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Species richness and floral diversity around 'Teesta Barrage Project' in Jalpaiguri district of West Bengal, India with emphasis on invasive plants and indigenous uses

Dibyendu Talukdar
Department of Botany, RPM College (University of Calcutta), Uttarpara, Hooghly, West Bengal, India.

Correspondence: dibyendutalukdar9@gmail.com

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Abstract

An investigation was carried out in Gajoldoba beels, Saraswatipur forest, tea gardens and village areas around 'Teesta Barrage Project' (TBP) to document floral diversity and their uses by local people during 2011-2012. Around 81 plant species distributed in 75 genera, along with 4 fern species, all under 45 families (dicot - 33, monocot - 08, fern - 04) have been documented. Family Fabaceae dominated with highest number (12 taxa) of plant species, and was followed by monocot family Poaceae with 7 taxa. Plant species showed marked variations in frequency, density and abundance in 200 randomly laid quadrat studies. Among the flowering plants, *Lantana camara*, *Mikania indica*, *Parthenium hysterophorus*, *Ageratum conyzoides*, and *Cynodon dactylon* exhibited aggressive invasions. About 36 (44.44%) plant species were used by local people for diverse medicinal purposes. The study revealed presence of rich biodiversity, local traditional knowledge on herbal medicine and resource utilization in TBP area which need urgent conservation.

Keywords: Biodiversity; plant invasion; indigenous use; Teesta Barrage Project.

Introduction

The river Teesta is the most dynamic river in Sikkim and Darjeeling Himalayas and plays vital roles in conservation of diverse but fragile Himalayan as well as sub-Himalayan ecological and natural resources. It has originated in Cho Lhamu Lake at an elevation of 5,330m above sea level in the Sikkim Himalayas, and is then fed by rivulets, which arise in Thangu, Yumthang and Donkia-La ranges and flows past the town of Rangpo at the border between Sikkim and West Bengal up till Teesta Bazaar. At Teesta Suspension Bridge, which joins Kalimpong with Darjeeling, the river is met by its main tributary, the Rangeet River. At this point, it changes course southwards and hits the plains of West Bengal at Sevoke. The river then courses its way to Jalpaiguri and then to Lalmonirhat district of Bangladesh, before finally merging with the mighty Brahmaputra (Jamuna) in Gaibandha. The upper catchment receives a total annual rainfall of 1,328 mm, while the middle of the basin receives 2,619 mm with a mean of 2471.3 mm in Jalpaiguri district (WBSAPCC, 2010). It has been recorded that about 77-84% of the annual rainfall is received between June and September. Several barrages have been constructed in India and Bangladesh to tap the huge hydro-power resources of this mighty river of which TBP at Gajoldoba in Jalpaiguri district of West Bengal is an ambitious multipurpose project. It plans to irrigate 9.22 lakh ha of land in six districts of Indian north Bengal without any storage system.

However, due to excessive deforestation, human settlements, agriculture and diversion of river water through construction of barrages and possibly for climate change, the flow of Teesta is gradually dwindling, thus threatening a huge ecological catastrophe in Terai (western part of river) and Dooars (eastern part of river) of Eastern Himalayas (Sarker *et al*., 2011). The region is extremely rich in biodiversity, indigenous ethnic tribes and their cultural heritage and knowledge regarding ethno-medicinal and resource utilization, organic farming and tea plantations. The district of Jalpaiguri constitutes the major part of 'Dooars' in the foothills of Himalaya with numerous small and large rivers flowing through it. Despite rich in floral diversity, limited information is available regarding status and conservation of flora in this region, especially at 'Gajoldoba' where the TBP resides. Recently, zooplankton and avifaunal diversity have been studied in perspective of human interference around ‘Gajoldoba’ wetland (Datta, 2011a,b). No reports, however, are available regarding floral diversity and its indigenous uses by local people inhabiting around ‘Gajoldoba beel’.

Alien and invasive plant species are second worst threat to native biodiversity after habitat destruction. Accumulating evidences indicate that threat by invasiveness increases with increasing water stress, drought, metal toxicity, environmental pollution and climate change (Vilá *et al*., 2007; Yang *et al*., 2007). The ‘Gajoldoba beel’ and its surroundings are now exposed to huge transportation, tea garden activities, agriculture, human settlements, and tourism, all of which may pose huge risk to native biodiversity and indigenous knowledge-based medicine. As TBP is a trans-national issue, the status of floral diversity, invasiveness and ethno-medicinal uses need urgent inventory and documentation. Considering all the above perspectives, the present study was undertaken around TBP regions to document the plant diversity, and use of herbal plants by indigenous people in this biodiversity rich wetland. The main objectives were to 1) document the plant community, 2) perform ecological analysis, and 3) identify plants showing invasiveness and used in various purposes, especially for medicine by local people in the study area.

Materials and Methods

(a) Study area

The present study was conducted in and around TBP (26° 20' N/ 88° 4' E) covering ‘Gajoldoba beel’, Saraswatipur Village, Saraswatipur tea garden and adjoining forest areas. The ‘Gajoldoba beel’ is actually a perennial cut-off meander of river Teesta in the Jalpaiguri district of West Bengal (Figure 1), and about 22 km away from its nearest tourist destination, Lataguri. This beel is managed by state-owned TBP, Odlabari division, and as it is connected with river Teesta, its water level fluctuates with Teesta and rate of river water discharge through barrage. Saraswatipur village is situated just south-west of the wetland, after which Saraswatipur tea garden is located. The rest of the region is covered by mountainous dense forest, forest roads, canals, and a road connected to Lataguri. The area experiences about 78% rainfall during the monsoon (June to September) and only 0.98% rainfall during winter (December to February) (Datta, 2011b). The average rainfall of this region is about 3200 mm and the mean temperature ranges from 32.8^{0}C (max) to 6.9^{0}C (min).

