Tropical Plant Research
An International Journal
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ISSN (E): 2349 – 1183
ISSN (P): 2349 – 9265
3(1): 120–130, 2016

Research article

Inventory of invasive alien plants in Bethuadahari wildlife sanctuary in Nadia district, West Bengal, India

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Abstract: A survey was performed in 'Bethadahari wildlife sanctuary', Nadia district, West Bengal during the span of 2010-2015 to invent the invasive alien plant species in 121 hectare forest area and adjoining five villages. Study revealed occurrence of 103 alien angiosperm plant species under 32 families, with four monocot families (Araceae, Poaceae, Cyperaceae, Pontederiaceae). Fabaceae leads with 20 taxa and followed by Asteraceae with 17 plant species. Amaranthaceae, Solanaceae, and Euphorbiaceae were some other important families which possessed eight, seven, and five taxa, respectively. Year-wise quadrat studies revealed increasing number of alien species in the study area. *Parthenium hysterophorus, Ageratum conyzoides, A. haustonianum, Eupatorium odoratum, Chromolaena odorata* of Asteraceae; *Cassia sophera* and *Leucaena leucocephala* of Leguminosae; *Amaranthus spinosus* and *Alternanthera sessilis* of Amaranthaceae; *Lantana camara* of Verbenaceae and *Trema orientralis* of family Urticaceae were the major invasive species. Remarkably, several alien species have been used in diverse economic purposes by villagers, showing use of nearly 49% plants in local health-care systems.
Keywords: Invasive alien plants - Biodiversity - Bethuadahari wildlife sanctuary - Folk use.

[**Cite as:** Talukdar D & Talukdar T (2016) Inventory of invasive alien plants in Bethuadahari wildlife sanctuary in Nadia district, West Bengal, India. *Tropical Plant Research* 3(1): 120–130]

INTRODUCTION

Invasive alien species have potential to spread and established themself outside their native ranges which affect the native natural ecosystems or local human-mediated systems (Mooney & Hobbs 2000, Lockwood *et al*. 2007). Biological invasions by alien taxa are the second worst threat to native ecosystem and become a recurrent cost for agriculture and forestry. Due to rapid increase and extent of invasive species, diversity of world's flora and fauna is becoming homogenized (Lockwood *et al*. 2007) and is recognized as a primary concern for loss of biodiversity (Sax *et al*. 2002, Davis 2003). Yet, a large number of invasive and alien plant species are regularly used for wood fuel, sheltering, fishing, medicinal, and other purposes (Singh *et al*. 2010, Talukdar & Talukdar 2012a, b, 2013).

At least 10% of the world's vascular plants (~3,00,000) can invade native ecosystems and its flora and fauna in direct and indirect ways (Raghubanshi *et al*. 2005). About 40% of the Indian flora is alien and 25% of which are invasive alien species predominantly of neotropic origin (Raghubanshi *et al*. 2005, Reddy 2008, Mandal 2011). As India possesses rich biodiversity, reports on invasive and alien taxa may pave the way for comprehensive regional and national data base for effective management and utilization of exotic floras (Srivastava & Singh 2009, Rastogi *et al*. 2015).

The state of West Bengal is located between 85˚50′ and 89˚50′ E and 21˚38′ and 27˚10′ N, and one of populous as well as biodiversity rich states of India. The lower Indo-Gangetic basin constitutes fertile land for diverse types of flora and fauna, introduced by anthropogenic activities since time immemorial. The Nadia district (situated between 22˚52′30″ and 40˚05′40″ N latitude and 88˚08′10″ and 88˚48′15″E longitude) is an important part of this basin, possessing forested areas, wetlands, and agricultural lands. Bhagirathi is the major river and with Jalangi, Churni, Ichhamati and some small rivers constitute the riverine and floodplain ('Baor') systems in this district. Among the 14 wildlife sanctuary in West Bengal, 'Bethuadahari' wildlife sanctuary is

Received: 03 November 2015
Published online: 29 February 2016

situated in this district. It is 122 Km from state capital Kolkata and represents middle part of lower Gangetic basin. The tropic of cancer passes through this district. The climate of the district is tropical monsoon with three distinct seasons, summer (March–early June), rainy (June–September) and winter (October–February), and mean annual rainfall *ca.* 1800 mm. While maximum summer temperature may soar to 43°C, winter is extremely chilled with temperature may plummet to 2–3 °C. The sanctuary is very rich in biodiversity and famous for spotted deer. As biological invasions are frequently influenced by ecosystem functioning (Sausa *et al*. 2011), climate change (Thuiller *et al*. 2007, Bradley *et al*. 2009, Biswas *et al*. 2014), environmental pollution (Crooks *et al*. 2011), and other physico-chemical mechanisms, a proper first hand inventory in protected areas is absolutely essential to measure threats imposed by alien species on indigenous resources.

Although one report is available regarding the floral diversity of Bethuadahari reserve forest (Das & Lahiri 1990), no investigation was carried out to document the invasive alien plants in this forest area. This sanctuary is 121 hectare man-made deer sanctuary, situated close to National Highway (NH) 34, linking state capital Kolkata with North Bengal and Bhutan. In recent years, widening of NH 34 accompanied by vehicle and rail transport and constructions of inhabitants in and around the forest has greatly impacted the forest ecosystem. The sanctuary has a deer park, a wetland inside and is an attractive destination of migratory birds during winter. As invasive species has huge ecological impacts and preference over native species in forest ecology, documentation of alien plants in this important sanctuary is necessary. The objectives of the present study are, thus, to make an inventory of the alien flora, their classification and use by local people in and around the sanctuary.

