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Inventory of invasive alien plant taxa in gundla brahmeswaram wildlife sanctuary, Nallamalais, India: Implications for monitoring and management

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Abstract
Gundla Brahmeswaram wildlife sanctuary is invaded by many alien plant taxa which interfere with native biodiversity. It is highly important to explore the concerned problems caused by the intrusion of invasive plant taxa and to mitigate the impact on native diversity. To achieve this, the present study has taken up for the first of its kind and listed the 102 plant species representing 84 genera and 32 families. Of these, 54 plant species have their origin in Tropical America followed by many other parts of the world. The predominant family was Asteraceae with 23 plant species, followed by Fabaceae (12), Amaranthaceae (10), Convolvulaceae (7), Malvaceae (6), Euphorbiaceae, Lamiaceae, Solanaceae (4 each), Acanthaceae, Poaceae (3 each), Apocynaceae, Asparagaceae, Cleomaceae and Cuscutaceae (2 each). 18 families were contributed with single species each. The abundant and most serious invasive species were recognized in the sanctuary, namely, *Hyptis suaveolens*, *Lantana camara*, *Senna uniflora*, *Parthenium hysterophorus*, *Ageratum conyzoides*, *Waltheria indica*, *Chromolaena odorata*, *Mimosa pudica* and *Prosopis juliflora*, *Cuscuta* species. The present study calls for a standard, unique planning in early identification, spreading and infestation of invasive weeds and involve taxonomists, forest managers, ecologists to control and monitor.

Keywords: invasion - native diversity - monitor - control - management– wildlife sanctuary

Introduction

Invasive species are non-native which have the potential to threat many aspects such as environment, health and even economy. These are 'the second worst threat to native diversity in the planet earth' after habitat destruction (CBD 1992) [4], and they are severe threat to native biodiversity, habitat destruction and the greatest component of global climatic change (Khuroo *et al*. 2007, Pasha *et al*. 2014) [17, 26]. Alien species are recognized as of casual, naturalized and invasives (Richardson *et al*. 2000) [39]. The introduction of plants to a new place is an age old practice to human kind during migration and is enormously influenced by various factors such as cultural background, political history, extent of trade, etc. (Rhuiller *et al*. 2005, Bomford 2009, Reshi and Khuroo 2012) [2, 40, 38] and accidentally or intentionally happened through the crop seeds, or imported biota (Pimentel *et al*. 2000) [28]. The introduction and spread of non-native species can significantly alter the ecological functions of forest ecosystem and the primary productivity of plant taxa in time and space (Shah *et al*. 2012) [40]. Many indigenous species are threatened by competition and predation from invaders, while many other species are endangered by hybridization and ecosystem changes caused by alien species (Pimentel *et al*. 2005) [29]. Over 40% of the species on the list of threatened and endangered species are due to the invasive species only (Wilcove *et al*. 1998) [51]. Majority of the alien introduced species escape from cultivation, spread slowly and silently at initial stage, but become dominant and widespread at later stages to attain an invasive status in the introduced range and prove detrimental for the native biodiversity (Khuroo *et al*. 2008, 2010) [18, 16]. A large number of plants that are using today either for food, plantation or for ornamental purpose were deliberate introductions during post Columbian period, especially from tropical America (Purseglove 1969, Simmonds 1976, Ferra 1994) [31, 44, 9]. Invasive alien species (IAS) cause major environmental and economic problems in agriculture, forestry, and several other segments of the world economy; adversely affect ecosystem structure and function in habitats through the world by reducing native species, changing soil nutrient status, and altering geomorphological process (Pimentel *et al*. 2000, Mandal and Joshi 2014) [28, 21,]. It is estimated that in India alien species are causing 30% loss in potential crop production worth about US$ 90 billion per year (Kohli and Batish 1996) [19]. Native biodiversity have revealed that both the structural organization and the functional integrity of ecosystems are affected due to invasion by alien species. There is a growing catalogue of the potential impacts of invasive species on native species, wildlife habitats, disturbance regimes, and ecosystem services (Hiremath and Sundaram 2013, Simberloff *et al*. 2013, Foxcroft *et al*. 2014) [14, 43, 10] in worldwide. IAS not only pose a serious threat to native biodiversity but also influence serious consequences for the ecology, economy, public health and biosecurity of the countries involved (Pejchar and Mooney

2009) [27]. Invasive species are able to take more rapid advantage of available resources and at the same time use nutrients more efficiently in low resource environments, when compared with native species (Funk and Vitousek 2007) [11]. Invasive species typically produce large numbers of fruits thus enabling them to exert propagule pressure, both in space (by widespread dissemination or abundant plantings) and time (by long history of cultivation) (Pumberton and Liu 2009, Bucharova and van Kleunen 2009) [30, 3]. The importance of invasive species is underlined by Article 8(h) of the Convention on Biological Diversity (CBD 2002) which asks for measures to prevent the introduction, control or even root out of those alien species which threatens ecosystems, habitats or species. Suthari *et al*. (2016) [48] called for the importance of invasive species documentation, monitoring, spread and implementation levels to control the impacts of invasive species. Weeds grow luxuriantly due to its production of more number of seeds.

