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DIVERSITY AND DISTRIBUTION PATTERN OF ALIEN PLANT SPECIES ALONG THE ALTITUDINAL GRADIENT IN DISTRICT PAURI, UTTARAKHAND, INDIA

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ABSTRACT

Human activities are involved in direct destruction of habitats. Next to man alien invasive plants are major threats to natural ecosystem. The present study attempts to understand baseline information which can measure future effects of climate change and anthropogenic changes on vegetation in mountain areas. The observed pattern of associations between species distribution and elevation zones is likely to help in understanding the possible effects of climate change and its impact in alien plant species distributions shifting towards higher altitudes. Maximum alien species distribution is found at 1600 to 2000 m (amsl) in the study site. A total of 82 plant species under 72 genera, belonging to 39 families are identified as alien plant species based on extensive field observations, herbarium and literature consultations. Distribution of invasive species based on growth form shows that the maximum number of exotic species contribution in the study area are herbs (56%), followed by shrubs(20%), and trees (24%). Among these Tropical American native species contribute 26%, South American native species contribute 21%, and African, European species each realm respectively contribute 9%, 8%. In the study area 67% alien species are naturalized and 33% species are casual. There is an increasing concern among foresters, ecologists, botanists, conservationists, and policy makers about the threat of uncontrolled introduction of alien aggressive, invasive plant species.
Keywords: Invasive, Alien plant species, Nativity, Altitude

Introduction

Biological invasion occurs when species move from one geographical region to another, where they establish, proliferate, and persist (Mack *et al*., 2000). In a community, a native species is the one that is naturally found in a given area, whereas introduced or exotic species result from human-induced introductions or accidental entries (Carlton, 1996).With increase in global trade over the last few decade, humans have been accidentally and deliberately dispersing and introducing plants to ecosystems beyond their native range (Mack *et al*., 2000).

Alien species become invasive when they are introduced intentionally or unintentionally outside their natural habitats into new areas where they express the capability to establish, invade and out-compete native species (Patil *et al*., 2010; Pant and Sharma, 2010). Not every introduction results in naturalization, and only a few of those that become naturalized may become invasive. As a statistical generalization, Williamson and Fitter (1996) proposed the ‘tens rule’. This rule suggests that 1 in 10 of the biota brought into a region will escape and appear in the wild, 1 in 10 of those will become naturalized as a self-sustaining population, and 1 in 10 of those populations will become invasive.

Mountains are of great significance owing to the fact that they support very diverse ecological communities, including many endemic species (Körner, 1999), and have great value for historic, aesthetic and economic reasons. Many factors are known to determine distribution of alien plant species. In mountain areas, altitude has the most obvious effect on distribution of plant species with many environmental factors varying simultaneously along elevation gradients (Körner, 2007).

The Himalaya has been recognized as one of the 36 global biodiversity hotspots for its unique and rich biodiversity that is under severe threats (Palni and Rawal, 2013; Sharma *et al*., 2016). The Indian Himalayan region contributes a large proportion of this hotspot. This region is provider of goods and range of ecosystem services to sustain life of millions of people within and well beyond its physical boundaries. Value of diverse forest ecosystem of Himalayan region is well known Singh, (2014). The Indian National Action Plan on Climate Change (NAPCC) has recognized Himalayan region vital for ecological security of the country. However, NAPCC also underlines the intense vulnerability of the region due to anthropogenic activities and environmental perturbations, including climate change and biological invasion (Adhikari *et al*., 2015; Mamgain and Joshi, 2017; Negi *et al*., 2019).