(b) Field study

Field work was carried out from October 2011 to January 2012, and June-November 2012 to document vegetation and their uses by local communities. The stratified random sampling approach was followed for phyto diversity survey in the present study. Sampling was done in all the strata i.e. trees, shrubs and herbs, as followed earlier (Talukdar and Talukdar, 2012c) with some modifications for the present area. The size of the quadrat for sampling of trees, shrubs and herbs was determined by species-area-curve method (Misra, 1968; Mueller-Dombois and Ellenberg, 1974). A 20×20 m quadrat for trees (C30 cm cbh), 5×5 m quadrats for shrubs and 1×1 m quadrats for herbs were laid at each sample site. In each quadrat, the circumference at breast height (cbh) of all the trees with ≥ 30 cm was measured. Trees with <30 cm cbh were considered as shrubs. For herbs, the number of species in the four 1×1 m quadrats was recorded. A total of 200 quadrats were randomly laid in the study sites. The plant species were identified using regional flora, IPNI (International Plant Names Index; www.IPNI.org) and herbarium collection in the Central National Herbarium, Kolkata, and voucher specimen was deposited at departmental herbarium of Botany Department, RPM College, Hooghly, West Bengal.

(c) Ecological parameters

Base line data of total plant number, frequency (%), density and abundance were calculated following Talukdar and Talukdar (2012a,c). Invasive nature of alien species, enlisted by IUCN, was studied using techniques of Baider and Florens (2011) and other recent works (Huang *et al*., 2009; Feng and Zhu, 2010), namely through 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 as mentioned above. The specimens were identified through extensive survey of available literatures, monographic works, and confirmed by IPNI data base (www.IPNI.org).

(d) *Ethno-botanical study*
For ethno-botanical study, village elders and local tribal healers were interviewed on the basis of semi-structured questionnaires and interactions, as described earlier in detail (Talukdar and Talukdar, 2012c). In majority of cases, the respondents (both male and female; the male constituted over 70% of respondents) targeted were over 35 years of age. Also, younger generation was taken into confidence to get their awareness and interests in the traditional ethno-botanical practices. Local weekly markets (hats) in the vicinity of the Baikunthapur forest and Saraswatipur tea gardens were also surveyed to take a glimpse of availability and utilization of plant resources. Plant specimen was tabulated through interviews of knowledgeable people like temple priests, village head, old experienced folk, medicine men, farmers, teachers, etc. Gathered information was thoroughly cross-checked through structured questionnaires, and documented thereafter. Voucher specimen was deposited at departmental herbarium of Botany Department, RPM College, Hooghly.

(e) Statistical analysis
Data of different seasons were pooled for analysis. A level of $P < 0.05$ was considered significant.

Results

In the present study, as many as 81 plant species (77 angiosperms and 4 ferns) distributed in 75 genera in 45 families have been identified and documented. Among the flowering plants, 61 species belonged to dicots and 16 species were monocots. Among the 45 families, dicot plants belonged to 33 families, while monocots were represented by 8 families. Family Fabaceae contained highest number of plant species, represented by 12 taxa and was followed by monocot family Poaceae with 7 taxa, and dicot Asteraceae with 5 species. Family Malvaceae and Euphorbiaceae possessed 4 taxa each, and were closely followed by Rubiaceae, Lamiaceae, Verbenaceae in dicot and family Zingiberaceae in monocot with 3 taxa in each case. Rest of the families contained either 1 or 2 taxa in the study area (Table 1). Maximum numbers (60.49%) of plants were herbaceous, followed by trees (22.22%), climbers (9.87%), shrubs (6.19%) and epiphytes (1.23%). Four fern taxa (*Marsilea*, *Salvinia*, *Ampelopteris* and *Ceratopteris*) distributed in four families were also documented in the present study (Table 1).

Among the base line diversity parameters, plant frequency (%), density and abundance varied greatly in the study area. Plant frequency ranged between 3.50% and 99% with maximum frequency was recorded for *Ageratum conyzoides, Eichhornia crassipes,* and *Lantana Camara*, and minimum for rubiaceous climber *Hedyotis scandens* (Table 1). More than 90% frequency was estimated for the 9 taxa *Alternanthera sessilis, Achyranthes aspera, Bauhinia variegata, Cassia alata, Cynodon dactylon*, *Lemna acquinoctialis Mikania indica*, *Mimosa pudica, and Trema orientalis*, while *Parthenium hysterophorus, Mallotus philippensis, Enhydra fluctuans, Echinochloa crusgalli, Commelina bengalensis, Bauhinia variegata, Crotalaria pallida,* and the fern *Ampelopteris prolifera* either touched 90% or was very close to it. The density which denoted total number of individuals per quadrat crossed 1.0 value in 41 species with highest value of 17.88 recorded in grass *Cynodon dactylon*, and it was closely followed by verbenaceous shrub *Lantana camara* (11.84) and the two daisies, *Mikania indica* (11.66) and *Parthenium hysterophorus* (9.83). Rest of the species exhibited values <1.0 of which density of *Spilanthes oleracea* in the family Asteraceae, *Polygonum hydropiper* in Polygonaceae, and *Phyllanthus fraternus* in the family Euphorbiaceae was 0.99 in each case (Table 1). Lowest density was estimated for *Ficus hispida* (0.05) of Moraceae with very close value of 0.06 in rubiaceous member *Hedyotis scandens*. Highest abundance (19.33) was observed for *Cynodon dactylon*, and it was closely followed by *Mikania indica* (12.21), *Lantana camara* (12.02), and *Parthenium hysterophorus* (11.04). Low density but high abundance was observed for *Anisomelis indica*, *Arundo donax, Bambusa tulda, Bombax ceiba, Calamus rotung, Cassia tora, Clitoria ternatea, Coix lacryma-jobi, Ficus hispida, Hedyotis scandens,* and the epiphytic orchid *Vanda tessellata* (Table 1).