The growth of weeds reduces the ground flora, sprouts, and palatable grass, and competes with local flora and inhibits the growth of other species due to its allelopathic effect. India is one of the mega diverse nations in the world with rich plant diversity and has a long history of introduction of exotic plant species to various parts of the nation due to unregulated transportation, quarantines from one place to another. These exotics are widespread in the country. The percentage of alien plant species is negatively correlated with native plant diversity (Liu *et al*. 2005) [20]. Many studies have been conducted on alien species and estimated that India has about 39% (Chatterjee 1940) [6], 40% (CBD 2005), 173 plant taxa are invasives which represent 1% of the Indian Flora (Reddy *et al*. 2008, Goyal and Arora 2009) [36, 13] and 20% or more and in many islands the proportion is 50% or more (Singh *et al*. 2010) [45]. Suthari *et al*. (Suthari *et al*. 2016) [48] documented 74 alien Asteraceae members and their intrusion, residence time in Telangana and Andhra Pradesh states. The problem of plant invasion needs global co-ordination for its effective monitoring and management (McNeely *et al*. 2011). Lack of data on alien species would make the economic and environmental information underestimation. Earlier, many workers provided catalogues of the invasive alien plant species in different parts of the country (Khuroo *et al*. 2007, Hiremath and Sundaram 2013, Suthari *et al*. 2016, Reddy *et al*. 2008, Singh *et al*. 2010, Sharma and Pandey 1984, Pandey and Parmar 1994, Rao and Murugan 2006, Bhatt *et al*. 2002, Jaryan *et al*. 2013, Naidu *et al*. 2015) [17, 14, 48, 36, 45, 41, 25, 35, 15, 24]. Ellis (1987) [8] recorded 743 plant taxa from Nallamalais region and documented in *Flora of Nallamalais* and Rao *et al*. (2007) [34] conducted floristic studies in the area and documented 1521 angiospermous plant taxa of which the 124 species of exotics. Of these, 27 species are endemic to Nallamalais (Reddy *et al*. 2006) [36]. The data on the impact of alien invasive plant species on ecosystem of protected area is sparse, so it is highly needed to estimate the range of threat to existing diversity, and there is no particular study on the inventory and effect of invasive alien plant taxa and ecological significance of Gundla Brahmeswaram wildlife sanctuary (GBWS). The present study focuses on the distribution and quantitative structure of alien invasive species and ecological consequences in Gundla Brahmeswaram wildlife sanctuary, Nallamalais, Andhra Pradesh, India.

Material and Methods

Study area

Our study was conducted at Gundla Brahmeswaram wildlife sanctuary, Andhra Pradesh which plays an important role in the maintenance of ecological balance and biological diversity in the Eastern Ghats. The sanctuary is located in Nallamalais region, the ranges of parallel hills integral to the Eastern Ghats. These hills stretch across parts of Kurnool, Mahabubnagar, Prakasam, Guntur and Kadapa districts. Gundla Brahmeswaram wildlife sanctuary is one of the biologically rich areas in Eastern Ghats, lies between 15°40′ to 15°89′N latitudes and 76°61′ to 78°09′E longitudes and situated in Gundla Brahmeswaram plateau of the central Nallamalais, south to the Nagarjunasagar-Srisailam Tiger Reserve which is the largest tiger reserve in India, spread over an area of 3600 sq km. The sanctuary is one of the oldest sanctuaries in Andhra Pradesh and was established in 1998 for its rich and diverse biota, is an off shoot of *Southern Eastern Ghats*, covering an area of 1194 sq km, supported by the tropical moist and dry deciduous forests and with a domain of rich habitat for many endangered flora and its associated fauna.

Methodology

A comprehensive list of invasive alien plant species from Gundla Brahmeswaram wildlife sanctuary based on the extensive field surveys conducted during the last five years (2014-2019) and the database compiled by after perusal of the available floristic literature dealing with the vascular flora of Andhra Pradesh. Data was collected through standard quadrat method by laying 31.62 × 31.62 m at random sampling method by covering core zone, buffer zones including water bodies and marshy areas (Suthari 2013) [46]. A total of 45 sample sites of which 15 in core areas, 15 in open degraded areas, and 15 in transition areas (edges) were laid in and around the protected area of Gundla Brahmeswaram wildlife sanctuary. The field surveys were resulted in generation of a master list of all plant taxa occurring in Gundla Brahmeswaram along with their family. The nativity of the plants using published information (Khuroo *et al*. 2007, Suthari *et al*. 2016a, Reddy *et al*. 2008, Singh *et al*. 2010, Jaryan *et al*. 2013) [17, 48,36,45, 15] and followed the website http://www.isws.in/invaisve.plant.of.india.php. The alien species were categorized into herbs, shrubs and climbers based on their growth-form with in the alien category, naturalized, noxious and interfering plant species have been recognized. Identification of the plant species was done with the help of standard floras (Rao *et al*. 2007, Cooke 1903, Gamble and Fischer 1915-1935) [34, 7, 12], e-floras, revisions and recent monographic studies of the taxa concerned. Nomenclature of the plant taxa was updated following *International Code of Nomenclature for Algae, Fungi, and Plants* (Shenzhen Code) (Turland *et al*. 2018) and www.theplantlist.org.

Results and Discussion

The present inventory on plant invasions documented 102 plant taxa in various regions of GBWS (Table 1). A total of 102 invasive alien plant species of GBWS has been documented, which are pertaining to 84 genera and 32 families. The scientific name, family, habit, nativity and category were provided in tabular form (Table 1). The plant populations which have the potential of individual growth and recruitment through seeds were treated as *naturalized*, while some species in disturbed areas which show adverse impact on native species categorized as

noxious. The noxious species are notorious and compete with local plant species for space, sunlight, nutrients, and harbor to pests which show harmful effects on native species. Some species are neither harmful nor noxious to indigenous vegetation but these plants interfere to the growth of the native species, these are categorized as *interfering* species in the present study (Table 1).

