Kharkongor 1981). Local people apply the fresh juice of *Eupatorium* leaves to stop bleeding from cuts and wounds (NBLP 2001).

Ecological impact

The dominance of *Eupatorium* species has occurred in transitional zones with adequate moisture (Kunwar 2000) and disturbance regimes, which can be easily seen in disturbed forest sites (Baniya and Bhattarai 1984). This plant inhibits growth and may even kill local plants and domestic animals (Jha and Sah 1985). Although many factors interact to determine the susceptibility of an ecosystem to invasion by *Eupatorium*, habitats may be ranked according to their vulnerability: undisturbed forest < moderately disturbed forest < disturbed forest < shrub land < grassland < dunes < denuded land (Richardson and Higgins 1998). Roads or trails, which usually occur in transition areas, often function as conduits for the dispersal of alien plants (Hobbs and Mooney 1991).

Invasive alien species (*Ageratum conyzoides*, *Eupatorium* spp., *Imperata cylindrica* etc.) grow luxuriantly in sunny exposed wasteland (Kunwar et al. 2001) and encroach fresh landslides or areas with deep gullies and open grasslands. The invasive species spread primarily through wind dispersal and propagate through

vegetative means (Saxena and Ramakrishnan 1984). The once slow, erratic and small-scale transfer of species has shifted to a rapid and large-scale translocation; the rate of invasions in San Francisco Bay, for instance, has accelerated from an average of one new species established every 55 weeks during the period 1851-1960 to one new species every 14 weeks during the period 1961-1995 (Cohen and Carlton 1998). Thus, the invasive effects of these species become compounded because of their growth mode and the reproductive strategy. They can promote fire and alter water and nutrient availability. Moreover, the cattle grazing and trampling has allowed noxious *Eupatorium* spp. to take root (NEPA 1998).

It is argued that the complexity of the interactions between alien plants, the native biota and the environment they invade precludes prediction (Bruke and Grime 1996). Invasive alien species reduce biodiversity, replace economically important native plant species and increase the investment in agriculture and silviculture (Ricciardi et al. 2000), disrupt prevailing vegetation dynamics and alter nutrient cycling (Richardson 1998). The invasion process affects all ecosystems but the impact of particularly aggressive species is especially severe on the structure and function of vulnerable and isolated ecosystems (SCBD 2001). In native forests, invasive alien plants are able to dominate the understorey, to strangle saplings and to suppress native species (Denslow 2002). The problem will likely worsen with time because of climatic changes that promote species migration worldwide.

Invasive plants also have a major impact on catchment hydrology: 30-70% lower water runoff is reported from watershed areas with dense stands of alien species (Geldenhuys 1986). Most impacts are detrimental to the invaded systems and threaten sustained functioning and the provision of important ecosystem services. The reduced stream flow obviously has detrimental impacts on aquatic biota. It can also disrupt stock watering, irrigation, tourism and recreational use of resources and heritages.

Controlling measures

The spread of invasive alien species is creating complex and far-reaching challenges that threaten both the natural biological niches of the earth and the well-being of its citizens. Some aspects of the problem require solutions addressing the specific values, needs, and priorities of local ecosystems, national environment and sustainable development. It is now widely accepted that the control of invasive alien species is not a short-term or single effort. On the contrary, it requires detailed surveillance, monitoring and research into the most suitable long-term control options. Much effort is devoted to controlling them after they are established, but a better understanding of why species become invasive offers the possibility of taking pre-emptive measures (Clay 2003).

A variety of well-known methods can be used as measures to control alien invasive species and their spread. These vary from administrative (national and international cooperation and coordination, database management, legislation regarding quarantine and so on), to mechanical (including digging up root systems, slashing and chopping), to chemical (utilizing acceptable and tested herbicides) and to biological (making use of plant specific insects or pathogens to damage and control aliens). These options are generally incorporated into integrated control programme employing a combination of strategies which together may impede and control the invasive species to some extent.

Suitable strategies are needed to conserve the forest and its biodiversity while ensuring a sustainable resources base for indigenous people. Biological control of *Eupatorium* species using gall fly *Procecidochares utilis* has been carried out throughout world including Nepal. It was successful in Hawaii, USA, and elsewhere (Bess and Haramota 1971); however, this technique has not yet been successful in Nepal. 'Best management practices' should include removal of known invasives, and their use should be discouraged. Known invasive alien plant should be replaced with non-invasive native species or with exotics unlikely to spread into native plant communities. Horticultural material such as seed and green mulch should be inspected for their potential to introduce troublesome species. Nurseries, botanical gardens and government agencies should inform the public of the potential danger of invasive species and should encourage the use of alternative native or exotic species unlikely to contribute future invasive species problem.

Some strategies that urgently require implementation are: (i) alert local people to the importance and impacts of alien species; (ii) accord highest priority to preventative initiatives designed to protect vulnerable ecosystems; (iii) give priority to the eradication of invasive alien species on areas that with highly distinctive ecosystems and threatened and endemic species ; (iv) undertake a systematic compilation of research and educational materials and initiate a database on invasive species; (v) conduct more research; (vi) introduce legislation regarding quarantines; and (vii) strengthen international cooperation, national coordination, and local implementation of policies concerning alien species.

Conclusion

The deliberate introduction of alien invasive species threatens to native species, habitats and ecosystem functions and is economically costly. The major impact of alien invasion follows reduction in forest product availability, which directly affects the rural livelihood because the subsistence of rural livelihood entirely relies on such products. Thus, some aspect of the problem requires solutions addressing the specific needs and priorities of human livelihood, local ecosystems and national environment and sustainable development. Concurrently, it is more essential to understand why these species become invasive. ■

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