Status of four taxa i.e. *Cynodon dactylon*, *Lantana camara*, *Parthenium hysterophorus* and *Mikania indica* showing very high frequency, density as well as abundance in the study areas has been documented. Among the 200 quadrats laid, *Lantana camara* was recorded in maximum (197) number of quadrats, followed by presence of *M. indica*, *C. dactylon* and *P. hysterophorus* in 191, 185 and 178 number of quadrats, respectively. Among these four most abundant species, *Lantana*, *Mikania* and *Parthenium* exhibited tremendous capacity to grow along roadside as well as deep inside the study areas. Cultivated fields and banks of water bodies were preferred by 20% and 10% species, respectively. Quadrat studies revealed high frequency and abundance of some other taxa like *Ageratum conyzoides, Cassia alata, Eichhornia crassipes, Leucaena esculenta, Mallotus philippensis, and Phragmites australis* (Table 1). The ratio of number of plants (cumulative of 200 quadrats) between cultivated field and roadside varied between 0.23-0.90, but it was close to 1.0 for *Mikania indica, Cynodon dactylon* (0.98), and >1.0 for *Lantana camara* as the data pooled over different seasons (Table 1). Among these 7 species, *Mallotus philippensis* showed highest density (7.83) and abundance (8.69), followed by rest six species in different magnitudes (Table 1).

Table 1: Documentation of floral diversity around TBP, Jalpaiguri, West Bengal. Data pooled over 20 selected study sites and 10 quadrats/site (200 quadrats).

S. No.	Botanical name, habit, use, family	Total number of individuals of the species (a)	Number of quadrats in which a particular species occur (b)	F (%) = b/200 × 100	D = a/200	AB = a/b
1	**Abutilon indicum* (L.) Sweet, M, Herb, Malvaceae	90	95	47.5	0.45	0.94
2	**Acacia catechu* (L.) willd., oliv., tree, M, food, fodder, Fabaceae	109	150	75.0	0.55	0.73
3	**Aeschynomene aspera* L., commercial sola, M, Herb, Fabaceae	337	65	32.5	1.69	5.18
4	*Albizia lebbeck* (L.) Benth., tree, forage, wood, Fabaceae	191	116	58.0	0.96	1.65
5	*Alpinia nigra* (Gaertn.) Burtt. Herb, Zingiberaceae	133	122	61.0	0.67	1.09
6	**Alternanthera sessilis* (L.) R.Br.ex DC, M, Herb, Amaranthaceae	390	195	97.5	1.95	2.0
7	**Achyranthes aspera* L., M, Herb, Amaranthaceae	498	190	95.0	2.49	2.62
8	*Ageratum conyzoides* L., herb, Asteraceae	836	198	99.0	4.18	4.22
9	**Ampelopteris prolifera* (Retz.) Copel Veg, M, Herb fern, Thelypteridaceae	765	176	88.0	3.83	4.35
10	*Anisomelis indica* L., herb, Lamiaceae	77	39	19.5	0.39	1.97
11	**Annona reticulata* L., M, tree, fruit, Annonaceae	145	151	75.5	0.73	0.96
12	*Arundo donax* L., shrub, fodder, Poaceae	85	76	38.0	0.43	1.12
13	*Bambusa arundinacea* (Retz.) Willd., pickles, Fishing, shelter, tree, Poaceae	265	67	33.5	1.33	3.96
14	*Bambusa tulda* L, tree, fuel, constructions, fodder, Poaceae	139	54	27.0	0.70	2.57
15	**Bauhinia variegata* L., tree, ornamental, M, fuel wood, Fabaceae	414	181	90.5	2.07	2.29
16	* *Bombax ceiba* L., tree, M,	71	80	40.0	0.36	0.89