Materials and Methods

Study Area

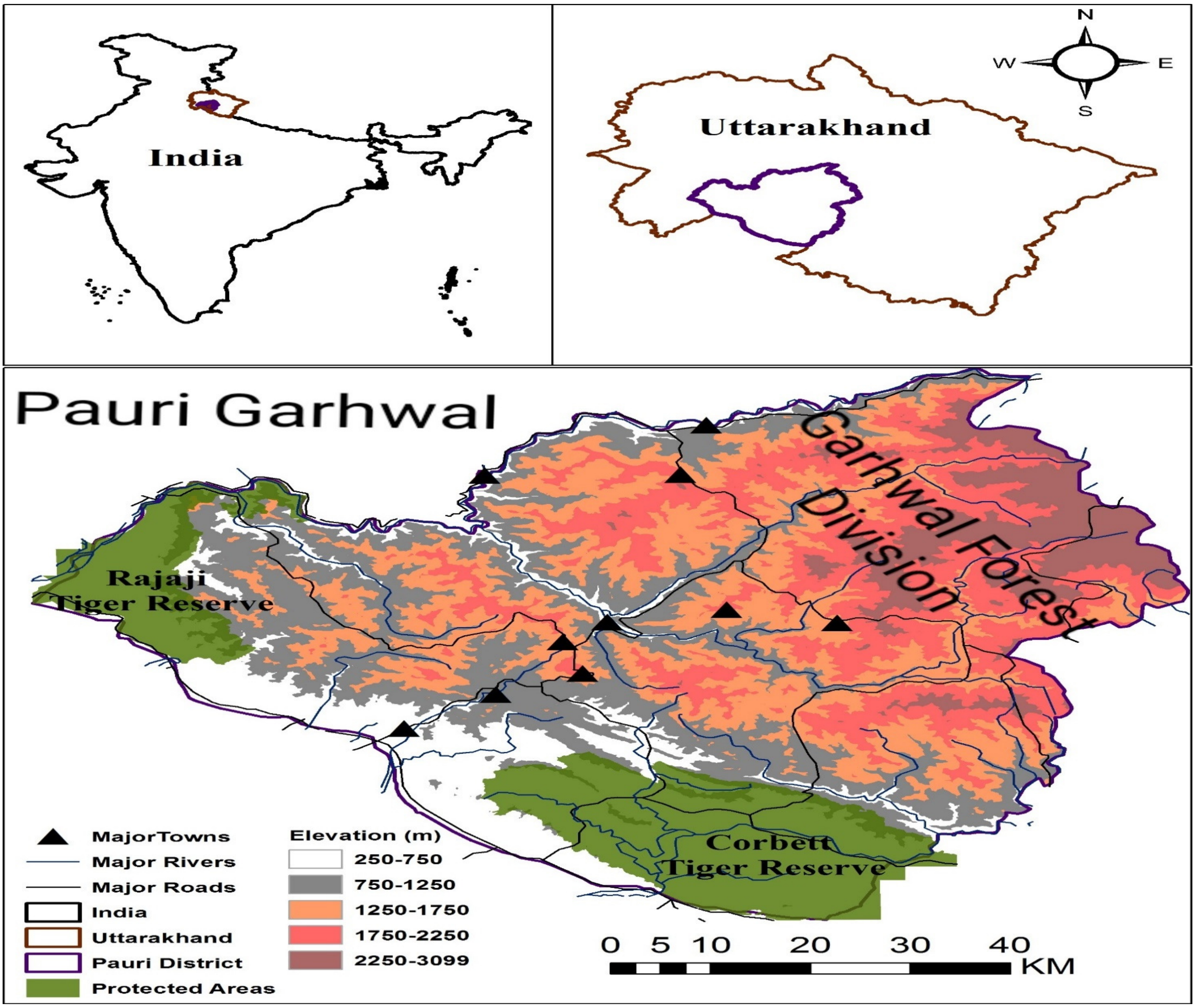
The present study was conducted in sub-tropical to temperate zone between the altitudes 800m to 3100m mean above sea level in Pauri Garhwal district of Uttarakhand between 29^0 45’ to 30^0 North Latitude and 78^0 24’ to 79^0 23’ East Longitude.

The climate of study area is represented by three main seasons: The cool and moderately dry winter in December to March, warm and dry summer in mid-April to June and warm and wet period in mid-July to September or the monsoon or rainy season. The temperate area receives moderate to high snowfall from December to February on high elevations.

The number of factors i.e., precipitation, temperature, relative humidity, wind, radiation, in association with elevation, slop, aspects, drainage, vegetation, etc., causes variation in climate at local or even micro level. During winters, snowfall is common above 2000m altitude. The annual rainfall varies from place to place, depending upon vegetation, elevation and wind impact in monsoon season (June to September). Output of precipitation is in the form of rainfall, besides occasional occurrence of dew, hailstorm, fog snowfall, etc.