Of these alien species, 54 plant taxa have their origin in Tropical America, followed by Tropical Africa (12), Tropical South America (9), Mediterranean (3), Tropical Central America (3), Tropical North America (3), West Indies (3), Brazil (2), Europe (2), and Mexico and Central America (2). Only single invasive plant species reached the study area from various native ranges such as Afghanistan, Australia, Mascarene Islands, Mexico, Temperate South America, Tropical Central-South America, Tropical South-Eastern Africa, West Africa and Western Europe (Figure 1). Of 32 families having alien plant species, Asteraceae was the predominant family with 23 plant taxa, followed by Fabaceae (12), Amaranthaceae (10), Convolvulaceae (7), Malvaceae (6), Euphorbiaceae, Lamiaceae, Solanaceae (4 each), Acanthaceae, Poaceae (3 each), Apocynaceae, Asparagaceae, Cleomaceae and Cuscutaceae (2 each). 18 families such as Adiantaceae, Aizoaceae, Cactaceae, Cannabaceae, Nyctaginaceae, Onagraceae, Oxalidaceae, Papaveraceae, Passifloraceae, Pedaliaceae, Phyllanthaceae, Polygonaceae, Portulacaceae, Rubiaceae, Sapindaceae, Scrophulariaceae, Typhaceae and Zygophyllaceae were distributed with single species each within the sanctuary (Figure 2). Of the total plant invasions, 67 species were categorized as naturalized, 22 species as interfering and 8 species as noxious (Figure 3). The alien exotic weed herbs (84 species) and climbers (7 species) are the major menace in the sanctuary. During our field visits, we have observed abundant populations of alien weeds in peripherals of the wildlife sanctuary. They species include *Hyptis suaveolens*, *Lantana camara*, *Senna uniflora*, *Parthenium hysterophorus*, *Ageratum conyzoides*, *Waltheria indica*, *Chromolaena odorata*, *Mimosa pudica* and *Prosopis juliflora*, *Cuscuta* species (stem parasite). Even in the core areas of the sanctuary some of the invasive species such as *Hyptis suaveolens*, *Ageratum conyzoides*, *Waltheria indica*, *Bidens pilosa*, *Alternanthera paronychioides* were found. These noxious weeds are rapidly distributed in the sanctuary due to their prolific seed production, light weight of seeds, seed dispersal through different factors, fast-spreading ability, allelopathic effect on other plants, strong competitiveness with indigenous species for nutrients, space, water, sun light and other sources. These species are major invaders and affect the distribution, abundance and reproduction of many indigenous species and cause loss of native biodiversity (Table 1). These can also alter the nutrient cycling, water table, fire regimes, Native vegetation, Availability of native diversity and wildlife populations, prevent recruitment of native species, ecological balance, etc.

Table 1: Inventory of plant invasions from gundla brahmeswaram wildlife sanctuary

	Plant taxon	Family	Habit	Nativity	Category
1	*Aeschynomene americana* L.	Fabaceae	Herb	West Africa	Naturalized
2	*Acacia farnesiana* (L.) Willd.	Fabaceae	Shrub	Tropical South America	Naturalized
3	*Acanthospermum hispidum* DC.	Asteraceae	Herb	Brazil	Naturalized
4	*Acmella paniculata* (Wall. ex DC.) R.K.Jansen	Asteraceae	Herb	Tropical South America	Naturalized
5	*Adiantum lunulatum* Burm.f.	Adiantaceae	Herb	Australia	Naturalized
6	*Aerva javanica* (Burm.f.) Juss. ex Schult.	Amaranthaceae	Herb	Tropical America	Naturalized
7	*Aerva lanata* (L.) Juss.	Amaranthaceae	Herb	Tropical Africa	Naturalized
8	*Agave americana* L.	Asparagaceae	Herb	Tropical America	Naturalized
9	*Agave vivipara* L.	Asparagaceae	Herb	Mexico and Central America	Naturalized
10	*Eupatorium glandulosum* Kunth	Asteraceae	Herb	Mexico and Central America	Naturalized
11	*Ageratum conyzoides* (L.) L.	Asteraceae	Herb	Tropical America	Noxious
12	*Alternanthera paronychioides* A.St.-Hil.	Amaranthaceae	Herb	Tropical America	Naturalized
13	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	Herb	Tropical America	Naturalized
14	*Alternanthera pungens* Kunth	Amaranthaceae	Herb	Tropical America	Naturalized
15	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae	Herb	Tropical America	Naturalized
16	*Amaranthus spinosus* L.	Amaranthaceae	Herb	Tropical America	Naturalized
17	*Antigonon leptopus* Hook. & Arn.	Polygonaceae	Climber	Tropical America	Noxious
18	*Argemone mexicana* L.	Papaveraceae	Herb	Tropical Central-South America	Noxious
19	*Bidens pilosa* L.	Asteraceae	Herb	Tropical America	Naturalized
20	*Blumea lacera* (Burm.f.) DC.	Asteraceae	Herb	Tropical America	Interfering
21	*Boerhavia diffusa* L.	Nyctaginaceae	Herb	Tropical South-Eastern Africa	Naturalized
22	Car*diospermum halicacabum* L.	Sapindaceae	Climber	Tropical America	Naturalized
23	*Calotropis gigantea* (L.) Dryand.	Apocynaceae	Shrub	Tropical Africa	Interfering
24	*Calotropis procera* (Aiton) Dryand.	Apocynaceae	Shrub	Tropical Africa	Interfering
25	*Celosia argentea* L.	Amaranthaceae	Herb	Tropical Africa	Naturalized
26	*Chamaesyce hirta* (L.) Millsp.	Euphorbiaceae	Herb	Tropical America	Naturalized
27	*Chloris elata* Desv.	Poaceae	Herb	Tropical America	Naturalized
28	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Asteraceae	Shrub	Tropical America	Interfering
29	*Chrozophora rottleri* (Geiseler) A.Juss. Ex Spreng.	Euphorbiaceae	Herb	Tropical Africa	Naturalized
30	*Cleome gynandra* L.	Cleomaceae	Herb	Tropical America	Naturalized
31	*Cleome viscosa* L.	Cleomaceae	Herb	Tropical America	Naturalized
32	*Convolvulus arvensis* L.	Convolvulaceae	Herb	Europe	Naturalized