	Ornamental, Malvaceae					
17	*Calamus rotang* L., climber, furniture, Arecaceae	70	69	34.5	0.35	1.01
18	**Cassia sophera* L., M, Herb, Fabaceae	87	90	45.0	0.44	0.97
19	**Cassia tora* L., Herb, M, Fabaceae	79	75	37.6	0.40	1.05
20	**Cassia alata* L., Herb, Fabaceae	880	190	95.0	4.40	4.63
21	**Centella asiatica* (L.) Urban, M, Herb, Apiaceae	339	101	50.5	1.70	3.36
22	**Ceratopteris thalictroides* (L.) Brongn M, Herb-fern, Parkeriaceae	202	165	82.5	1.01	1.22
23	*Chenopodium album* L., Veg, Herb, Chenopodiaceae	116	80	40.0	0.58	1.45
24	*Clerodendrum infortunatum* L, herb, Verbenaceae	230	128	64.0	1.15	1.80
25	**Clitoria ternatea* L, M, Climber, Fabaceae	39	19	9.50	0.20	2.05
26	**Costus speciosus* (Koenig ex Retz.) Smith, herbs, M, Zingiberaceae	98	69	34.5	0.49	1.42
27	**Coix lacryma-jobi* L., M, Herb, Fishing, Poaceae	55	26	13.0	0.28	2.12
28	*Commelina bengalensis* L., Herb, Commelinaceae	148	180	90.0	0.74	0.82
29	**Crotalaria pallida* L., M, herb, Fabaceae	763	176	88.0	3.82	4.34
30	**Croton bonplandianum* L.,M, Herb, Euphorbiaceae	147	115	57.5	0.74	1.28
31	**Curcuma longa* L,herb, M, spice, Zingiberaceae	343	80	40.0	1.72	4.29
32	**Cynodon dactylon* (L.) Pers., M, Herb, Poaceae	3576	185	92.5	17.88	19.33
33	*Dentella repens* (L.) Forst., Veg, Herb, Rubiaceae	549	140	70.0	2.75	3.92
34	*Dillenia indica* L., Food, tree, Dilleniaceae	354	177	88.5	1.77	2.0
35	*Echinochloa crusgalli* (L.) P.Beauv., fish feed, compost, Herb, Poaceae	303	180	90.0	1.52	1.68
36	*Eichhornia crassipes* (Mart.), Manure, aquatic herb, Pontederiaceae	760	198	99.0	3.80	3.84
37	**Enhydra fluctuans* Lour., M, compost, Herb, Asteraceae	404	180	90.0	2.02	2.24
38	*Evolvulus nummularius* (L.) L. Herb, Convolvulaceae	270	130	65.0	1.35	2.08
39	**Ficus hispida* Linn.f., M, Veg, Tree, Moraceae	67	20	10.0	0.05	3.35
40	**Ficus racemosa* L., Veg, M, Tree, Moraceae	88	49	25.0	0.44	1.80
41	*Gmelina arborea* Roxb., tree, wood, Lamiaceae	398	173	86.5	1.99	2.30
42	*Grewia tiliaefolia Vahl.,* tree, Tiliaceae	105	95	47.5	0.53	1.11
43	*Hibiscus vitifolius* L., herb, Malvaceae	337	138	69.0	1.69	2.44
44	**Hedyotis scandens* Roxb., M, Climber, Rubiaceae	11	7	3.50	0.06	1.57

45	**Hygrophila schulli* (Buch. Ham) M.R. and S.M. Almeida, M, Herb, Acanthaceae	187	90	45.0	0.94	2.08
46	*Hydrilla verticillata* (L.f.) Royle, fish food, Herb, Hydrocharitaceae	212	107	53.5	1.06	1.98
47	**Ipomoea aquatica* Forrsk., M, Herb, Convolvulaceae	190	79	39.6	0.95	2.41
48	**Justicia adhatoda* L., shrub, M, Acanthaceae	139	111	55.5	0.70	1.25
49	*Lantana Camara* L, var. *aculeata*, var. *armata*, and *mista*, shrub, Verbenaceae	2367	197	99.0	11.84	12.02
50	*Lathyrus sativus* L., Herb, pulse, forage, veg, Fabaceae	70	100	50.0	0.35	0.70
51	*Lemna acquinoctialis* Welw. A.Pont, compost, Herb, Lemnaceae	557	189	94.5	2.79	2.95
52	*Leucaena esculenta* L, shrub, Fabaceae	878	165	82.5	4.39	5.32
53	*Leucas lavandulaefolia* Rees, Veg, Herb, Lamiaceae	238	106	53.0	1.19	2.25
54	*Mikania indica* L, climber, Asteraceae	2332	191	95.5	11.66	12.21
55	**Mallotus philippensis* (Lam.) Muell. Arg., tree, M, Euphorbiaceae	1565	180	90.0	7.83	8.69
56	*Marsilea minuta* L., Veg, Herb, fern Marsileaceae	200	85	42.5	1.00	2.35
57	*Mimosa pudica* L., Herb, Fabaceae	779	192	96.0	3.90	4.06
58	**Nymphaea nouchali* Burm.f., Veg, M, Herb, Nymphaeaceae	433	98	49.0	2.17	4.42
59	**Ocimum basilicum* L., M, Herb, Lamiaceae	118	79	39.5	0.59	1.49
60	**Oxalis corniculata* (DC.) Raeusch., M, Veg, Herb, Oxalidaceae	439	162	81.0	2.20	2.71
61	*Parthenium hysterophorus* L., herb, Asteraceae	1965	178	89.0	9.83	11.04
62	*Phragmites australis* (cav.) trin. ex. Steud., herbs, thatching, Poaceae	769	139	69.5	3.85	5.53
63	*Phyllanthus fraternus* Webster, Herb, Euphorbiaceae	198	113	56.5	0.99	1.75
64	*Phyla nodiflora* (L.) Greene Herb, Verbenaceae	185	89	44.5	0.93	2.08
65	*Pistia stratiotes* L., manure, Herb, Araceae	222	77	38.5	1.11	2.88
66	*Polygonum barbatum* L., Herb, Polygonaceae	187	156	78.0	0.94	1.20
67	**Polygonum hydropiper* L., M, Herb, Polygonaceae	198	119	59.5	0.99	1.66
68	**Rauvolfia serpentina* (Linn.) Benth. ex Kurz., M, Herb, Apocynaceae	232	82	41.0	1.16	2.83
69	*Ricinus communis* L., shrub, oil yielding, Euphorbiaceae	178	155	77.5	0.89	1.15
70	*Salvinia cuculata* Roxb., manure, fern, Salviniaceae	178	70	35.0	0.89	2.54
71	*Scoparia dulcis* L., herb,					