Temperature is varying with elevation. In May and June maximum temperature (45ºC) was recorded December and January are the coldest months, the minimum temperature (5ºC) in high elevation of mountain.

Relative humidity is maximum during rainy season (July to September) which is gradually decreased in outer foot hills of mountain in summer and winter season. Impact of winds on the upper mountain zone and steep slopes influence temperature, precipitation and vegetation. Foggy clouds during rainy season and winter fog are more pronounced. Foggy clouds during rainy season and winter fog are more or less dependent on humidity and wind impacts in the region.



(Map source: DOI 10.7717/ peerj.9544)

Fig. 1 : Map of the study area

Data Collection

Extensive field survey was carried out in the study area for the collection of plant specimens during various seasons in 2019 and 2020. Field data on local names, morphology, general association, availability and distribution in terms of elevation were noted.

To assess the diversity of plants the specimens of each species were collected as per (Jain & Rao, 1977) and identified with the help of existing floras (Naithani, 1984-1985; Gaur, 1999) of the region and herbaria like Forest Research Institute (DD) and Botanical Survey of India, Northern Circle, DehraDun (BSD).

The species are enumerated in (Table 1) with the information on botanical name, local name, family, habit, availability status, distributions range in the study area and species native to as per major geographical reason of the world considered on the bases of https://powo.science.kew.org/. The accepted scientific names of species are as per www.worldfloraonline.org and www.theplantlist.org. Plant growth forms realized are herb (H), shrub (S), and tree (T), categorized in casual or naturalized by its occurrence with their altitudinal range and nativity of the species.

Result

A total of 82 plant species represented by 72 genera under 39 families (Figure 2) are identified as exotic plant species. Exotic, species in the study area reveal that herbs species, shrubs species, and tree species contribute 56%, 20%, 24% respectively were recorded (Figure 3). The dicots and monocots were represented by 37 families and 2 families respectively. Asteraceae with 19exotic species is dominant followed by Solanaceae 7 exotic species, Rosaceae 5 exotic species, Euphorbiaceae, Amaranthaceae, Fabaceae, Lamiaceae each contain 4 exotic species Cannabaceae and Lauraceae contain 2 exotic species each. Rest of the 29 families are represented by only single exotic species.

Maximum genera in the study area included Asteraceae with 18 exotic genera, Fabaceae and Rosaceae with 4 exotic genera, Amaranthaceae, Euforbiaceae, Lamiaceae, Solanaceae each with 3 exotic genera, Canabaceae, Lauraceae, Mimosaceae, each with 2 exotic species, and 29 genera with single exotic species (Figure 5). Out of these 33% exotic species occurred causally and 67% at naturalized state (Figure 4).

On the basis of earths lithospheric realms. The major contribution of exotic species in the study area includedtropical America (26%). South America (21%), Africa continent (9%), Europe (8%), and Mediterranean basin, China, Australia, Arabia each with (4%), North America contain (3%) and 6 realms each contains (2%) and rest of 9 realms contribute (1%) each exotic species by virtue of its origin is two or more realms are repeated. (Figure 6).

In the present study site maximum alien species distribution along elevation gradient are 1600-2000>, 1200-1600>, 2000-2400>, <1200>, 2400-2800>, 2800< (Figure 7) out of total species some species repeated with two or more ranges.

Discussion

These alien species with time, naturalization in changing climatic conditions migrate fast to the less disturbed deep forest areas (Kleinbauer *et al*., 2010). The gradual spread of invasive alien plant species in an ecosystem become a threat to the indigenous species and leads to climate change and influence the global environmental diversity (Kushwaha, 2012; Gret-Regamey *et al*., 2012). The naturalized alien species were found proliferating mostly along human disturbed areas, construction areas, forest edges and open canopy areas, as also observed by (Kosaka *et al*., 2010).

The Mountain ecosystems are being subjected to drastic changes in vegetation (Lomolino, 2001). Although mountain ecosystems previously assumed to be at low risk, are not inherently immune to invasion than other types of ecosystems and are experiencing many threats (McDougall *et al*., 2011; Pauchard *et al*., 2009). Anthropogenic activities like increased human land activities, human population growth, and expansion of tourism and climate warming pose serious threat to these ecosystems (Kueffer *et al*., 2013; Mamgain and Joshi, 2017).