33	*Corchorus aestuans* L.	Malvaceae	Herb	Tropical America	Naturalized
34	*Croton bonplandianus* Baill.	Euphorbiaceae	Herb	Temperate South America	Naturalized
35	*Cuscuta chinensis* Lam.	Cuscutaceae	Herb	Mediterranean	Interfering
36	*Cuscuta reflexa* Roxb.	Cuscutaceae	Climber	Mediterranean	Interfering
37	*Cynodon dactylon* (L.) Pers.	Poaceae	Herb	Tropical Africa	Naturalized
38	*Cyperus iria* L.	Poaceae	herb	Tropical America	Naturalized
39	*Datura metel* L.	Solanaceae	Herb	Tropical America	Interfering
40	*Echinops echinatus* Roxb.	Asteraceae	Herb	Afghanistan	Naturalized
41	*Eclipta prostrata* (L.) L.	Asteraceae	Herb	Tropical America	Naturalized
42	*Emilia sonchifolia* (L.) DC. ex DC.	Asteraceae	Herb	Tropical America	Naturalized
43	*Evolvulus alsinoides* (L.) L.	Convolvulaceae	Herb	Tropical America	Naturalized
44	*Evolvulus nummularius* (L.) L.	Convolvulaceae	Herb	Tropical America	Naturalized
45	*Flaveria trinervia* (Spreng.) C.Mohr	Asteraceae	Herb	Tropical Central America	Naturalized
46	*Galinsoga parviflora* Cav.	Asteraceae	Herb	Tropical America	Naturalized
47	*Gnaphalium coarctatum* Willd.	Asteraceae	Herb	Tropical America	Interfering
48	*Gomphrena serrata* L.	Amaranthaceae	Herb	Tropical America	Naturalized
49	*Grangea maderaspatana* (L.) Poir.	Asteraceae	Herb	Tropical South America	Naturalized
50	*Hyptis saveolens* (L.) Poit.	Lamiaceae	Herb	Tropical America	Interfering
51	*Indigofera astragalina* DC.	Fabaceae	Herb	Tropical America	Naturalized
52	*Ipomoea obscura* (L.) Ker Gawl.	Convolvulaceae	Climber	Tropical America	Naturalized
53	*Ipomoea carnea* Jacq.	Convolvulaceae	Shrub	Tropical America	Naturalized
54	*Ipomoea hederifolia* L.	Convolvulaceae	Climber	Tropical America	Naturalized
55	*Lantana camara* L.	Lamiaceae	Shrub	Tropical America	Noxious
56	*Leonotis nepetifolia* (L.) R.Br.	Lamiaceae	Herb	Tropical Africa	Interfering
57	*Lagascea mollis* Cav.	Asteraceae	Herb	Tropical Central America	Noxious
58	*Mikania micrantha* Kunth	Asteraceae	Climber	Tropical America	Noxious
59	*Mimosa pudica* L.	Fabaceae	Herb	Brazil	Naturalized
60	*Ludwigia adscendens* (L.) H.Hara	Onagraceae	Herb	Tropical America	Naturalized
61	*Martynia annua* L.	Pedaliaceae	Herb	Tropical America	Interfering
62	*Melochia corchorifolia* L.	Malvaceae	Herb	Tropical America	Interfering
63	*Merremia dissecta* (Jacq.) Hallier f.	Convolvulaceae	Herb	Tropical America	Naturalized
64	*Ocimum americanum* L.	Lamiaceae	Herb	Tropical America	Naturalized
65	*Opuntia stricta* (Haw.) Haw.	Cactaceae	Herb	Tropical America	Noxious
66	*Oxalis corniculata* L.	Oxalidaceae	Herb	Europe	Naturalized
67	*Parthenium hysterophorus* L.	Asteraceae	Herb	Tropical North America	Noxious
68	*Passiflora foetida* L.	Passifloraceae	Climber	Tropical South America	Interfering
69	*Peristrophe paniculata* (Forssk.) Brummitt	Acanthaceae	Herb	Tropical America	Interfering
70	*Phyllanthus tenellus* Roxb.	Phyllanthaceae	Herb	Mascarene Islands	Naturalized
71	*Physalis angulata* L.	Solanaceae	Herb	Tropical America	Interfering
72	*Portulaca oleracea* L.	Portulacaceae	Herb	Tropical South America	Naturalized
73	*Prosopis juliflora* (Sw.) DC.	Fabaceae	Shrub	Mexico	Naturalized
74	*Pupalia lappacea* (L.) Juss.	Amaranthaceae	Herb	Tropical Africa	Interfering
75	*Ricinus communis* L.	Euphorbiaceae	Shrub	Tropical Africa	Interfering
76	*Ruellia longifolia* (L.) Roxb.	Acanthaceae	Herb	Tropical America	Interfering
77	*Ruellia tuberosa* L.	Acanthaceae	Herb	Tropical America	Naturalized
78	*Scoparia dulcis* L.	Scrophulariaceae	Herb	Tropical America	Naturalized
79	*Senna absus* (L.) Roxb.	Fabaceae	Herb	Tropical America	Naturalized
80	*Senna alata* (L.) Roxb.	Fabaceae	Herb	West Indies	Interfering
81	*Senna obtusifolia* (L.) H.S.Irwin & Barneby	Fabaceae	Herb	Tropical America	Naturalized
82	*Senna occidentalis* (L.) Link	Fabaceae	Herb	Tropical South America	Interfering
83	*Senna tora* (L.) Roxb.	Fabaceae	Herb	Tropical South America	Naturalized
84	*Senna uniflora* (Mill.) H.S.Irwin & Barneby	Fabaceae	Herb	Tropical South America	Interfering
85	*Sida acuta* Burm.f.	Malvaceae	Herb	Tropical America	Naturalized
86	*Solanum americanum* Mill.	Solanaceae	Herb	Tropical America	Interfering
87	*Solanum torvum* Sw.	Solanaceae	Shrub	West Indies	Naturalized
88	*Solidago canadensis* L.	Asteraceae	Herb	Tropical North America	Naturalized
89	*Sonchus asper* (L.) Hill	Asteraceae	Herb	Mediterranean	Interfering
90	*Spermacoce articularis* L.f.	Rubiaceae	Herb	Tropical America	Naturalized
91	*Synedrella nodiflora* (L.) Gaertn.	Asteraceae	Herb	West Indies	Naturalized
92	*Trema orientalis* (L.) Blume	Cannabaceae	Herb	Tropical Africa	Naturalized
93	*Trianthema portulacastrum* L.	Aizoaceae	Herb	Tropical Africa	Interfering
94	*Tribulus lanuginosus* L.	Zygophyllaceae	Herb	Tropical America	Naturalized
95	*Tridax procumbens* (L.) L.	Asteraceae	Herb	Tropical Central America	Naturalized
96	*Triumfetta rhomboidea* Jacq.	Malvaceae	Herb	Tropical America	Naturalized

