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Invasive Alien Species: Diversity, Impact, and Ecological Significance with Reference to Rishikesh, Uttarakhand, India

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Abstract: India, as one of the world's megadiverse countries, faces significant ecological challenges from the spread of invasive alien species (IAS). This study investigates the diversity and ecological impact of IAS in and around Rishikesh, Uttarakhand, located in the foothills of the Himalayas. A total of 30 invasive plant species were recorded across varied habitats including wastelands, agricultural fields, and forest margins. Field surveys, herbarium references, and community consultations revealed that most species were herbs or undershrubs, primarily of tropical American origin. These species have caused native displacement, habitat degradation, and soil quality reduction. However, some also offer limited ecosystem services, such as pollinator support and medicinal use. The study emphasizes the importance of early detection, public awareness, and integrated management strategies—manual, mechanical, chemical, and biological—for effective IAS control. It underscores the urgent need for systematic monitoring and sustainable mitigation strategies to protect native biodiversity in the fragile Himalayan ecosystem.

Keywords: Invasive Alien Plant Species • Nativity • Ecological Impact • Rishikesh • Uttarakhand

Introduction

India, accounting for only 2.4% of the world's land area, contributes approximately 8% to global species diversity. Of the estimated 1.75 million described species worldwide, a significant proportion is recorded in India (Mandal 2011). Notably, fungi and insects comprise nearly 60% of India's biological wealth (Khoshoo 1996). With about 45,000 plant species and 90,000 animal species, India remains one of the world's 17 megadiverse countries, although only about half its territory has been thoroughly surveyed (MoEF 2008).

India also hosts a vast number of alien species, including about 18,000 plant species. Among these, approximately 25% are considered invasive (Raghubanshi et al 2005). Invasive species—non-native organisms that adversely affect ecosystems—pose a serious threat to biodiversity, agriculture, health, and livelihoods. They tend to exhibit rapid growth, high reproductive output, aggressive dispersal, and environmental adaptability.

Most Invasive Alien Species (IAS) arrived unintentionally through global trade, agriculture, or as ornamental introductions. Their traits—such as extended flowering, short generation time, and broad habitat adaptability—enable them to become dominant pioneers. Some also exhibit allelopathic effects, suppressing native flora.

The impacts of IAS are diverse and severe. In forests, grasslands, and aquatic systems, invasive species suppress native vegetation, alter nutrient cycles, and degrade ecosystems. Agricultural losses attributed to invasive species account for nearly 45% of total crop losses, surpassing losses due to insects and pathogens. Despite their harm, some IAS offer ecosystem services, such as supporting pollinators or providing ethno-botanical resources. This duality necessitates context-sensitive management approaches.

The Himalayan region, Indo-Gangetic plains, Western Ghats, and Deccan Plateau have all experienced increasing biological invasion due to a combination of anthropogenic pressures, climate change, and global trade. The socio-economic impact is also significant, as invasive degrade agricultural lands, affect livelihoods, and lead to loss of ecosystem services such as soil fertility, pollination, and water retention. Based on field surveys, literature reviews, and local observations around the Rishikesh region of Uttarakhand, this manuscript documents the presence and spread of major invasive alien plant species, their origin, their ecological impacts, economic impacts, and control measures.

Materials and Methods

Study Area: Rishikesh City, (30.103368°N, 78.294754°E), located at an elevation of 372 m, lies in the Dehradun district of Uttarakhand. It is also known as the "Gateway to the Garhwal Himalayas" and the "Yoga Capital of the World". Surrounded by forested foothills of the Himalayas, the region represents a transitional ecological zone that makes it vulnerable to biological invasions. The city lies along the banks of the Ganga River, which plays a vital role in shaping its hydrological and ecological dynamics. Rishikesh occupies a transitional ecological zone – a region where the plains meet the mountainous terrain of the Himalayas. This unique positioning fosters a rich mosaic of habitats, ranging from riverine ecosystems to forested hills. However, such ecological diversity also makes the area highly susceptible to biological invasions, particularly from invasive plant species that can outcompete native flora and disrupt local food chains.