Alien flora of India shows maximum 58% species from Tropical America. In the present study maximum (26%) exotic species belong to Tropical America closely followed by South America (21%). A greater viability and tolerance to harsh conditions could result this preponderance of herbs in the alien flora Uttarakhand (Sekar and Manikandan, 2012). In the present study Asteraceae is the dominant invasive family in the study area similar with our earlier work on the area (Kuldeep *et al*., 2021) and resemble with the dominance of Asteraceae in invasive alien flora of Uttar Pradesh (Rao and Murugan, 2006). Asteraceae is dominant family in alien flora of India.

The invasive species cause loss of biodiversity including species extinction, and changes in ecosystem function. Differences between native and exotic plant species in their requirements and modes of resource acquisition and consumption accelerates change in soil structure, its profile, decomposition, nutrient content of soil, moisture availability, etc. Invasive species are thus a serious hindrance to conservation and sustainable use of biodiversity with significant undesirable impacts on the goods and services provided by ecosystems.

In the present study, a gradual decline in alien species with rising altitude was observed. Same pattern has been reported by many other studies (Alexander *et al*., 2011; Barni *et al*., 2012; Seipel *et al*., 2011) and majority of the studies have advocated directional filtering (Alexander *et al*., 2011; Averett *et al*., 2016) as possible explanation for describing the pattern. Since majority of alien species are introduced in lowland areas around human habitation, sub-sequent unidirectional expansion of alien species from anthropogenic sources at low elevations and progressive ecological filtering from low elevations to high elevations (Alexander *et al*., 2016).

Besides, only alien plants with broad climatic tolerances capable of growing across a wide elevation range have been reported to be reaching higher altitudes (Alexander *et al*., 2011; Becker *et al*., 2005; Marini *et al*., 2013). Harsh climate conditions like very low temperature of high altitude areas favors perennial life span (Evette *et al*., 2009; Klimeš *et al*., 1997; Klimešová *et al*., 2010; Körner 1999).

Conclusion

This study provides baseline information from which we can measure future effects of climate change and anthropogenic changes on vegetation in mountain areas. The observed pattern of associations between species distribution and elevation bands is likely to help in understanding the possible effects of climate change as climate change is expected to change species distributions with species shifting towards higher altitudes.

The human-induced changes, the introduction of invasive species, particularly in the foothills, has caused severe harm to its precious native floral diversity. There is an increasing concern among foresters, ecologists, botanists, conservationists, and policy makers about the threat of uncontrolled introduction of aggressive plant species.

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Table 1: Acheck-list of alien plant species along with growth form, occurrence, altitudinal range and nativity.