97	*Typha angustata* L.	Typhaceae	Herb	Tropical America	Interfering
98	*Ulex europaeus* L.	Fabaceae	Shrub	Western Europe	Interfering
99	*Urena lobata* L.	Malvaceae	Shrub	Tropical Africa	Naturalized
100	*Waltheria indica* L.	Malvaceae	Herb	Tropical America	Naturalized
101	*Xanthium strumarium* L.	Asteraceae	Herb	Tropical North America	Interfering
102	*Youngia japonica* (L.) DC.	Asteraceae	Herb	Tropical South America	Naturalized

Total area surveyed for alien plant species was 4.5 ha by laying quadrats with a size of 31.62 × 31.62 m

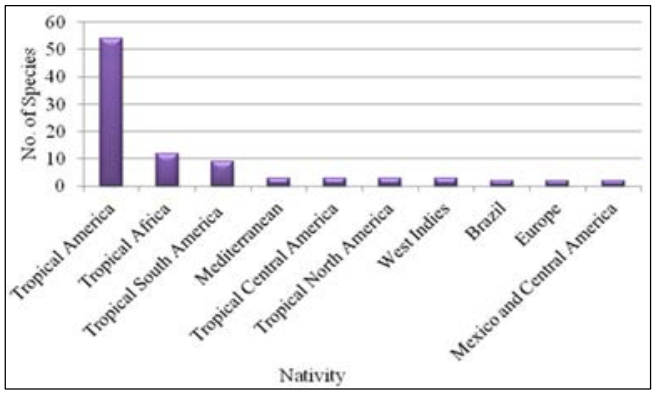

Fig 1: Top five native regions of invasive species documented from GBWS

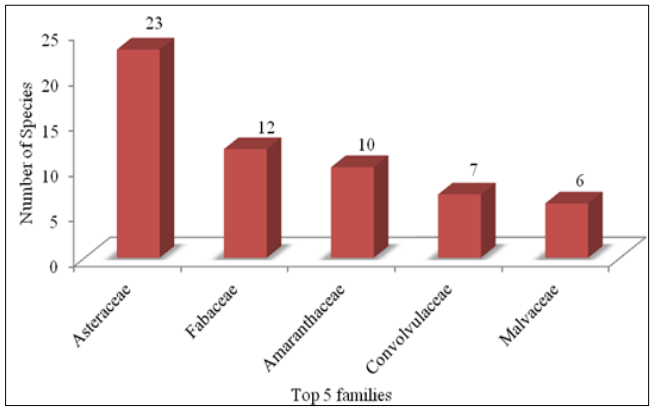

Fig 2: Families accounting for >5 invasive species in Gundla Brahmeswaram wildlife sanctuary, Nallamalais

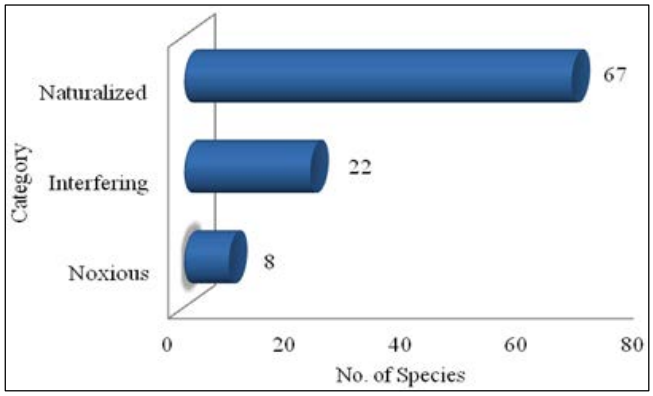

Fig 3: Three various categories of invasive plant taxa in GBWS

Monitoring and Management

Forests are the living resource base for sustenance of its inhabitants besides serving as a storehouse of biodiversity. India is the seventh largest and one of the 17 mega diversity countries of the world and accounts with just 2.5% of the total land area having 7.8 % of the recorded species and 668 Protected Areas account for about 4.9 % of the country's geographic area (Raju *et al*. 2010) [33]. Habitat destruction is the single greatest threat to native biodiversity followed by introduction of alien species (CBD 1992) [4]. Habitat destruction is caused due to agricultural practices, land conversions, grazing of livestock, mining activities, logging, developmental activities (roads/tracks/reservoirs/dams construction), outdoor recreation, pollutants, disruption of fire ecology, military activities, establishment of new towns/cities, etc. Invasive alien species are emerging as one of the major threats to sustainable development. The global extent and rapid increase in invasive species is homogenizing the world's flora and fauna (Mooney and Hobbs 2000) [23] and is recognized as a primary cause of global biodiversity loss. In most of the areas of the existing ecosystems are already degraded due to anthropogenic pressure leading to the creation of habitats suitable for colonization by exotics. This has paved the way for successful invasion of the forest areas by alien plants.