	Scrophulariaceae	434	163	81.5	2.17	2.60
72	*Shorea robusta* Gaertn.f., tree, wood, leaves, Dipterocarpaceae	1009	153	76.5	5.05	6.59
73	*Sida cordata* (Burm. f.)Borssum Herb, Malvaceae	176	90	45.0	0.88	1.96
74	*Solanum torvum* L., Shrub, fuel, Solanaceae	228	68	34.0	1.14	3.35
75	*Solanum xanthocarpum* Schrad & Wendl, Herb, fuel, Solanaceae	75	40	20.0	0.38	1.88
76	*Spermacoce hispida*, herb, Rubiaceae	250	158	79.0	1.25	1.58
77	*Spilanthes oleracea* L., Veg, Herb, Asteraceae	197	160	80.0	0.99	1.23
78	*Terminalia bellirica* L., tree, M, Combretaceae	158	100	50.0	0.79	1.58
79	*Tinospora cordifolia* (Willd.) Hook & Thoms., Lianes, M, Menispermaceae	276	174	87.0	1.38	1.59
80	*Trema orientalis* (L.) Bl., tree, fuel wood, Ulmaceae	380	187	93.5	1.90	2.03
81	*Vanda tessellata*. (Roxb.) Hook, epiphyte, Orchidaceae	93	87	43.5	0.47	1.07

Note: * Plants used for medicinal purposes, data pooled over several trips in different seasons.

Table 2: Mode of preparation and use of medicinal plant/parts by local community in the study area.

S. No.	Botanical name	Plant parts used	Mode of preparation	Uses
1	*Abutilon indicum* (L.)	Flower, stem cut, leaves, roots	Sun-dried powder, decoction of the whole plant, poultice of the leaves, roots	Anti-diabetic, digestive, expectorant, diuretic, astringent, analgesic, anti-inflammatory, anthelmintic and aphrodisiac. Decoction in toothache and tender gums, boils and ulcers (leaves), fever, chest pain and urethiritis (roots)
2	*Acacia catechu* (L.) willd., oliv.	Bark	Dried powder	fungal infection
3	*Aeschynomene aspera* L.,	Leaves	Leaf extract	Cough, cold and fever
4	*Alternanthera sessilis* (L.) R.Br.ex DC	Leaves	Fresh juice	Fever
5	*Achyranthes aspera* L.	Leaves	Fresh juice	Cough and cold fever
6	*Ampelopteris prolifera* (Retz.) Copel	Fresh frond (leaves)	Cooked with 'methi' seeds	In diabetes
7	*Annona reticulata* L	Bark, root	Root decoction, bark powdered and mixed with honey	During fever (root), in diarrhea and dysentery (bark)
8	*Bauhinia variegata* L.	Bark, root, flower buds	Bark is sun-dried, powdered, root decoction, flower juice	Bark is astringent, anthelmintic, roots in snake poisoning, flower buds in diarrhea and dysentery
9	*Bombax ceiba* L.	Resin, leaves, bark	Resin, Leaf juice, bark powder	Cough and cold, cut and wounds
10	*Cassia sophera* L	Leaves	Fresh juice or mixed with little salt	In high blood sugar
11	*Cassia tora* L.	Leaves, seeds	Decoction of leaves, seed powder alone or mixed with water	In high blood sugar, carminative, anti-cholesterol, seed powder in skin disease
12	*Cassia alata* L.	Leaves	Dried, ground in a	In ringworm and fungal infection