Botanical name	Family	Local name	Growth form	Occurr-ence	Range in m (amsl)	Native
Alternanthera philoxeroides (Mart.) Griseb	Amaranthaceae	-	H	C	1500-2200	South America
Amaranthus cruentus L.	Amaranthaceae	-	H	N	1500-2200	Tropical America
Amaranthus spinosus L.	Amaranthaceae	Chua	H	C	1300-2100	South America
Gomphrena celosioides Mart.	Amaranthaceae	-	H	C	1300-1400	South America
Cotinus coggygria Scop.	Anacardiaceae	Jultulg	S	N	1000-2000	Europe, Tropical America
Apium graveolens L.	Apiaceae	Slari	H	N	2000-2500	Europe, Africa
Phoenix humilis (L.) Cav.	Arecaceae	Thakal	T	C	1200-1800	Europe, Africa
Asclepias curassavica L.	Asclepiadaceae	-	H	C	1500-2000	Tropical America, South America
Agave americana L.	Asparagaceae	Rambans	S	N	900-1600	Tropical America
Ageratina adenophora (Spreng.) R.M. King & H. Rob.	Asteraceae	Guyajhar, Pagalghass	S	N	1300-2600	Tropical America
Ageratum conyzoides (L.) L.	Asteraceae	-	H	N	1300-2000	Tropical America
Ageratum houstonianum Mill.	Asteraceae	-	H	N	1800-2000	Tropical America
Artemisia maritima L. ex Hook.f.	Asteraceae	-	S	N	1500-2000	Europe
Athanasia linifolia Burm. f.	Asteraceae	Bhootkesh	H	C	2900-3000	South Africa
Bidens bipinnata L.	Asteraceae	-	H	N	1400-2000	Tropical America, North America
Cosmos sulphureus Cav.	Asteraceae	-	H	C	1500-1900	Tropical America
Crassocephalum crepidioides (Benth.) S. Moore	Asteraceae	-	H	C	1300-1400	Africa
Eclipta prostrata (L.) L.	Asteraceae	Bhangraw	H	N	1800-2000	South America, Tropical America
Galinsoga parviflora Cav.	Asteraceae	Jhar	H	N	2000-2400	South America, Tropical America
Grindelia integrifolia DC.	Asteraceae	Papadi	T	N	1000-1500	North America
Parthenium hysterophorus L.	Asteraceae	Gajar - Gha s	H	C	1300-1600	Tropical America, South America
Pentanema indicum (L.) Ling	Asteraceae	-	H	N	1300-1600	Africa
Picris babylonica Hand.-Mazz.	Asteraceae	Majnu	T	N	1600-2000	Arabia
Saussurea auriculata (DC.) Sch. Bip.	Asteraceae	-	H	C	2600-3000	China
Sonchus oleraceus (L.) L.	Asteraceae	-	H	N	1400-2100	Europe, Africa
Tagetes minuta L.	Asteraceae	Jangali-Genda	S	N	1200-2500	South America
Tridax procumbens (L.) L.	Asteraceae	-	H	N	1300-1800	Tropical America, South America
Xanthium strumarium L.	Asteraceae	Gokhru	H	C	1400-1600	South America, Tropical America
Jacaranda acutifolia Bonpl.	Bignoniaceae	Jakaranda	T	N	1800-2300	South America
Cardamine flexuosa With.	Brassicaceae	-	H	N	1800-2500	Europe, Arabia, Africa
Opuntia stricta (Haw.) Haw.	Cactaceae	Nagfani	S	N	1500-2000	Tropical America
Cannabis sativa L.	Cannabaceae	Bhang	S	N	800-1800	Central Asia
Celtis australis L.	Cannabaceae	Khadik	T	N	1200-2000	Mediterranean Basin
Drymaria cordata sub sp. diandra (Blume) J. A. Duke	Caryophylaceae	-	H	N	1300-2000	Tropical America, South America, Africa
Chenopodium foliosum Asch.	Chenopodiaceae	Biyoth	H	N	1300-2300	South America, Tropical America
Kalanchoe integra (Medik.) Kuntze	Crassulaceae	-	H	N	1800-2800	Madagascar
Euphorbia heterophylla L.	Euphorbiaceae	-	H	N	1300-2000	Tropical America, South America
Euphorbia hirta L.	Euphorbiaceae	Dudhi	H	N	1300-1500	Tropical America, South America