The study involved ecological surveys across diverse habitats in Rishikesh, including wastelands, agricultural fields, riverbanks, roadsides, and forest margins. Field identification was supported by herbarium records, literature, and local consultations. Invasive species were documented in a tabular format including their botanical name, family, life form, origin, habitat, and local uses.

Results and Discussion

A total of 30 invasive alien plant species were recorded in present study. Most species were herbs (80%), followed by shrubs (10%), trees (6.66%), and grasses (3.33%). Dicots comprised 93.35% of the total species, the rest being monocots. The species included *Ageratum conyzoides*, *Lantana camara, Parthenium hysterophorus, Eichhornia crassipes,* and *Prosopis juliflora* among others. Dominant families included Asteraceae, Mimosaceae, Convolvulaceae, Solanaceae, Amaranthaceae and Poaceae. In terms of habitat, these species were predominantly found in wastelands (48%), followed by agricultural fields (20%), roadsides (14%), and forests (8%). The highest percentage of invasive taxa was found within 1,500m altitude (94%). The majority of species originated from tropical America (49%), tropical Africa (9%), South America (7%), and Europe (4%). According to Sekar et al., (2012) the American continents contributed majority of noxious invasive plants in the Uttarakhand. Around 84 species, including those mentioned in regional studies, are known for medicinal use. Other uses include fiber production from *Cannabis sativa* and *Sida acuta*, handicrafts from *Borassus flabellifer*, and fuel or social forestry applications of *Leucaena leucocephala*. However, 27 species had no significant known local uses.

Highly disruptive species such as *Lantana camara* and *Parthenium hysterophorus* were observed to have strong allelopathic effects, competitive dominance, suppression of native regeneration, reduced species richness, and disruption of soil chemistry and food chains (Thiruppathi et al., 2020; Sharma et al., 2017; Negi et al., 2021). Comparisons with other studies in Uttarakhand and Central India reflect similar patterns, with genera such as *Ipomoea*, *Solanum*, *Euphorbia*, and *Corchorus* being dominant (Singh & Kohli, 2006;

Tripathi et al., 2019). These American-origin plants are particularly successful in colonizing Indian ecosystems due to absence of natural predators, climatic compatibility, and frequent land disturbances. (Lake et al., 2004).

The impacts of these species extend beyond ecology. In agriculture, invasive reduce yields, degrade soil, and necessitate increased input costs. In forests, they alter structure and species composition. In aquatic habitats, species like *Eichhornia* obstruct water flow, impact fish diversity, and interfere with local livelihoods. Nonetheless, certain IAS support pollinators by providing consistent floral resources from spring through winter.

Control and Management Strategies: There are four main strategies to control or eradicate invasive species: manual, mechanical, chemical, and biological (Syrett et al., 2000). Encroachment by several invasive alien species into uphill of Himalaya is matter of concern, as some of the invasive species are able to form large carpets of themselves on the land surface and change the natural habitats which may eradicate several habitat specific native species from the area. (Rawat et al. 2017). Although manual removal and community awareness campaigns have been implemented, they remain insufficient. Mechanical methods include uprooting and tillage. Chemical control using herbicides is effective but environmentally hazardous. Crop competition through intercropping and strong rotations can suppress invasive growth. Biological control, such as the introduction of natural enemies (e.g., *Zygogramma bicolorata* against *Parthenium* or *Cactoblastis cactorum* against Opuntia), offers eco-friendly alternatives. Eco-restoration, replanting native flora, and ethnobotanical usage promotion are other viable strategies. Policymaking should emphasize strict quarantine, invasive species risk assessment, and integration of IAS control into forestry and agriculture planning.