MATERIALS AND METHODS

Study site

The present investigation was carried out by extensive field survey during the last six years (2010–2015) in different intervals (March–June, September–January) in sanctuary area of 121 hectares and 5 villages adjacent it (Fig. 1).

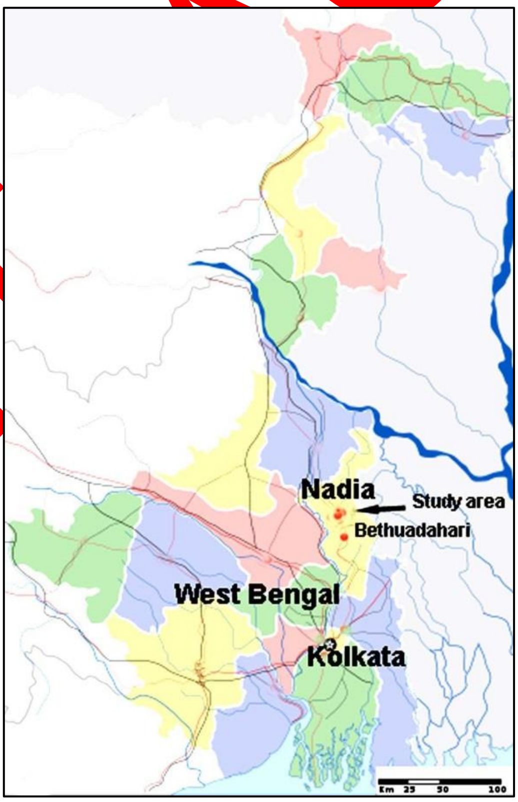

Figure 1. A map of study areas (red dots) in the position of Nadia district, West Bengal, India.

Collection of data and methods of inventory

Plant samples were collected either in flowering or in fruiting stage, and voucher specimens were deposited in departmental herbaria, R.P.M. College, Uttarpara, Hooghly. Invasiveness of the alien species, enlisted by previous works (Lowe *et al*. 2000, Huang *et al*. 2009), was studied using techniques of Baider & Florens (2011).

Accordingly, a combination of random walks through the area along with a more quantitative sampling of the seedlings and larger woody plants (flowering or fruiting stage) in a series of square quadrats (1 × 1 m for seedlings and 10 × 10 m for tree) was followed. Frequency (F) of particular plant species was calculated by dividing the number of quadrats in which a particular species occur with total number of quadrats laid down. The identity of specimens was verified with existing literatures, monographs, and was also confirmed by IPNI (International Plant Names Index) data base (www.IPNI.org). Economic use of different flora was investigated through interviews of knowledgeable people like village elders, medicinemen, farmers, teachers, etc. Collected information was critically cross-checked by structured questionnaires, and documented thereafter. Nativity of the species was documented from the existing literatures (Rao & Murugan 2006) and the works done in the region (Das & Lahiri 1990).

RESULTS

Documentation and classification of alien taxa

Present inventorization of the alien invasive flora in the 'Bethuadohori wildlife sanctuary' pointed out presence of 103 species which is belonging to 83 genera under 32 families (Table 1). Regarding plant growth type, 85% of total documented plant species were herbs, and it was followed by shrub (9%), tree (4%) and climbers (2%). Several genera were found to possess three or more species (Table 1). Major proportion (94%) of alien flora is dicotyledonous which is grouped under 96 species and 28 families (Table 1). It was followed by Monocotyledons (6%) distributed in seven genera of four families. Among the total 32 families, Fabaceae dominated with 20 species, followed by Asteraceae (17 species), Amaranthaceae (8), Solanaceae (7) and then others (Table 1; Fig. 2).

Table 1. Invasive alien plant species in 'Bethuadohori Wildlife Sanctuary' at Nadia district of West Bengal, India