			mortar, mixed with vegetable oil to a paste	
13	*Centella asiatica* (L.) Urban	Shoots	Powder, leaf juice	Anthelmintic, in stomach disorder
14	*Ceratopteris thalictroides* (L.) Brongn	Leaves (fronds)	Fresh juice prepared	Skin-disease
15	*Clitoria ternatea* L	Leaves	Decoction of leaves, fresh juice	Used in inflammation, as analgesic, diuretic, in diabetes (fresh juice)
16	*Costus speciosus* (Koenig ex Retz.) Smith	Rhizome	Dried powder, paste	used to treat fever, rash, asthma, bronchitis, and intestinal worms
17	*Coix lacryma-jobi* L	Seeds	Powdered and mixed with oil to make paste	In stiffness of limbs
18	*Crotalaria pallida* L.	Leaves, roots	Leaf extract, root poultice	to treat urinary problems and fever, a poultice applied to swelling of joints and an extract of leaves to expel intestinal worms
19	*Croton bonplandianum* L.	Leaves	Fresh leaf juice or paste	In cut and wounds
20	*Curcuma longa* L,	Rhizome	Raw, Dried and powdered, paste made with water	In inflammation, liver disorder
21	*Cynodon dactylon* (L.) Pers.	Leaves	Fresh juice, paste with turmeric and ginger	Cough and cold, carminative, pains, inflammation, toothache
22	*Enhydra fluctuans* Lour.	Shoots	Dried shoot powder	Analgesic and in inflammation
23	*Ficus hispida* Linn.f.	Leaves, fruits	Cooked fruit, leaf juice	In treating fever and jaundice
24	*Ficus racemosa* L.	Fruits	Directly or dried pulp powder	used for treating intestinal worms, leucorrhea
25	*Hedyotis scandens* Roxb.	Leaves, roots	Leaf cooked, root paste	In gastro-intestinal problems
26	*Hygrophila schulli* (Buch. Ham) M.R. and S.M. Almeida	Leaves	Cooked	In stomach disorder
27	*Ipomoea aquatica* Forrsk	Leaves	Decoction	In high blood sugar, gastric disorder
28	*Justicia adhatoda*	Leaves	Decoction of leaves alone or mixed with *Ocimum*, tal-misri'	In cough and cold,
29	*Mallotus philippensis* (Lam.) Muell. Arg.	Fruit	Brown powder on fruit cover	In treating fever, cut and wounds, ulcers
30	*Nymphaea nouchali* Burm.f.,	Leaves, flower, rhizomes	Fresh juice, dried flower, boiled or roasted rhizome	Used in indigestion and treating diabetic
31	*Ocimum basilicum* L.	Leaves	Fresh juice, mixed with 'vasak'	In cough and cold, as tonic
32	*Oxalis corniculata* (DC.) Raeusch.	Leaves	Fresh juice	Treating bloody diarrhea
33	*Polygonum hydropiper* L.,	Whole shoot	Cold water infusion, mixed with wheat bran	Used in cough and cold, in bowel syndrome
34	*Rauvolfia serpentina* (Linn.) Benth. ex Kurz.	Bark, root	Bark powdered, root extract with water	Used in treatment of insomnia, hypertension, and blood pressure related symptoms, root extracts in intestinal problem, diarrhea and dysentery, root used as an antidote of snake
35	*Terminalia bellirica* L.	Fruit	Raw or powdered	Used as expectorant in cough and cold, tonic
36	*Tinospora cordifolia* (Willd.) Hook & Thoms.	Stem, root	Aqueous stem and root extract	As anti-spasmodic, anti-inflammatory, antiarthritic, anti-allergic and anti-diabetic (root extract), febrifuge

Figure 1: Part of study area with 'Gajoldoba beel' and surrounding forest in TBP area.

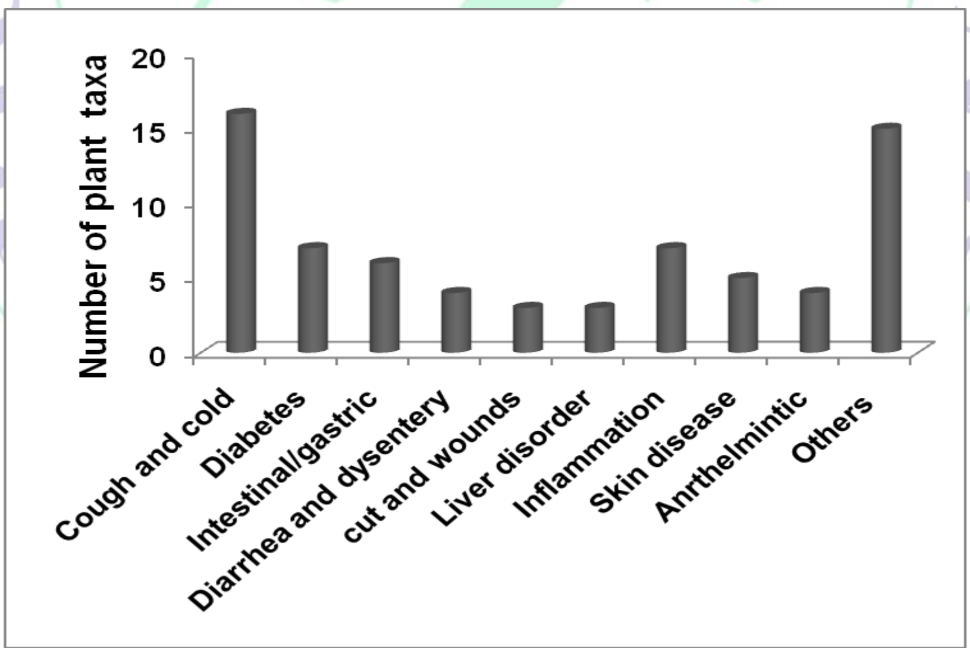

Figure 2: Number of taxa used for diverse medicinal purposes by local people residing around TBP area. Others include snake bites, high blood cholesterol, allergy, arthritis, limb stiffness, toothache, and as tonic.