Table 1: Invasive Alien Species Observed in Rishikesh and Their Characteristics

SN	Name of species	Common name	Life form	Habit	Origin	Family	Local Uses
1.	*Ageratum conyzoides*	Billy goat weed	Herb	Annual	Tropical America	Asteraceae	Medicinal
2.	*Alternanthera philoxeroides*	Poppy plant	Herb	Perennial	Tropical Americana	Amaranthaceae	Not known
3.	*Argemone mexicana*	Poppy plant	Herb	Annual	South America	Papaveraceae	Medicinal
4.	*Calotropis gigantea*	Crown flower	Shrub	Perennial	Tropical Africa	Asclepiadaceae	Medicinal, sacred plant
5.	*Cannabis sativa*	Marijuana, bhang	Herb , undersh rub	Annual/pe rennial	Central Asia	Cannabaceae	Rope making, clothe making, sac making, medicinal, condiment, fibre
6.	*Catharanthus pusillus*	Tiny Periwinkle	Herb	Annual	Tropical America	Apocynaceae	Medicinal and ornamental properties
7.	*Celosia argentea*	Plumed cockscomb	Herb	Annual	Tropical America	Amaranthaceae	Control growth of the parasitic striga plant.
8.	*Chenopodium album*	Wild spinach/ bathua	Herb	Annual	Europe	Chenopodiacea e	Food
9.	*Convolvulus arvensis*	Field bindweed	Herb	Annual	Europe	Convolvulacea e	Medicinal
10.	*Corchorus aestuans*	East Indian mallow	Herb	Annual	Tropical America	Tiliaceae	Medicinal
11.	*Cuscuta reflexa*	Giant dodder	Herb	Annual	Mediterran ean	Cuscutaceae	Medicinal

12.	*Eicchornia crassipes*	Water hyacinth	Herb	Annual	Tropical America	Pontederiaceae	Excellent source of biomass
13.	*Eupatorium adenophorum*	Sticky snakeroot	Herb	Annual	Tropical America	Asteraceae	Medicinal, vegetable
14.	*Euphorbia hirta*	Asthma plant	Herb	Annual	Europe	Euphorbiaceae	Medicinal, vegetable
15.	*Impatiens balsamia*	Touch me not	Herb	Annual	Tropical Americana	Balsaminaceae	Traditional remedies for disease and skin
16.	*Ipomoea ericarpa*	Morning glory	Herb	Annual	Tropical America	Convolvulaceae	Edible and medicinal uses
17.	*I. quamoclit*	Cypress vine	Herb	Perennial	Tropical America	Convolvulaceae	Ornamental
18.	*Lantana camara*	Tick berry/gum phool in Assam	Herb	Perennial	Tropical America	Verbaceae	Medicinal, ornamental and as a host plant
19.	*Leucacena latisiliqua*	Wild tamarind	Tree	Perennial	Tropical America	Mimosaceae	Forage and fodder, green manure and biomass production, as a food for paper industry
20.	*l. leucocephala*	Cow/horse tamarind	Tree	Perennial	Tropical America	Mimosaceae	Medicinal, as a dye, ornamental, as a host and nitrogen fixer.
21.	*Malvastrum coromandelianum*	Threelobe false mallow	Herb	Annual	Tropical America	Malvaceae	Medicinal, fibre.
22.	*Mikania micrantha*	Bitter wine	Herb	Perrenial	South America	Asteraceae	Heal cuts and stop minor external bleeding.
23.	*Mirabilis jalapa*	4'0 clock plant	Herb	Annual	Peru	Nyctaginaceae	Food colouring, for vulnerably (wound healing purposes), helps in bioremediation, used to treat diarrhoea, dysentery, syphilis.
24.	*Opuntia vulgaris*	Prickly pear	Shrub	Perennial	South America	Cactaceae	Fruits edible
25.	*Oxalis corniculata*	Wood sorrel	Herb	Perennial	Europe	Oxalidaceae	Vegetable
26.	*Parthenium hysterophorus*	Carrot grass/gajar ghas	Herb	Annual	Tropical Americana	Asteraceae	Medicinal, herbicide, insecticide and pesticide.
27.	*Passiflora foetida*	Wild maracuja/ water lemon	Herb	Perennial	Tropical South America	Passifloraceae	Fruit and young leaves are edible, dry leaves used in tea to relieve sleeping problems.
28.	*Pennisetum purpureum*	Elephant grass or Uganda grass	Grass	Annual	Tropical America	Poaceae	Fodder crop, prevents soil erosion improve soil fertility.
29.	*Prosopis juliflora*	Cuji, aippia	Shrub	Perennial	Mexico	Mimosaceae	Traditional source of food in peru, chile and California, as an

							alcoholic beverage
30.	*Solanum nigrum*	European black nightshade	Herb	Annual	Tropical America	Solanaceae	Medicinal, fruit edible