S.No.	Species	Family	Life form	Nativity	Use
1	*Aerva javanica* (Burm. f.) Juss. ex Schult	Amaranthaceae	Herb	Trop. America	M
2	*Achyranthes aspera* L.	Amaranthaceae	Herb	Trop. America	M
3	*Aeschynomene americana* L.	Fabaceae	Herb	Trop. America	Co, 'shola'
4	*Ageratum conyzoides* L.	Asteraceae	Herb	Trop. America	NU
5	*Ageratum houstonianum* Mill.	Asteraceae	Herb	Trop. America	NU
6	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	Herb	Trop. America	Veg
7	*Alternanthera pungens* Kunth	Amaranthaceae	Herb	Trop. America	M
8	*Alternanthera sessilis* (L.) R.Br. ex DC	Amaranthaceae	Herb	Trop. America	M, Veg
9	*Amaranthus spinosus* L.	Amaranthaceae	Herb	Trop. America	M
10	*Argemone mexicana* L.	Papaveraceae	Herb	Trop. America	NU
11	*Bidens pilosa* L.	Asteraceae	Herb	Trop. America	M
12	*Blumea lacera* (Burm. f.) DC.	Asteraceae	Herb	Trop. America	M, veg
13	*Boerhaavia erecta* L.	Nyctaginaceae	Herb	Trop. America	M, veg, Cf
14	*Calotropis gigantea* (L.) R.Br.	Asclepiadaceae	Shrub	Trop. Africa	M
15	*Calotropis procera* (L.) R.Br.	Asclepiadaceae	Shrub	Trop. Africa	M
16	*Cassia alata* L.	Fabaceae	Shrub	West Indies	M, Thatching
17	*Cassia javanica* L.	Fabaceae	Tree	S.E. Asia	Or, M
18	*Cassia occidentalis* L.	Fabaceae	Herb	Trop. S. America	M, Bf
19	*Cassia sophera* L.	Fabaceae	Herb	Trop. S. America	M, Bf
20	*Catharanthus pusillus* (Murray)Don	Apocynaceae	Herb	Trop. America	M
21	**Chromolaena odorata* (L.) King & Robinson	Asteraceae	Herb	Trop. America	NU
22	*Chrozophora rottleri* (Geis.) Spreng.	Euphorbiaceae	Herb	Trop. Africa	M
23	*Chenopodium album* L.	Chenopodiaceae	Herb	Europe	Veg, Cf
24	*Cleome gynandra* L.	Cleomaceae	Herb	Trop. America	M
25	*Cleome monophylla* L.	Cleomaceae	Herb	Trop. America	M
26	*Cleome rutidosperma* DC.	Cleomaceae	Herb	Trop. America	M
27	*Coix lacryma-jobi* L.	Poaceae	Herb	S. E. Asia	Pearl, fishing
28	*Crotalaria pallida* Dryand	Fabaceae	Herb	Trop. America	Bf

29	*Crotalaria retusa* L.	Fabaceae	Herb	Trop. America	Bf
30	*Croton bonplandianum* Boil.	Euphorbiaceae	Herb	Temp.S. America	M
31	*Cryptostegia grandiflora* R.Br.	Asclepiadaceae	Woody Climber	Trop. Africa (Madagascar)	M
32	*Cuscuta chinensis* Lam.	Cuscutaceae	Herb	Mediterranean	NU
33	*Cuscuta reflexa* Roxb	Cuscutaceae	Herb	Mediterranean	NU
34	*Cyperus rotundus* L.	Cyperaceae	Herb	Africa, S. Europe	M
35	*Cytisus scoparius* (L.) Link	Fabaceae	Herb	Europe	M
36	*Datura innoxia* Mill.	Solanaceae	Shrub	Trop. America	M
37	*Datura metel* L.	Solanaceae	Shrub	Trop. America	M
38	*Dentella repens* (L.) Forst	Rubiaceae	Herb	E. Asia, Australia	Veg
39	*Digera muricata* (L.) Mart.	Amaranthaceae	Herb	S. W. Asia	Veg
40	*Duranta repens* L.	Verbenaceae	Shrub	Trop. America	Or
41	*Echinochloa crusgalli* (L.) P.Beauv.	Poaceae	Herb	Trop. S. America	M
42	*Echinacea paradoxa* Britton	Asteraceae	Herb	Europe	NU
43	*Eclipta prostrata* (L.) Mant.	Asteraceae	Herb	Trop. America	M
44	******Eichhornia crassipes* Kunth	Pontederiaceae	Aq. Herb	Trop. America	NU
45	**Eupatorium odoratum* L.	Asteraceae	Herb	Europe	NU
46	*Euphorbia hirta* L.	Euphorbiaceae	Herb	Trop. America	Cf
47	*Euphorbia heterophylla* L.	Euphorbiaceae	Herb	Trop. America	Cf
48	*Evolvulus nummularius* (L.) L.	Convolvulaceae	Herb	Trop. America	Cf
49	*Gnaphalium coarctatum* Willd.	Asteraceae	Herb	Trop. America	NU
50	*Gnaphalium pensylvanicum* Willd.	Asteraceae	Herb	Trop. America	NU
51	*Gomphrena serrata* L.	Amaranthaceae	Herb	Trop. America	Or
52	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	Herb	Trop. America	Aromatic
53	*Impatiens balsamina* L.	Balsaminaceae	Herb	Trop. America	Or
54	*Indigofera astragalina* DC.	Fabaceae	Herb	Trop. America	Cloth washing
55	*Indigofera linifolia* (L. f.) Retz.	Fabaceae	Herb	Trop. America	NU
56	*Ipomoea quamoclit* L.	Convolvulaceae	Herb	Trop. America	Bf
57	*Ipomoea aquatica* Forsk	Convolvulaceae	Aquatic	Trop. America	M, veg
58	**Lantana camara* L.	Verbenaceae	Herb	Trop. America	Bf
59	*Lathyrus aphaca* L.	Fabaceae	Herb	Mediterranean	M, Cf, mulching
60	*Lathyrus sativus* L.	Fabaceae	Herb	Mediterranean	Pulse, Fd, besan, Cf, veg
61	*Leonotis nepetiifolia* (L.) R.Br.	Lamiaceae	Herb	Trop. Africa	M
62	**Leucaena leucocephala* (Lam.) de Wit	Fabaceae	Tree	Trop. America	Bf, basket making,
63	*Ludwigia perennis* L.	Onagraceae	Herb	Trop. America	M
64	*Malachra capitata* (L.) L.	Malvaceae	Herb	Trop. America	M
65	*Mecardonia procumbens* (Mill.) Small	Scrophulariaceae	Herb	Trop. N. America	NU
66	*Melilotus alba* Desv.	Fabaceae	Herb	Europe	Insecticide
67	**Mikania micrantha* Kunth	Asteraceae	Climber	Trop. America	NU
68	*Mimosa pudica* L.	Fabaceae	Herb	Trop. S. America	M
69	*Monochoria vaginalis* (Burm.f.) C. Presl.	Pontederiaceae	Aquatic herb	Trop. America	M
70	*Nicotiana plumbaginifolia* Viv.	Solanaceae	Herb	Trop. America	NU
71	*Ocimum basilicum* L	Lamiaceae	Herb	Trop. America	M
72	**Opuntia stricta* (Haw.) Haw.	Cactaceae	Herb	Trop. America	NU
73	*Oxalis corniculata* (DC.) Raeusch.	Oxalidaceae	Herb	Europe	M
74	*Parthenium hysterophorus* L.	Asteraceae	Herb	Trop. N. America	NU
75	*Pennisetum purpureum* Schum.	Poaceae	Herb	Trop. N. America	Cf
76	*Peperomia pellucida* (L.) Kunth	Piperaceae	Herb	Trop. America	Folk play
77	*Peristrophe paniculata* (Forssk.) Brummitt	Acanthaceae	Herb	Trop. America	NU