Jatropha curcas L	Euphorbiaceae	Pahadi-Arand	T	N	1200-1800	Tropical America, South America
Phyllanthus amarus Schumach. & Thonn.	Euphorbiaceae	-	H	C	1300-1400	Tropical America, South America
Delonix regia (Hook.) Raf.	Fabaceae	Gulmohar	T	N	800-1800	Madagascar
Desmodium triflorum (L.) DC.	Fabaceae	Kudalia	S	N	1800-2500	Africa
Mimosa pudica L.	Fabaceae	Chui-Mui	S	N	900-1600	Tropical America, South America
Robinia pseudoacacia L.	Fabaceae	Robiniya	T	N	800-1800	North America
Isodon japonicus (Burm. f.) H. Hara	Lamiaceae	-	H	N	1700-2200	China, Japan, Korea
Mentha piperita L.	Lamiaceae	-	H	N	1200-2300	Mediterranean Basin
Stachys melissifolia Benth.	Lamiaceae	-	H	C	2400-2800	Chile
Stachys sericea Cav.	Lamiaceae	-	H	C	2400-2700	Chile
Neolitsea aciculata (Blume) Koidz.	Lauraceae	Chari	T	N	1200-2500	Japan, Korea, Taiwan
Ocotea lancifolia (Schott) Mez	Lauraceae	Kaul	T	N	1200-1800	South America
Punica granatum L.	Lythraceae	Dadim	T	N	900-1500	Iran, Iraq, Afganistan, Turkey
*Urena lobata*L.	Malvaceae	-	H	C	1300-1900	Africa
Martynia annua L.	Martyniaceae	Bichu	H	C	1300-1400	Tropical America
Acacia dealbata Link	Mimosaceae	Vatal	T	C	800-1800	Australia
Acacia mearnsii De Wild.	Mimosaceae	Vatal	T	C	800-1800	Australia
Eucalyptus globulus Labill.	Myrtaceae	Eukaliptus	T	N	800-1800	Australia
*Mirabilis jalapa*L.	Nyctaginaceae	-	H	N	1300-1600	Tropical America
Oenotherarosea L'Her. ex Aiton	Onagraceae	-	H	N	1300-2000	Tropical America, South America
Lepanthes dodiana Stimson	Orchidaceae	Kumkum	T	C	900-1200	Puerto Rico
Oxalis latifolia Kunth	Oxalidaceae	-	H	N	1400-2000	Tropical America, South America
Phryma leptostachya L.	Phrymaceae	-	H	C	1600-2000	North America, Tropical America
Peperomia schizandra Trel.	Piperaceae	Agali	S	C	1200-2500	Maxico
Dactylis glomerata L.	Poaceae	Auchard-Ghass	H	N	1000-1800	Mediterranean Basin
Portulaca oleracea L.	Portulacaceae	Luniya	H	C	1300-1600	Mediterranean Basin, Africa, Arabia
Grevillea robusta A.Cunn. ex R.Br.	Proteaceae	Silver-Oak	T	N	1100-2000	Australia
Eriocapitella japonica (Thunb.) Nakai	Ranunculaceae	-	H	N	1200-2200	China, Taiwan, Vietnam
Croton triqueter Lam.	Rhamnaceae	-	S	N	1000-2400	South America
Prunus domestica L.	Rosaceae	Alu-Bukhara	T	N	750-1500	Turkey
Prunus persica (L.) Batsch	Rosaceae	Aadu	T	N	900-2400	China
Pyrus communis auct. iber.	Rosaceae	Jungali-Naspati	T	N	1100-1900	Europe
Rubus foliolosus D.Don	Rosaceae	Kanda	S	N	1800-2400	Europe
Sibbaldia parviflora Will.	Rosaceae	-	H	C	2600-3000	Mediterranean Basin, Arabia
Salix acutifolia Willd.	Salicaceae	Bash, Broi	T	N	1000-2400	Europe, Russia
Cestrum parqui Benth.	Solanaceae	Ratki-Rani	S	N	1000-1700	South America
Datura metel L.	Solanaceae	Dhatura	S	N	1200-1700	Tropical America
Datura stramonium Thunb.	Solanaceae	Dharura	S	N	900-1600	Tropical America
Nicandra physalodes(L.) Gaertn.	Solanaceae	Dhatur	H	C	1300-2000	South America
*Physalis heterophylla*Nees	Solanaceae	Dhatur	H	N	1700-1900	North America
Physalis minima L.	Solanaceae	-	H	C	1300-1500	Tropical America
Physalis peruviana L.	Solanaceae	-	H	C	1400-1900	South America
Elatostema sessile J.R. Forst. & G. Forst	Urticaceae	-	H	C	2300-2700	Society Islands
Lantana camara L.	Verbiniaceac	Kuri	S	N	1100-2500	Tropical America

Abbreviation H= herb, S = shrub, T= tree, C = casual, N = naturalized

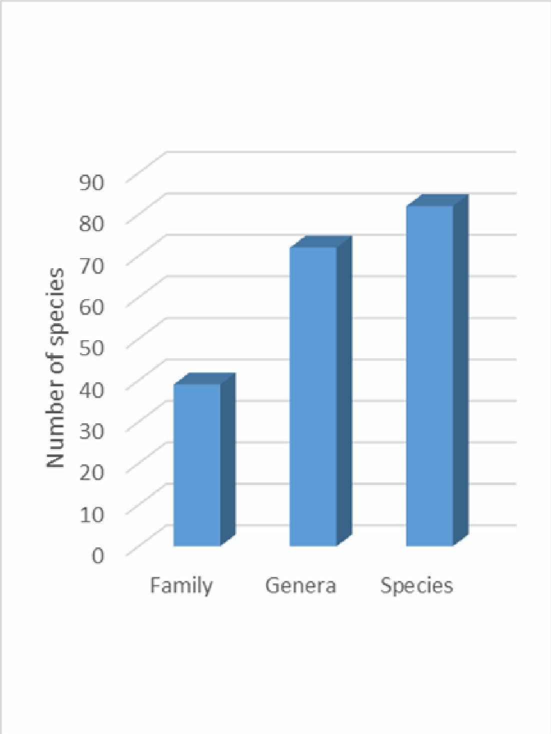

Fig. 2 : Contribution of different taxa of alien species.

