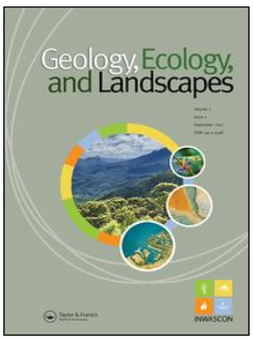

Geology, Ecology, and Landscapes

ISSN: (Print) 2474-9508 (Online) Journal homepage: https://www.tandfonline.com/loi/tgel20

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To cite this article: M.K. Hossain, Abdul Alim, Saddam Hossen, Md. Akhter Hossain & Anisur Rahman (2019): Diversity and conservation status of tree species in Hazarikhil Wildlife Sanctuary (HWS) of Chittagong, Bangladesh, Geology, Ecology, and Landscapes, DOI: 10.1080/24749508.2019.1694131

To link to this article: https://doi.org/10.1080/24749508.2019.1694131

Published online: 28 Nov 2019.

GEOLOGY, ECOLOGY, AND LANDSCAPES
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RESEARCH ARTICLE

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Diversity and conservation status of tree species in Hazarikhil Wildlife Sanctuary (HWS) of Chittagong, Bangladesh

M.K. Hossain, Abdul Alim, Saddam Hossen, Md. Akhter Hossain and Anisur Rahman

Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong, Bangladesh

ABSTRACT

Hazarikhil Wildlife Sanctuary (HWS), located in the Fatikchari upazila of Chittagong district, Bangladesh with a land area of 2,908.5 acres, is a Protected Area IUCN Category II. Once the forest was very rich in flora and fauna but apparently, it seems that some lesser known species may have been disappeared from the area due to changes in overall conditions. The study was conducted through systematic quadrat method where the size of the plot was 20 m×20 m. A total of 162 tree species (having ≥5 cm diameter at breast height (dbh)) belonging to 50 families were recorded where Euphorbiaceae family possess the highest number of species (18) followed by Moraceae (12 species). Conservation status of the plants indicated that 52% species (85 species) were Least Concern (LC) which was maximum among the conservation categories. However, the Vulnerable, Endangered, Near Threatened and Critically Endangered tree species were represented by 20% (32 species), 6% (9 species), 1% (1 species) and 2% (3 species) respectively. The study created a baseline of information on the tree species diversity of the protected area which is expected to be helpful to the future researchers as well as in taking managerial actions by the policy makers.

ARTICLE HISTORY
Received 1 July 2019
Accepted 14 August 2019

KEYWORDS
Tree species; threatened; Hazarikhil; conservation; Wildlife Sanctuary

Introduction

The vegetation of Bangladesh is a part of the Indo-Myanmar region, which is one of the 10 global hot spot areas for biodiversity (Mittermeier, Myers, Thomsen, Defonseca, & Olivieri, 1998) and possess rich biological diversity due to its unique geophysical location (Chowdhury, 2001; Hossain, 2001; Nishat, Huq, Barua, Reza, & Khan, 2002). The country has a rich biological heritage containing about 3,611 flowering plants (Ahmed et al., 2008), of which 2,260 species are reported from Chittagong region alone (Khan, Nishat, & Haque, 2008). The diversity of trees is fundamental to total tropical forest biodiversity, because tree provides resources and habitats for almost all other forest species (Canon, Peart, & Leighton, 1998; Huston, 1994). But many areas of the country have been either poorly investigated or remain unexplored to date. Floristic collections are essential for expanding the holdings from those under-represented areas in order to conserve biodiversity of the country.

Hazarikhil Wildlife Sanctuary has been recognized for its ecological, scientific, educational, aesthetic and spiritual values. Hazarikhil natural forest is one of the most important forests which is composed of a number of tropical evergreen and semi-evergreen tree species. The present Hazarikhil natural forest is a remnant of previous evergreen natural reserve forest with many important indigenous tree species Wrong management, illegal felling, encroachments due to population pressure resulted in the degradation of the natural tree cover endangering many native tree species with restricted distribution (Khan, 1990). Conserving the remaining forest is important because they have the highest biodiversity of all sequences. In Bangladesh, there is an urgent need to effectively protect and manage the existing reserve forest areas (Hossen, Hossain, et al., 2019a; Hossen, Hossain, et al., 2019b; Hossen, Hossain, et al., 2019c). Hazarikhil Wildlife Sanctuary stands a better chance for protection against loss of native tree species as well as biodiversity as it has been declared as Wildlife Sanctuary in 2010.