78	*Phaseolus aureus* L.	Fabaceae	Herb	Trop. America	Fd, Cf, veg
79	*Phyllanthus fraternus* Webster	Euphorbiaceae	Herb	Trop. America	M
80	*Physalis angulata* L.	Solanaceae	Herb	Trop. America	Folk play
81	*Pilea microphylla* (L.) Liebm.	Urticaceae	Herb	Trop. America	NU
82	*Pistia stratiotes* L.	Araceae	Herb	Trop. America	M
83	*Polygonum barbatum* L.	Polygonaceae	Herb	S. E. Asia	M
84	*Polygonum hydropiper* L.	Polygonaceae	Herb	S. E. Asia	M
85	*Portulaca oleracea* L.	Portulacaceae	Herb	Trop. S. America	Or
86	*Prosopis juliflora* (Sw.) DC.	Fabaceae	Tree	Trop.S. America	Wood works
87	*Ruellia tuberosa* L.	Acanthaceae	Herb	Trop. America	Or
88	*Scoparia dulcis* L.	Scrophulariaceae	Herb	Trop. America	M
89	*Sesbania grandiflora* (L.) Pers.	Fabaceae	Shrub	Trop. America	Bf, veg, M, Or
90	*Sida acuta* Burm.f.	Malvaceae	Herb	Trop. America	M
91	*Solanum torvum* Sw.	Solanaceae	Shrub	Trop. America	M
92	*Solanum xanthocarpum* Schrad. & H. Wendl.	Solanaceae	Shrub	Trop. America	NU
93	*Solanum nigrum* L.	Solanaceae	Herb	Trop. America	M
94	*Sonchus oleraceus* L.	Asteraceae	Herb	Mediterranean	NU
95	*Spilanthes radicans* Jacq.	Asteraceae	Herb	Trop. America	M
96	*Tephrosia purpurea* (L.) Pers.	Fabaceae	Herb	Trop. America	M
97	*Torenia fournieri* Linden ex E. Fournier	Scrophulariaceae	Herb	Australia	NU
98	*Trema orientralis* (L.) Blume	Ulmaceae	Tree	S. E. Asia	M, Bf, fishing, thatching
99	*Tridax procumbens* L.	Asteraceae	Herb	Trop. America	M
100	*Urena lobata* L.	Malvaceae	Herb	Trop. America	M
101	*Wedelia chinensis* (Osbeck) Merr.	Asteraceae	Herb	S. E. Asia	M
102	*Vernonia cinera* L.	Asteraceae	Herb	Temperate America	NU
103	*Vigna sublobata* (L.) Wilczek	Fabaceae	Herb	S. E. Asia	Pulse, 'bori', besan, Cf

Note: *-enlisted in database of world's 100 worst invasive; M-medicinal, Co-compost, Or -ornamental, Bf-biomass fuel, Cf-cattle feed, Fd-Food, Veg-Vegetables, NU-not in use.