The increasing population and luxurious growth made competition on the native species. In earlier, weeds are grown in waste and degraded open areas but now they are common in crop and forest lands including protected areas due to uncontrolled measures by the authorities and lack of awareness. Monitoring is highly important in the invasive species management to determine the early detection of invasive species, spread and impact of exotic plants on native species. Invasive alien species are a worldwide problem and have variability and plasticity. These cannot be eradicated without the cooperation at international, national, regional, transboundary and local levels. Simberloff (2002) [42] recognized four main methods to eradicate the invasions, namely, mechanical control, chemical control, biological control and cultural control. The *physical and mechanical control* includes hand removal, tillage, deep ploughing, discing, mowing, sickling, grazing, burning, digging, mulching and summer fallow where in *chemical control*, it is the application of chemicals, i.e. soil application, foliar application. e.g. triazones, aniline, 2,4-D, atrazine, glyphosate, etc. Other mode of control is *biological* in which living organisms (bioagents) can be utilized to eradicate weeds (e.g. moths, some insects) while *cultural control* is basically associated with farming systems (Figure 5). Locally, the mechanical removal of these species before flowering and fruiting is most suitable and effective. This process may last for four to five years to eradicate the invasions completely. There is a need to improve the native species growth, reintroduction of native species for the restoration of indigenous vegetation to mitigate negative impacts of invasive alien species in the region. Chemical control is expensive and also shows effect on native useful plants, these chemicals may enter the plant body to living beings through food chain. Regular monitoring and biological control are the main processes for the eradication. The invasions prevent the growth

of grasses and herbaceous layer which lead to unpalatable to wild and domestic animals. Unbridled urbanization, agricultural expansion, unsustainable livestock grazing, unregulated introduction of alien plants for ornamental and plantation purposes, unplanned road construction, rapid development of tourism, clearing of open lands, etc. are also major causes for the intrusion of plant invasions. Apart from these, a '4Ps' formula strategy was also evolved for the management of invasive alien species, namely, prediction, prevention, prescription and public awareness. Public awareness about the economic, ecological, and health risks from invasives is essential for successful implementation of policy and enforcement. It is mandate to prevent the invasives to protect the native biodiversity. The local people are to be educated about the negative impacts of IAS to their agricultural crops and NTFPs extraction from the local forests. The Government of India has to develop a national level policy towards the control of invasive alien species and implement it at the earliest before we lose our indigenous biodiversity once for all (Suthari *et al*. 2016b) [48].

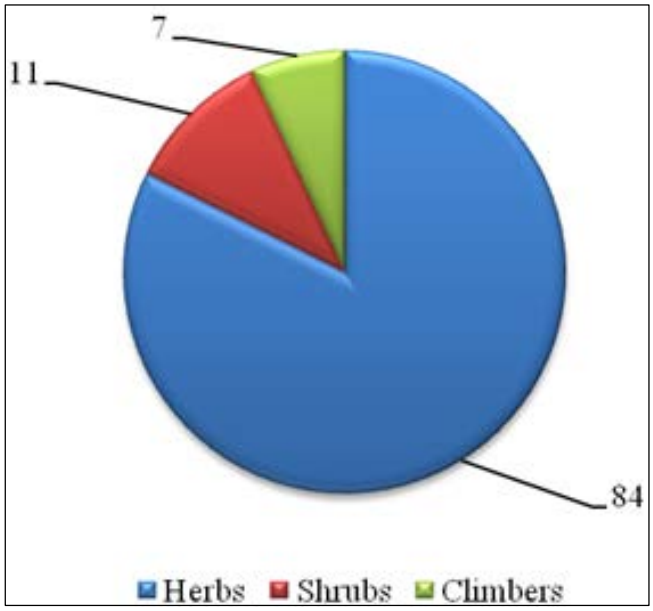

Fig 4: Number of plant invasive species under growth-form categories from GBWS

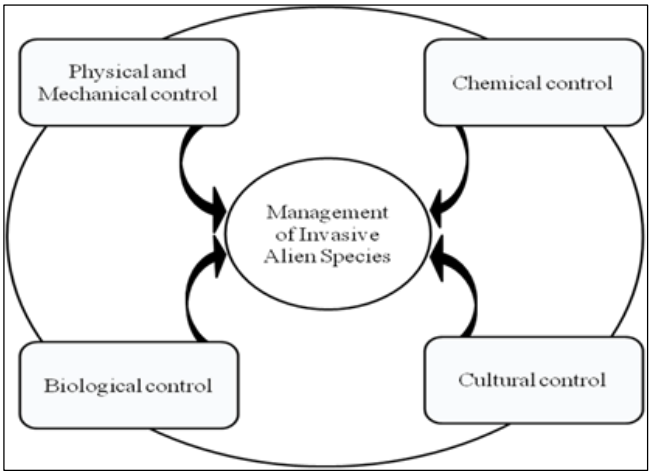

Fig 5: Integrated invasive species management

Conclusions

Early detection and rapid response activities are crucial ingredients of management programmes developed for invasives species. A comprehensive inventory of alien species needs to be formulated and launched. Introduction pathways and vectors of alien species need to be detected and necessary modeling approaches such as remote sensing (RS), geographical information systems (GIS) need to be undertaken. It is very important to utilize the newly emerging technologies and approaches for effective management of these alien species.