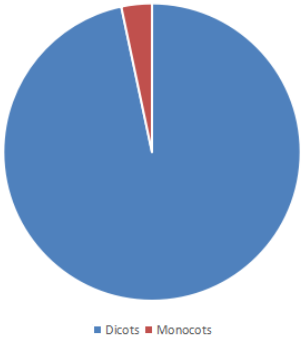

Figure 1: Pie chart showing percentage of dicots and monocots

Table 2: Impact of Selected Invasive Species on Ecosystem Services

Species	Primary Ecosystem Impact	Local Observations
Lantana camara	Outcompetes native shrubs, reduces grazing	Reduces understory diversity
Parthenium hysterophorus	Allelopathic, allergenic	Skin rash, asthma common in monsoon
Eichhornia crassipes	Blocks waterways, reduces oxygen	Found clogging Ganga canal outlets
Mikania micrantha	Covers native trees and shrubs	Seen in Rajaji buffer areas
Ageratum conyzoides	Rapid colonizer of disturbed soils	Common in maize and wheat fields

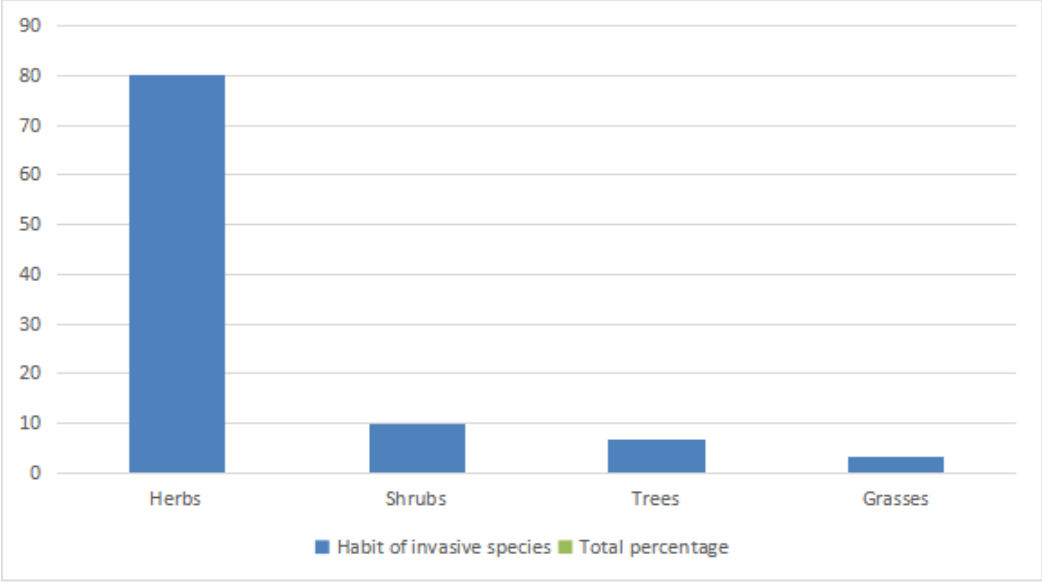

Figure 2: A bar graph depicting the total proportion of invasive species.

Conclusion

The study reveals the dominance of herbaceous invasive species in the Rishikesh region, mainly of American origin. These species have caused significant ecological and economic impacts, with a few also providing limited benefits. The findings emphasize the urgent need for integrated, context-sensitive management strategies combining ecological restoration, community participation, and

policy regulation to safeguard native biodiversity in the fragile Himalayan foothills.

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