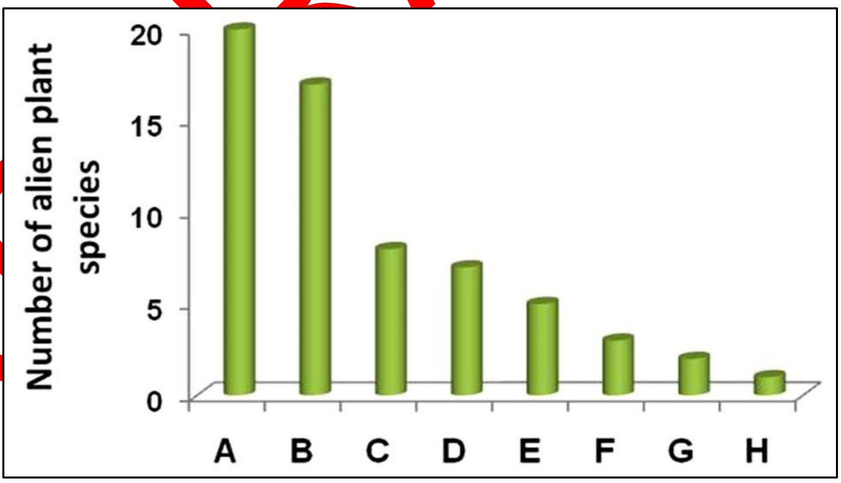

Figure 2. Distribution of alien plant species in different angiopsperm families; A-Family Fabaceae, B-Asteraceae, C-Amaranthaceae, D-Solanaceae, E-Euphorbiaceae, F-Malvaceae / Scrophulariaceae / Lamiaceae / Convolvulaceae / Asclrpia--daceae / Poaceae (three species each), G-Cuscutaceae / Verbenaceae / Pontederiaceae / Acanthaceae / Polygonaceae (two species each), H-rest of the 16 families with one species each, as mentioned in table 1.

Habitat distribution

About 38% of invasive species identified in the present study were most abundant in roadside (NH 34 and rural roads) close to forest. On the other hand 32% taxa were reported from forest area and 20% and 10% plant species preferred to grow in cultivated fields and banks of water bodies respectively. Ecological studies of last six years exposed the high frequency of *Parthenium hysterophorus*, *Eupatorium odoratum*, *Ageratum conyzoides*, *A. houstonianum*, *Chromolaena odorata* along the roadside than the interior of the forest (Fig. 3).

The ratio of number of plants (cumulative of 400 quadrats/year in six years) between forest area and roadside varied between 0.53–0.88 for these five aster members, while it was near to 1.0 for *Cassia sophera* (0.98), >1.0 for *Leucaena leucocephala*, *Trema orientalis, Alternanthera sessilis*, and *Amaranthus spinosus*, and was 2.15 for *Lantana camara* (Fig. 3). While, *Tridax procumbens*, *Eclipta prostrata* and *Wedelia chinensis* exhibited higher frequency in interior of the forest (F=80–86%) than the roadside (F=65–72%). Within the forest, members of Amranthaceae (*Achyranthes aspera*, *Alternanthera philoxeroides*, *Alternanthera sessilis* and *Amaranthus spinosus*) dominated intermingling with numbers of legumes (*Aeschynomene americana*, *Leucaena leucocephala* and *Mimosa pudica*) different species of *Crotalaria*, *Cassia*, and species of other families in different magnitudes. The frequency of *Parthenium* has been found to be reducing interestingly, in plots where species of family Amaranthaceae dominated. The tree *Trema orientralis* has been found flourishing in the forest area better than the roadside (Fig. 3). Members of family Polygonaceae, Araceae, Cyperaceae, Pontederiaceae preferred wetland areas, while Solanaceae, Euphorbiaceae, Malvaceae, Cactaceae, Convolvulaceae and Asclepiadaceae were more frequent in dry land.

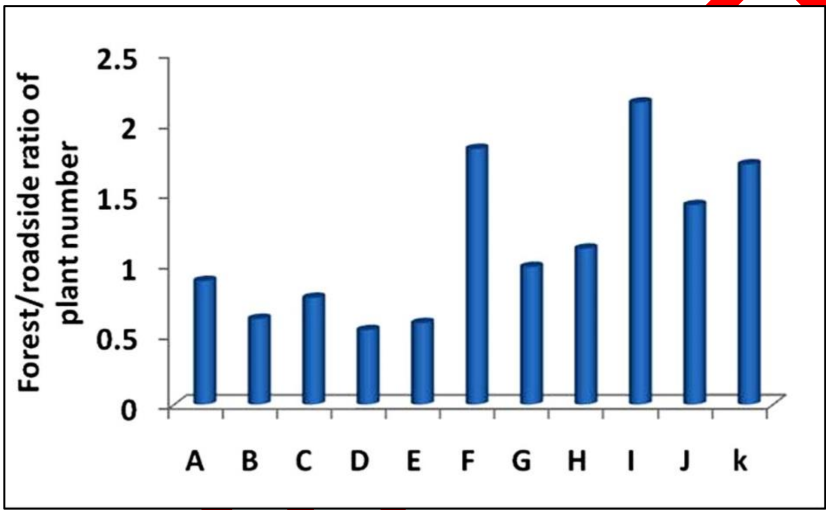

Figure 3. Forest/roadside ratio of number of plants for eleven alien taxa.

Documentation of spreading of alien flora over the last six years (2010–2015) pointed out a sharp increase of *Ageratum*, *Chromolaena*, *Parthenium*, *Eupatorium*, *Leucaena*, *Cassia*, *Amaranthus*, *Alternanthera*, *Lantana*, and *Trema* species (Fig. 4).