Regular surveillance, systematic removal and monitor the impact of invasive species on native biodiversity are very important aspects for the control of invasives. For the effective control, needs cooperation from local people, non-governmental, voluntary organizations, weed interest groups and the government should also create awareness among people about problems associated with these invasive species. For the effective prevention and management practices, also follow GISP (the Global Invasive Species Programme) toolkit which comprises 4 stages, namely, prevention, early detection, eradication and control (Wittenberg and Cock 2001) [52]. More taxonomic research is needed for the proper identification, documentation, monitoring and for the collection of baseline species data. Specific trainings should also be conducted for the identification tools, collection, monitoring techniques. Awareness programmes to be raised in various localities, communities, educational institutions through pamphlets, seminars, group discussions, print and electronic mass media and social network groups. There is also a need to build research networks throughout the world, nation or state, regional level that incorporate risk assessment and risk management of invasive species. Foresters, environmentalists, field researchers and conservation managers are need to pay urgent attention on the ecological impact of invasive exotics both at the species and at the ecosystem levels. The decisions need to be made on whether benefits derived from the invasive spread of an exotic species outweigh the reduced value of ecosystem services, e.g. the loss of grazing land in areas invaded with *Prosopis juliflora*. A better planning is needed for early detection and reporting of infestations of spread of new and naturalized weeds by creation of Plant Detection Network in each State by establishing communication links between taxonomists, ecologists and forest managers to monitor and control (Pyšek *et al*. 2004) [32].

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References

1. Bhatt JR, Singh JS, Singh SP, Tripathi RS and Kohli RK Invasive alien plants: an ecological appraisal for the Indian Subcontinent. CABI, New Delhi, 2012. (doi: 10.1079/9781845939 076.0000)
2. Bomford M, Kraus F, Barry SC, Lawrence E. Predicting establishment success for alien reptiles and amphibians: a role for climate matching. Biological Invasions,2009:11:713–724.
3. Bucharova A, van Kleunen M. Introduction history and species characteristics partly explain naturalization success of North American woody species in Europe. Journal of Ecology,2009:97:230–238.
4. CBD Invasive Alien species. Convention on Biological Diversity, 1992. http://www.biodiv.org/ programmes/cross-cuttings/Alien.
5. CBD. India's third national report. http://www.cbd.int/doc/world/in/in-nr-03-en.doc. (accessed: 13 Aug. 2020), 2005.
6. Chatterjee D. Studies on the endemic flora of India and Burma. Journal of Asiatic Society of Bengal,1940:5:19–67.
7. Cooke T. Flora of the Presidency of Bombay, Vol. I-III. Taylor and Francis, Red Lion Court, Fleet Street, London, 1903.
8. Ellis JL. Flora of Nallamalais. Botanical Survey of India, Calcutta, 1987.
9. Ferra JEM. The adventure of plants and the Portuguese discoveries. Institute of Tropical Scientific Research, Lisbon, Portugal, 1994.
10. Foxcroft LC, Pyšek P, Richardson DM, Genovesi P. The bottom line: impacts of alien plant invasions in protected areas. In: Foxcroft LC, Pyšek P, Richardson DM and Genovesi P (eds.), Plant Invasions in Protected Areas: Patterns, Problems and Challenges. Springer, Dordrecht, 2014, 19–41.
11. Funk JL, Vitousek PM. Resource use efficiency and plant invasion in low-resource systems. Nature,2007:446:1079–1081.
12. Gamble JS, Fischer CEC. Flora of the Presidency of Madras. Vol. 1-3 (by CEC Fischer). Adlard & Sons Ltd., London, 3, 1915-1936.
13. Goyal AK, Arora S. India's Fourth National Report to the convention on biological diversity. Ministry of Environment and Forests, Government of India, New Delhi, 2009.
14. Hiremath AJ, Sundaram B. Invasive plant species in India protected Areas: conserving biodiversity in cultural landscape. In: Foxcroft LC, Pyšek P, Richardson DM and Genovesi P (eds.), Plant Invasions in Protected Areas: Patterns, Problems and Challenges. Springer, Dordrecht, 2013:241–266.
15. Jaryan V, Uniyal SK, Gupta RC, Sharma RD. Alien flora of Himalayan state of Himachal Pradesh. Environmental Monitoring and Assessment,2013:185:(7):6129–6153. (doi: 10.1007/s10661-012-3013-2)
16. Khuroo AA, Malik AH, Dhar GH, Reshi ZA. From ornamental to detrimental: plant invasion of *Leucanthemum vulgare* (Ox-eye daisy) in Kashmir Valley, India. Current Science,2010:98:600–602.
17. Khuroo AA, Rashid I, Zafar R, Dhar GH, Wafai BA. The alien flora of Kashmir Himalaya. Biological Invasions,2007:14:99–113.
18. Khuroo AA, Reshi Z, Rashid I, Dhar GH, Khan ZS. Operational characterization of alien invasive flora and its management implications. Biodiversity and Conservation,2008:17:3181–3194.
19. Kohli RK, Batish DR. Environmental threat from billy-goat weed *Ageratum conyzoides*. Environmental Research Institute of Michigan (Ann Arbor, Michigan),1996:11:925–929.
20. Liu J, Liang SC, Liu FH, Wang RQ, Dong M. Invasive alien plant species in China: regional distribution patterns. Diversity and Distributions,2005:11:341–347.
21. Mandal G, Joshi SP. 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,2014:7:391–400.
22. McNeely JA, Mooney HA, Neville EL, Schei P, Waage JK. Global strategy on Invasive Alien Species. IUCN Gland, Switzerland, and Cambridge, UK, in collaboration with the Global Invasive Species Programme (GISP), 2001.
23. Mooney HA, Hobbs RJ. (eds.) Invasive Species in a Changing World. Island Press, Washington, DC, 2000.
24. Naidu MT, Kumar OA, Venkaiah M. Invasive alien plant species in tropical forests of Eastern Ghats in northern Andhra Pradesh, India. Indian Forester,2015:141:428–432.
25. Pandey RP, Parmar PJ. The exotic flora of Rajastan. Journal of Economic and Taxonomic Botany,1994:18:105–136.
26. Pasha SV, Satish KV, Reddy CS, Rao PVVP, Jha CS. Satellite image based quantification of invasion and patch dynamics of mesquite (*Prosopis juiflora*) in Great Rann of Kachchh, Kachchh Biosphere Reserve, Gujarat, India. Journal of Earth System Science,2014:123:(7):1481–1490.
27. Pejchar L, Mooney HA. Invasive species, ecosystem services and human well-being. Trends in Ecology and Evolution,2009:24(9):497–504.
28. Pimentel D, Lach L, Zuniga R, Morrison D. Environmental and economic costs of non-indigenous species in the United States. BioScience,2000:50:53–65.
29. Pimentel D, Zuniga R, Morrison D. Update on the environmental and economic costs associated with alien invasive species in the United States. Ecological Economics,2005:52:273–288.
30. Pumberton RW, Liu H. Marketing time predicts naturalization of horticultural plants. Ecology,2009:90:69–80.
31. Purseglove JW. Tropical crops: Dicotyledons and Monocotyledons. The English Language Book Society & Longman Group Limited, London, 1969, 1-2.
32. Pyšek P, Richadrson DM, Rejmanek M, Webster GL, Williomson M, Kirschner J. Alien plants in checklists and flora: towards better communication between taxonomists and ecologists. Taxon,2004:53:131–143.
33. Raju VS, Reddy CS, Suthari S. Flowering plant diversity and endemism in India: An Overview. ANU Journal of Natural Sciences,2010:2:(1):27–39.
34. Rao KT, Reddy KN, Pattanaik C, Reddy CS. Ethnomedicinal importance of Pteridophytes used by Chenchus of