Among the 81 plant species, 36 plants (44.44%) were documented as used by local people for diverse types of medicinal purposes including diabetes, diarrhea and dysentery, constipation, fever, cough and cold, jaundice, cut and wounds, as anthelmintic, in high blood pressure, inflammation and other disorders (Figure 2). Largest numbers of plants (16) have been used in treating cough and cold fever, followed by inflammation, diabetes, diarrhea and dysentery, intestinal/gastric disorder, skin disease/infection and other problems. One plant each was found used in high blood pressure (*Rouvolfia serpentina*) and in treating high blood cholesterol (*Cassia tora*). The plants used in diabetes involved *Abutilon indicum*, *Cassia sophera, Cassia tora, Clitoria ternatea, Nymphaea nouchali, Tinospora cordifolia* and the fern *Ampelopteris prolifera.* While tender fresh fronds of the fern was cooked with methi seeds and brinjal to prepare a dish of vegetables, leaves juices of *Abutilon*, *Cassia* and *Clitoria* were extracted and taken in empty stomach in diabetes. On the other hand, rhizomes of *Nymphaea nouchali* were boiled and roasted and roots extracts from *Tinospora cordifolia* were taken to reduce high blood sugar. The plant parts included leaves, stems, shoots, rhizomes, seeds, inflorescence, and the whole plant. Pharmacological preparations include aqueous extracts, paste, boiled or roasted, water-soaked seeds, juice and cooked (Table 2). Leaves were used by majority of cases (22 genera), followed by bark (5), whole shoot, rhizome, root and fruits (3 each) and other parts such as resin, flower buds and seeds. The 36 plant species identified with medicinal uses were distributed in 22 families, of which 8 genera belonged to Fabaceae, and 2 genera each in Malvaceae, Amaranthaceae, Acanthaceae, Moraceae, Euphorbiaceae, Zingiberaceae, and Poaceae. Rest of the families contained one taxon each.

Besides cultivation for medicinal purposes, a number of plants have been utilized by local people in the study area for food, forage, fuel wood, commercial wood, thatching, furniture making, preparation of pickles etc. Prominent plant species used as food source were fruit trees of *Diillenia indica, Ficus hispida, F. racemosa*, leaves of *Lathyrus sativus* L., and the fern *Ampelopteris prolifera*. Many plants such as *Acacia catechu*, *Albizia lebbeck*, *Cassia alata*, *Lathyrus sativus*, *Leucaena*, *Arundo donax*, and *Bambusa* have been used as fodder. Barring the latter two species, all belong to the family Fabaceae. The fuel wood was mainly collected from *Trema orientalis, Solanum, Bauhinia variegata, Bambusa* spp, and *Albizia lebbeck*, whereas trunk and branches of *Gmelina arborea* and *Shorea robusta* were used as commercial woods. Species of *Bambusa*, and *Calamus rotang* were utilized in making of household furniture and preparation of local pickles (young tender leaves of *Bambusa*), fishing food etc. A leguminous plant *Aeschynomene aspera* and a grass *Coix* have been extensively exploited for ‘commercial shola’ and preparation of village ornaments, respectively.

Discussion

Present investigation for the first time revealed base line information about floral diversity, plant invasiveness and indigenous uses of plants by local people residing around TBP. Results in Table 1 indicated dominance of dicot flora over monocot, and among the dicot families, Fabaceae dominated over others. Screening of 81 plant species, including 4 fern species, distributed in 75 genera under 45 families suggested rich biodiversity in the study area. This diversity was also manifested in plant habits which included herbs, shrubs, trees, lianes, climbers and epiphytes with clear dominance by herbaceous species in the study areas. Among the monocots, Poaceae with 7 members dominated over others. However, the dominance of leguminous members in the present study area is noteworthy, as these groups of plants exhibit diverse plant habits and are adapted in diverse agro-climatic regions showing higher tolerant to multiple stress factors like low temperature, drought, high rainfall, water stress, salinity, metal contaminations and biotic pressures (Talukdar, 2009a, 2011a, b). Wide range of frequency in plant species suggested significant variations in ecological parameters as revealed by quadrat study and uneven distribution of taxa. At least 20 species showed frequency around 90%, of which 3 species *Ageratum conyzoides, Eichhornia crassipes,* and *Lantana Camara* manifested frequency 99%, while distributions of *Cynodon dactylon*, *Mikania indica*, *Parthenium hysterophorus*, *Crotalaria pallida* and *Cassia alata* were >90%. Among these genera, *Ageratum conyzoides,* *Eichhornia crassipes, Lantana Camara, Mikania indica*, and *Parthenium hysterophorus* have been regarded as worst invasive flora by IUCN species survival commission (Lowe *et al*., 2000). The invasive nature of these taxa was also supported by high density as well as high abundance value in the present study area. It is also noteworthy that *Leucaena esculenta*, a mimosoid legume, exhibited abundant distribution in the study area, as revealed by randomly laid quadrats in different seasons. This observation has immense significance as a sister genus of *L*. *esculenta*, *Leucaena leucocephala* has been enlisted by IUCN in 100 worst invasive species (Lowe *et al*., 2000), and *Leucaena* reportedly exerts allelopathic effect on native flora during its invasion (Sahoo *et al*., 2007; Talukdar and Talukdar, 2012a). The absence of *L. leucocephala* in the present study area can be expected as plant cannot tolerate acidic soil and soils in North Bengal show acidic pH (Chakraborty *et al*., 2010). By contrast, the spread of *L. esculenta* in the present study sites revealed its tolerance to grow in acidic soil and indicated inter-specific differences in biological success of invasion for *Leucaena* species in different geographic and climatic conditions. Similar aggressive spread was also documented for *Cynodon dactylon*, *Lantana camara*, *Parthenium hysterophorus* and *Mikania indica*. This was evidenced by ratio of number of plants (cumulative of 200 quadrats) between cultivated field and roadside close to 1.0 in case of *M. indica, C. dactylon and P. hysterophorus* and >1.0 for *L. camara*. The results strongly indicated aggressive spread of species in open, under storey of forest and other ecotones with more successful establishment for *L. camara*. Results in Table 1 were pooled for three varieties of *L. camara*, showing distinct differences in flower color as red (*L. camara* var. *aculeata*), pink (*L. camara* var. *armata*) and brownish yellow (*L. camara* var. *mista*). The former two showed lower density but higher abundance than the latter (data not in Table). One of the strategies *Lantana* adopted during its successful invasion is a strong allelopathic effect through alteration of cellular and metabolic responses in target plants (Oudhia, 1999; Choyal and Sharma, 2011; Talukdar, 2013), and the plants possess strong bioactive compounds against bacterium (Bhadauria and Singh, 2011). Similar mechanism has been reported for *Parthenium hysterophorus* (Oudhia *et al*., 1997), *Mikania indica* (Ai-Ping *et al*., 2010), and *Eichhornia crassipes* (Chen *et al*., 2006). The spread of these alien and invasive weeds in the present study area is quite alarming to the conservation of native biodiversity in a disturbed area like TBP. Low density but high abundance as observed for *Anisomelis indica*, *Arundo donax, Bambusa tulda, Bombax ceiba, Calamus rotang, Cassia tora, Clitoria ternatea, Coix lacryma-jobi, Ficus hispida* and *Hedyotis scandens* indicated their sparse distribution in the study area. Among these taxa, gradual disappearance of *C. rotang* was evidenced by its low frequency in the quadrats which has very high economic value in the study area and is obviously under threat due to its low density. High frequency and abundance of *Shorea robusta*, as observed in the present study, is in agreement with an earlier study which revealed that plant diversity in moist *Shorea* forests of northern Bengal are higher than the dry forests of south-west Bengal (Kushwaha and Nandy, 2012).