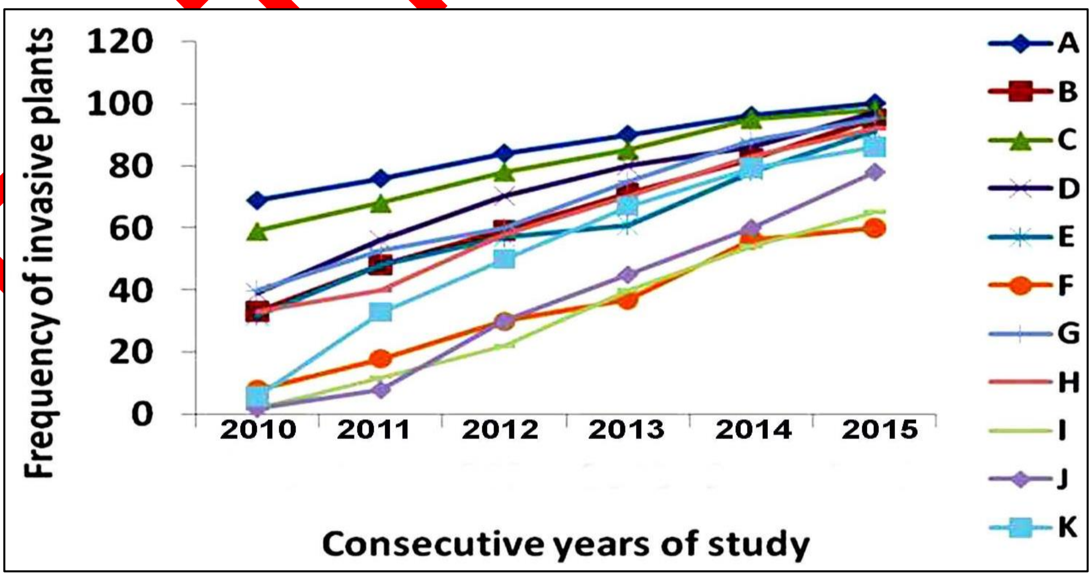

Figure 4. Frequency % of 11 invasive plants as recorded from six consecutive years (2010-2015) with 400 square quadrats laid down/year, A- *Parthenium hysterophorus* L., B- *Eupatorium odoratum* L., C- *Ageratum conyzoides* L., D- *Ageratum houstonianum* Mill., E- *Chromolaena odorata* (L.) King & Robinson, F- *Leucaena leucocephala* (Lam.) de Wit, G-*Cassia sophera* L., H- *Alternanthera sessilis* (L.) R.Br. ex DC, I- *Lantana camara* L., J- *Trema orientralis* (Linn.) Blume, and K- *Amaranthus spinosus* L.

Resource utilization of alien plants by local people

Local population in the present study area used the documented 103 plant species as food, fodder, ornamental, medicinal, religious, and other commercial purposes (Fig. 5). Fabaceae dominated as the most valuable source of food, fodder, manure, fuel, folk play and different other objectives (Table 1). According to local people, beans (*Phaseolus* spp), *mung* (*Vigna* spp), *khesari* (*Lathyrus sativus* L.) and *jangli matar (Lathyrus aphaca* L.) have been used considerably in their daily life. Seed flour has been used as food supplement, adulterant, the whole plant as fodder, soil fertilizer (mulching), and tender pods as vegetables and cattle feeds. About 49% of total alien plants were used as medicinal purposes, while 11.6% plants were utilized as food and 9.7% used as cattle feed. Among the small-scale cottage industries, preparation of beads on string using seeds of *Coix* (Poaceae) and commercial 'shola' using *Aeschynomene americana* (Fabaceae) were regular jobs for local people. Another financially viable activity within the sanctuary area was different types of wood works, for which *Prosopis julifera* (Fabaceae) tree was mainly used. Along with these, different plant parts have been used as insecticide and aromatic purposes (Table 1; Fig. 5).

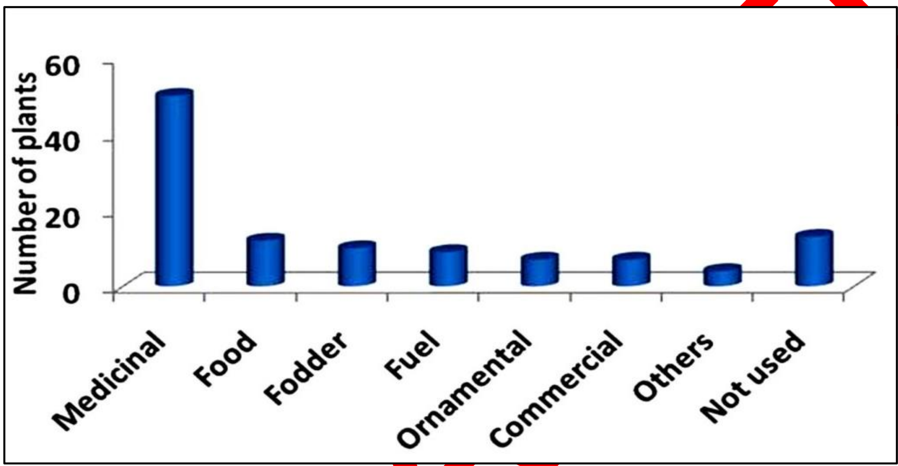

Figure 5. Utilization of resources of alien plants by local people; others include folk play, aromatic, insecticide.

Nativity of documented alien flora

Tropical America contributed nearly 60% plants, followed by share of South-East Asia, Europe and tropical South America, tropical Africa, the Mediterranean and other regions (Fig. 6).