Nallamalais, Andhra Pradesh, India. Ethnobotanical Leaflets,2007:22:1–5.
35. Rao RR, Murugan R. Impact of exotic adventives weeds on native biodiversity in India: Implications for conservation. In: Rai LC and Gaur JP (eds.), Invasive species and biodiversity in India. Banaras Hindu University, Varanasi,2006:269–292.
36. Reddy CS, Bhagyanarayana G, Reddy KN, Raju VS. Invasive alien flora of India. National Biological Information Infrastructure, USGS, USA, 2008.
37. Reddy CS, Brahmam M, Raju VS. Conservation prioritization of endemic plants of Eastern Ghats, India. Journal of Economic and Taxonomic Botany,2006:30:755–772.
38. Reshi ZA and Khuroo AA. Alien plant invasion in India: current status and management challenges. Proceedings of the National Academy of Sciences, India Section: B, Biological Sciences 82(Suppl.2),2012:305–312.
39. Richardson DM, Pyšek P, Rejmánek M, Barbour MG, Panetta FD,West CJ. Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distribution,2000:6:93–107.
40. Shah MA, Reshi ZA, Lavoie C. Predicting plant invasiveness from native range size: clues from the Kashmir Himalaya. Journal of Plant Ecology,2012:5:(2):167–173.
41. Sharma BD, Pandey DS. Exotic flora of Allahabad district. Kolkata, India. Botanical Survey of India, Calcutta, 1984.
42. Simberloff D. Managing established populations of alien species. In: Claudi R, Nantel P and Muckle-Jeffs E (eds.), Alien invaders in Canada's Waters, Wetlands, and Forests. Ottawa: Natural Resources Canada, 2002.
43. Simberloff D, Martin JL, Genovesi P, Maris V, Wardle DA, Aronson J. *et al*. Impacts of biological invasions: What's what and the way forward. Trends in Ecology and Evolution,2013:28:(1):58–66.
44. Simmonds NW. Evolution of crop plants. Longman Group Limited, London, 1976.
45. Singh KP, Shukla AN, Singh JS. State-level inventory of invasive alien plants, their source regions and use potential. Current Science,2010:99:107–114.
46. Suthari S. Biodiversity Characterization and Aboveground Vegetation Carbon Pool Assessment in Northern Telangana at Landscape Level Using Geospatial Technique (PhD Thesis). Department of Botany, Kakatiya University, Warangal, 2013.
47. Suthari S, Kandagatla R, Geetha S, Ragan A, Raju VS b. Intrusion of devil weed Chromolaena odorata, an exotic invasive, into Kinnerasani and Eturnagaram wildlife sanctuaries, Telangana, India. Journal of Threatened Taxa,2016:8:(2):8538–8540.
48. Suthari S, Kandagatla R, Ragan A, Raju VS a. Incidence of alien Asteraceae in Telangana and residual Andhra Pradesh and possible ecological implications. Current Science,2016:110:(7):1337–1343.
49. Thuiller W, Richardson DM, Pyšek P, Midgley GF, Hegghes GO, Rouget M. Niche-based modelling as a tool for predicting the risk of alien plant invasions at a global scale. Global Change Biology,2005:11:(12):2234–2250.
50. Turland NJ, Wiersema JH, Barrie FR, Greuter W, Hawksworth DL, Herendeen PS, *et al.* (eds.). International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017. Regnum Vegetabile 159. Glashütten: Koeltz Botanical Books, 2017.
51. Wilcove DS, Rothstein D, Dubow J, Philips A and Losos E. Quantifying threats to imperilled species in the United States: Assessing the relative importance of habitat destruction, alien species, pollution, over exploitation, and disease. BioScience,1998:48:607–615.
52. Wittenberg R, Cock MJW (eds.). Invasive alien species: a toolkit for best prevention and management practices. Global Invasive Species Programme, Cape Town, 2001.