Inventorying medicinal importance and resource utilization of plant species by local people was an integral part of the present study. The vast number of medicinal plants present in the region is an integral part of the livelihood of local communities. Results in Table 2 indicated extensive use of plant products by local people in different types of disorders including cough and cold fever, inflammation, diabetes, high blood pressure, high blood cholesterol, diarrhea and dysentery, intestinal/ gastric disorder, skin disease/infection, and other problems. A wide variety of plants were used through diverse modes of pharmacological preparations, in which largest number of species were utilized from Fabaceae and was distantly followed by other 21 families. Extensive use and mode of pharmacological preparations of leguminous plant products/parts by ethnic tribes was also reported very recently in different altitudes of Sikkim Himalayas (Talukdar and Talukdar, 2012b), Sub-Himalayan as well as in plains of Gangetic West Bengal (Talukdar and Talukdar, 2012b,c). The revelation of seven plants used in diabetes in the present study is also noteworthy, in which fresh extracts of leaves were taken in majority of cases and has high significance as metabolic stress markers have recently been identified for Sikkimese diabetes (Bhutia *et al*., 2011). Preparations like aqueous extracts, paste, boiling or roasting, water-soaking of seeds, juice and cooking utilizing variety of plant parts strongly suggested richness of local knowledge-based traditional medicine among the forest dwellers, villagers, plantation workers, and mountain people. The raising awareness towards the importance of Himalayan and outer-Himalayan biodiversity and alarming rate at which they are being exploited from natural habitats leads to initiate various conservation actions to mitigate such uncontrolled resource exploitation and its management (Ray *et al*., 2011). Rich knowledge regarding use of plants in ethno-medicinal purposes was also reported in different geographical regions of Indian sub-continent (Pareek and Trivedi, 2011; Singh and Rawat, 2011).

Besides cultivation for medicinal purposes, a number of plants have been utilized for food, fodder, fuel, commercial fishing, manuring, and other household purposes in the study areas. Food preparations included raw fruits (*Dillenia indica*. *Ficus* spp), and cooked leafy vegetables (*Ampelopteris prolifera*, *Lathyrus sativus*). Most of the leguminous plants like *Acacia catechu*, *Albizia lebbeck*, *Cassia alata*, *Lathyrus sativus*, and *Leucaena* were used as forage for cattle feed. Among these taxa, *Lathyrus sativus* or grass pea has been used as dual purpose crop in the study area. Use of this papilionoid crop legume by different ethnic tribes has been reported in different climatic conditions (Talukdar and Talukdar, 2012b, c), and has great significance as the plant is rich in high protein, flavonoids and other antioxidative compositions with introduction of low seed neurotoxin containing genotypes through mutagenesis (Talukdar, 2008, 2009a,b, 2010a,b, 2012a,b,c). Among the small scale cottage industries, commercial 'shola' using *Aeschynomene americana* were found highly beneficial for local economics. Different types of wood works like furniture making are carried out with woods from *Gmelina arborea* and *Shorea robusta*, while house hold requirements were mainly met by *Bambusa* spp. However, extensive use of *Trema orientale* and *Leucaena* as fuel crop by local people might have favored spread of these two alien trees in the TBP area. *Cynodon dactylon* was the most efficient riparian species in conservation of soil, water and nutrients in surface runoff, as also reported earlier (Srivastava and Singh, 2012).

Conclusion

The present investigation for the first time revealed rich floral diversity and traditional knowledge in utilization of local flora for medicine and other economic purposes. The TBP region where the present study was carried out is gradually witnessing urbanization due to pressure from local tourism and barrage related activities. Present inventory, therefore, may give vital clues in conservation of floral diversity in and around lower Teesta basin.

Conflict of Interests

None declared.

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