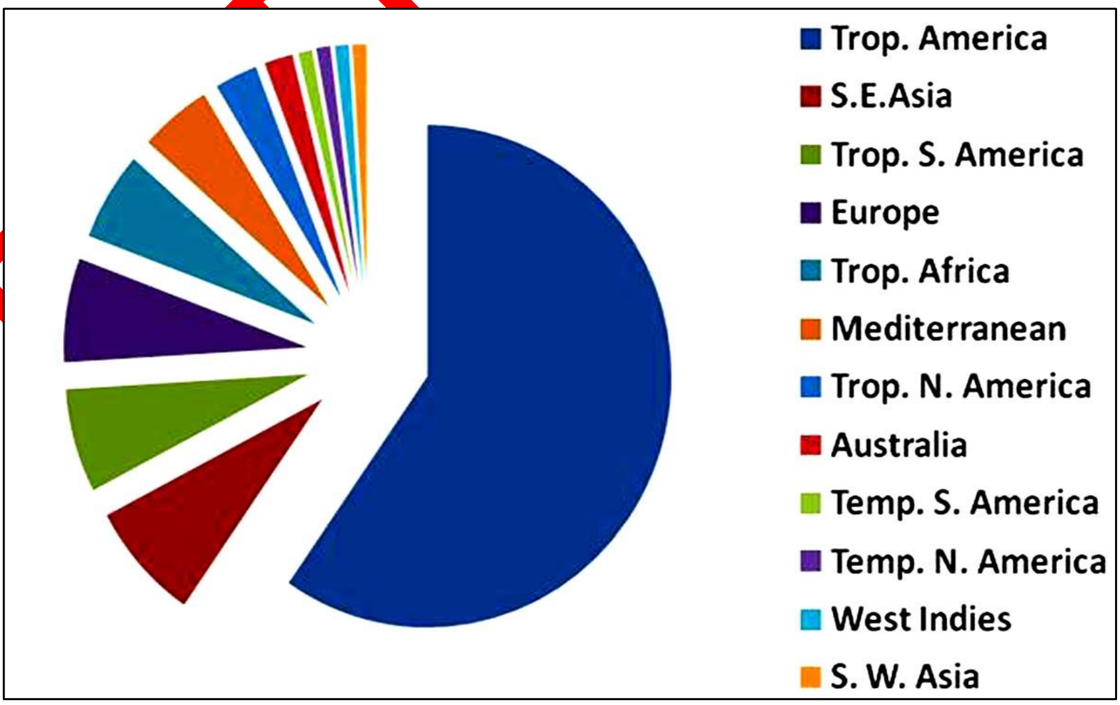

Figure 6. Nativity of 103 alien taxa in 12 world geographic regions with lion's share is from tropical (Trop) America, S-South, E-east, N-North, W-West.

DISCUSSION

The present investigation reported that the floral diversity of 'Bethuadahari Wildlife Sanctuary' consist 57.11% invasive species. However, rest of the flora was made up of native species. The results indicated dominance of alien flora in the forest areas. Herbs constituted major portions (85%) of this alien species and except only seven species, all others belong to 28 different dicot families. The result exhibited dramatic increase in number of herbaceous flora from the documentation of about 49.2% herbs in this forest area during 1990 (Das & Lahiri 1990), indicating introduction of more alien species in the forest areas in recent times. The presence of higher number of leguminous plants is also supported by earlier reports from Sub-Himalayan North Bengal (Talukdar 2013e, Talukdar & Talukdar 2012a, b), and other areas of Himalaya (Joshi 2002, Bajpai *et al.* 2015). Although Fabaceae contained largest number of alien species in the present study, the dominance of invasive alien species of Asteraceae was also found in some other regions of India (Rao & Murugan 2006) and other countries (Heywood 1989, Huang *et al*. 2009, Feng & Zhu 2010). The higher frequency of some asters along the roadside than the interior of the forest indicated uneven distribution of Asteraceae weeds in the present study area, resulting in forest/roadside ratio in number of plants below 1.0 for the family. Ecological study revealed that in contrast to asters, species of Amaranthaceae and Fabaceae were more evenly distributed. Larger number of *Trema orientralis* and *Lantana camara* in forest wasteland indicated aggressiveness and invasion potential of these taxa in nutrient-deficient areas in expense of growth of native taxa, leading to forest/roadside ratio for these two species over 1.0. The result is in partial agreement with earlier record, showing occurrence of *Lantana camara*, but not *Trema orientalis* in this reserve forest area during 1990 (Das & Lahiri 1990). This suggested introduction of *Trema* after 1990 in the study area, probably to meet the growing demand of fuel plants by local people. Besides abiotic and biotic constrains, relative degree of disturbances in habitats may profoundly affect physical environment, which can create permissive conditions for introduction and gradual establishment of alien species to invade native systems in this forest area (Huang *et al*. 2009, Singh *et al*. 2010). Habitat disturbances in the present study areas may be one of the prime reasons for rapid establishments of some of the worst invasive species in the present study area.