Most plot and transect-based species counts in tropical rain forests have dealt only with trees having >10 cm or > 5 cm dbh (Ahmed & Haque, 1993; Balslev, Luteyn, Ollgaard, & Holm-Nielsen, 1987; Boom, 1986; Foster & Hubbell, 1990; Gentry, 1988; Hossain et al., 1999; Nath, Hossain, & Alam, 1998; Rahman, Hossain, & Karim, 2000). Measuring biodiversity has not been easy and has remained a challenging task. The present study is an initiative to assess the status, composition, diversity, and distribution of tree species in Hazarikhil Wildlife Sanctuary. It was felt that such a survey would be useful in taking up appropriate action plans for arresting genetic erosion in the forest as improved understanding of successional factors and process may allow us to develop forest management system that benefit biodiversity conservation.

CONTACT Saddam Hossen saddamhossen.cu@gmail.com Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh

Conserving biodiversity in an ecosystem is also important since it is not always evident which species and what quantity of those species is necessary to maintain the ecosystem functioning (Burton, Balisky, Coward, Cumming, & Kneeshaw, 1992). Information on the composition of a forest is essential for its wise management in terms of economic value and regeneration potential (Wyatt-Smith, 1987), but very scanty information is available on the composition of this forest. The lack of information hampers our ability to comprehend the magnitude of the loss of biodiversity and to formulate sustainable alternative to resource depletion. Inventorying the trees is essential for better understanding of the levels, distribution, and dynamics of native tree species of a particular forest. Presence of systematic records of the flora of a forest and its regeneration will help in any plan to preserve its biodiversity. To achieve good conservation and management of our natural resources, we should know the status and structure of biological resources, especially the native tree species.

Materials and methods

Study area

Hazarikhil Wildlife Sanctuary was a part of the reserved forest of Chittagong North Forest Division in Bangladesh. It was declared as Hazarikhil Wildlife Sanctuary (2908.50 acres) on 6 April 2010 by the Ministry of Environment and Forest by gazette notification no. MoEF/For-Sec-02/02 Wildlife Sanctuary/11/2010/211 dated 06/04/2010 under the power given under section 23(3) of Bangladesh Wildlife (Preservation) (Amendment) Act 1974. The area is located about 65 km north of Chittagong city and western side of Chittagong-Khagrachari road (Figure 1).

HWS experiences tropical monsoon climate, characterized by basically four seasons, e.g., winter (December–February), summer (March–May), monsoon (June–September) and autumn (October–November). During the monsoon, the area receives an average annual rainfall of 3000 mm with a range of 1,611–3,878 mm. Temperature of the HWS varies from 12.5°C to 37°C whereas humidity from 67% to 88% round the year. The forest valleys comprising streams (chara), canals and lakes contain and carry the water to mainly the Feni River and some water is directly transmitted to the Sandwip channel of the Bay of Bengal. A number of sandy-bedded streams passed through the HWS and aquatic habitats associated with forest cover and riparian (streamside) vegetation, wildlife species are important part of the entire habitat. Some stream flow continuously but some of them become dry in winter. Part of Hajarikhil WS is covered by the low hill ranges while the rest is in the Bengal flood plain. The soils in this area range from clay to clayey loam on level ground and from sandy loam to coarse sand on hilly land. The wildlife sanctuary is covered basically with tropical semi-evergreen natural vegetation and scatter block plantations along with few degraded hills in the periphery (Figure 2).