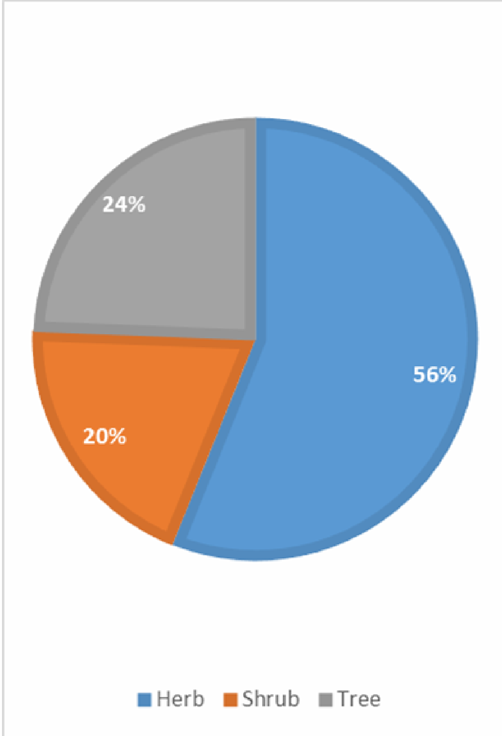

Fig. 3 : Percentage contribution of growth form of species

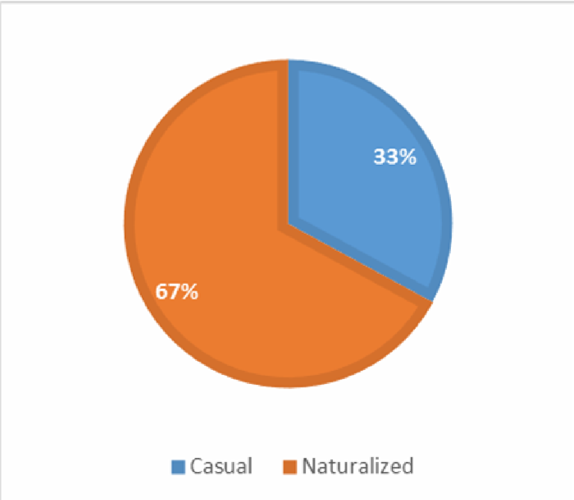

Fig. 4 : Mode of occurrence of alien plant species

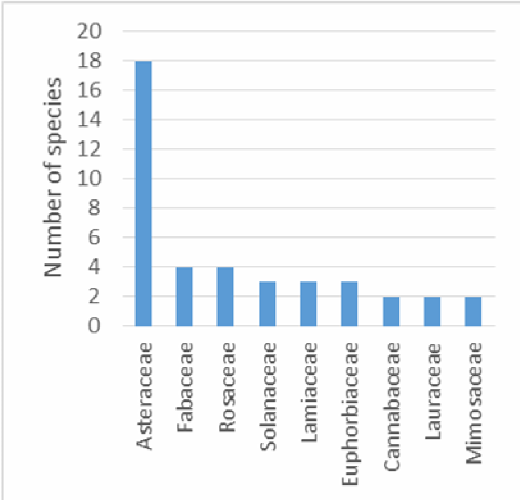

Fig. 5 : Dominant genera in the rank of family.