Reduction in frequency of one of the world's worst noxious weeds, *Parthenium hysterophorus* in plots where members of family Amaranthaceae dominated suggested antagonistic/allelopathic effect of species belonging to the family Amaranthaceae on spreading of *Parthenium*. Inhibitory or allelopathic effect has been found in many plant species interactions including effect of aster, *Blumea lacera* L. on cereals and common kharif weeds (Oudhia *et al*. 1989, Biswas *et al*. 2014, Sarkar *et al*. 2015). The inhibitory effects of one of the world's worst invasive plants *Lantana camara* has been reported regarding chromotoxicity and severe oxidative imbalance on target crop legumes in present (Talukdar 2013a). However, role of chromosomal rearrangements, ploidy level variations and other intrinsic biochemical mechanisms have been suspected behind aggressiveness of alien invasions, as polyploid species and favorable chromosomal rearrangements, reported in legumes like *Lathyrus* (Talukdar 2010a, b, 2012a, b) may have better fitness than common native plants (Pandit *et al*. 2011). Furthermore, altered morphological, biochemical and molecular make-up in aneuploid genomes and diploid mutated genotypes may confer new strategy for adaptations in stressful environments (Talukdar 2009a, b, 2011, 2012b, Talukdar & Biswas 2007), and thus, origin of new invasive flora cannot be ruled out.

Ecological study pointed out steep rise in population of 11 plants species (*Parthenium hysterophorous, Ageratum conyzoides, Eupatorium odoratum, Chromolaena odorata, Cassia sophera, Leucaena leucocephala, Lantana camara, Trema orientalis, Amaranthus spinosus, Alternanthera sessilis* and *Eichhornia crassipes*) in the present forest area during the last six years. Thus, these 11 taxa, were selected as indicator of invasion by non-indigenous species in the present forest area, and their distribution data manifested as ratio of forest and roadside was presented. The four taxa of asters (*Parthenium*, *Ageratum*, *Eupatorium*, *Chromolaena*) with 5 species, ascertained by this criteria, have no economic utilization by locals. However, both *Cassia* and *Leucaena* were extensively utilized as anti-diabetic medicine and fuel, respectively. The small tree, *Trema orientalis* was mainly used as cheap fuel. Three taxa exhibiting high aggressiveness in degraded forest areas were *Lantana camara*, *Amaranths spinosus* and *Alternanthera sessilis* which have been partially used by local people. It was found that majority (~49%) of the invasive plant species were used by village medicine men for primary health care systems, followed by food and feed. Many leguminous plants were used as both food and forage. This has enormous importance as legumes are cheap and easily available source of plant-origin protein with many essential amino acids, antioxidant flavonoids and minerals (Dixon & Sumner 2003, Talukdar 2013b).

Some recent surveys in Sikkim Himalayas (India) revealed extraordinary potential of legumes in formulation of diverse types of ethnic food and medicines (Talukdar 2013d, Talukdar & Talukdar 2012a, b). Conservation of legume germplasm is absolutely essential to prevent their dwindling genetic diversity throughout the world including India. Due to its remarkable hardiness against abiotic (salinity, heavy metals etc.) and biotic stress, *Lathyrus* spp. which have potential to grow well in low input and marginal farming condition and can sustain soil nutrition in degraded areas has been recognized in the present study areas. This assumes importance as potential of legume-based farming has been studied in recent decade and genetic improvement programs have been undertaken (Talukdar 2008, 2009a, b, 2010a, b,c, 2011, 2012a, b). A recent study revealed arsenic and other heavy metal bioaccumulation in photosynthetic and edible parts of crop legumes like *Phaseolus vulgaris*, *Lens culinaris*, *Cicer arietinum*, and *Lathyrus sativus* in the lower Gangetic basin led severe agronomic loss due to alteration in antioxidant defense mechanisms and severe impairment in plant growth (Talukdar 2012c, 2013b, c).

Among the 103 taxa documented in the present study, seven species (*Eupatorium odoratum*, *Chromolaena odorata*, *Eichhornia crassipes*, *Lantana camara*, *Leucaena leucocephala*, *Mikania micrantha*, *Opuntia stricta*) have been conscripted as world's 100 worst invasive species (Lowe *et al*. 2000). Tropical American flora was found dominated as alien and the strong allelopathic effects on native species may be one of the reasons of their dominance over indigenous flora (Huang et al. 2009, Talukdar 2013a). However, it is noteworthy that after introduction, tough competition exists among alien flora in the invaded areas which can be exploited for their better utilization, management and prevention of extinction of indigenous flora. Also, loss of diversity of native flora due to invasive species cannot be straightforward in a dynamic and functional ecosystem as increasing biotic and abiotic stress factors may impede growth and reproduction of native species with simultaneous introduction, establishment and successful invasion of more hardy alien species, better utilizing the rapidly depleting soil fertility, habitat fragmentation and other adverse conditions to colonize (Thuiller *et al*. 2007, Talukdar 2013e). Digitization of regional native flora in global scientific data bases may have significant impact in this regard (Talukdar 2015).

CONCLUSION

The result presented here is the cumulative of studies of six consecutive years. It is alarming to note that number of alien species in this protected wildlife sanctuary constitutes a major share of forest biodiversity, of which 11 species are enlisted as most aggressive invasive plants within the study area. It is also important to note that the alien plants have been used by local people for medicinal and other economic purposes, although they can impose considerable threat to the growth and reproduction of native flora in the forest area. Thus, the present study can be used as reference work for threat assessment, management and utilization of alien and alien invasive flora in this ecologically sensitive protected area.

ACKNOWLEDGEMENT

The authors are grateful to the local villagers and forest authorities for giving necessary supports during the entire course of the study.

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