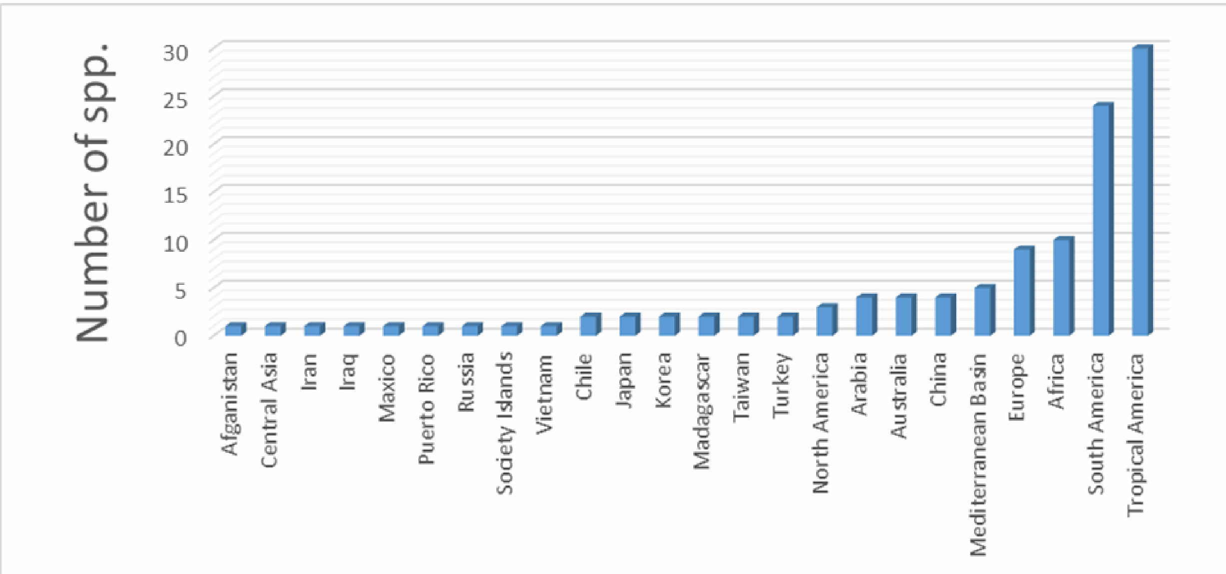

Fig. 6 : Alien spp.contribution status of different realms in the study area.

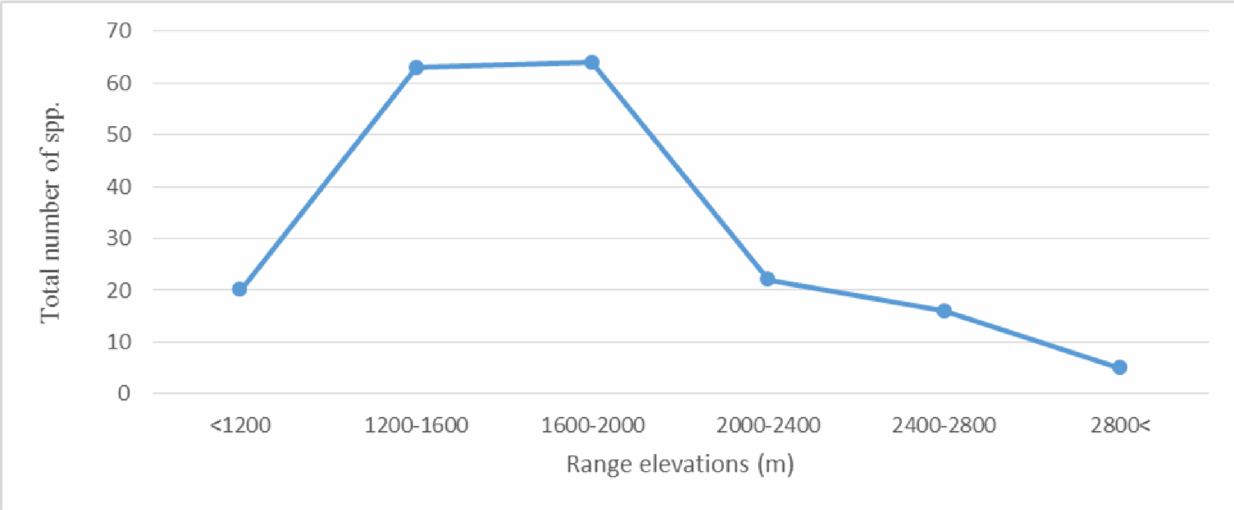

Fig. 7 : Distribution of spp. along different range elevations.

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