Reconnaissance survey

The research team visited the Hazarikhil Wildlife Sanctuary (HWS) to have an idea of species composition of the whole forest prior to selection of sampling procedure for floristic composition and diversity of

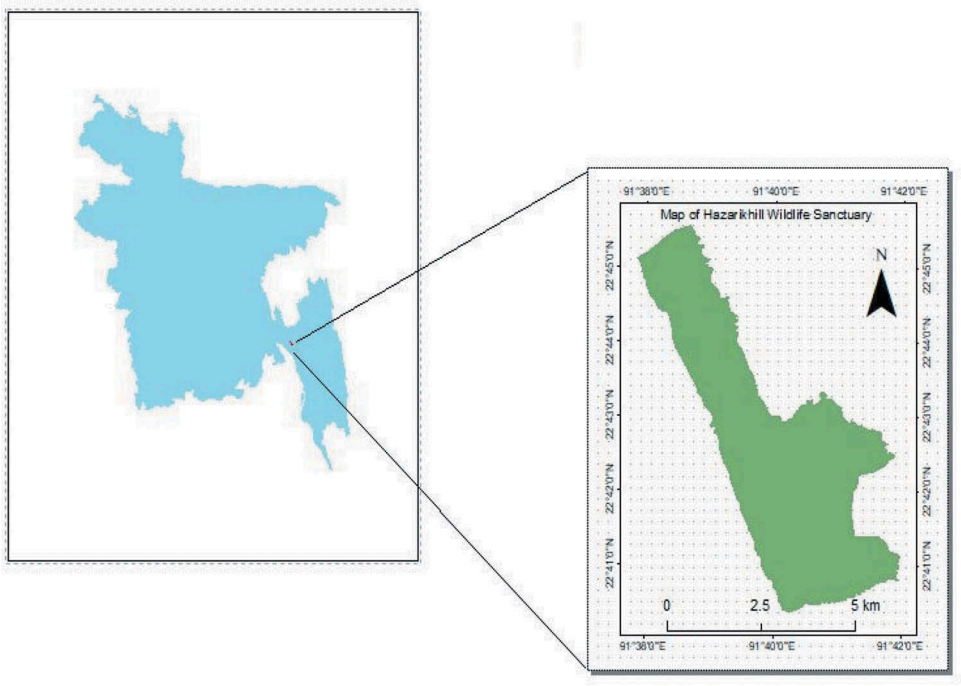

Figure 1. Location map of Hazarikhil Wildlife Sanctuary.

Figure 2. a – Natural forest patch; b – Plantation; c – Deforested site; d – Few old trees in Hazarikhil Wildlife Sanctuary.

the tree species. A thorough field visit was conducted in the whole forest at the onset of the fieldwork. A formal discussion was held with the concerned forest officials and some experienced forest villagers. A base map of the area was collected from the Forest Department. Detail information about the geography, land uses, plantations and present management systems were also collected from respective authority. Two transact walks (one from North to South and the other from East to West) across the forest were made with the help of the field assistants. The objectives of the walk were to familiarizing with the vegetation community, designing sampling design, planning accessibility and field works and to get an idea about the vegetation in the study area.

Field data collection and processing

The composition and diversity of the tree species in HWS were assessed through systematic quadrat survey with 20 m×20 m sized sample plots were conducted during January 2016 to December 2016 (Rahman & Hossain, 2002; Roy, Singh, & Porwal, 1993). The quadrat size was determined by applying species area curve method (Moore & Chapman, 1986). Quadrats were placed systematically at 13″ (thirteen seconds) spatial interval which is approximately 530 m along both longitudes and latitudes. The sampling intensity of the survey was 0.25%. Besides the quadrats trees were recorded from the walk ways (line transacts) whenever a new species occurred during the travel from one quadrat to another. All trees having ≥5 cm dbh were identified, counted by individuals and measured in the quadrats. Fertile materials the unknown trees were collected to prepare herbarium specimen for identification. The herbarium specimen of the Bangladesh Forest Research Institute (BFRI) were consulted along with Khan (1990), Rahman and Hossain (2002) and Ahmed et al. (2008) for identification of the unknown species. Conservation status of the plants were assessed based on the field observations along the consultation of Ahmed et al. (2008), Rahman (2013), Ara, Khan, and Uddin (2013) and Hossen and Hossain (2018). All the plants were compiled together and their number under respective families and conservation status were counted.

Results

Results of the study include tree (having dbh of ≥5 cm) species composition across the forest areas of HWS. A total of 133 tree species belonging to 46 families were recorded from the quadrats. Including the tree species recorded from the transacts the study reveals 162 tree species belonging to 50 families (Table 1). Euphorbiaceae family possess the highest number of tree species (18) followed by Moraceae (12) and Anacardiaceae, Mimosaceae and Myrtaceae each with 9 tree species. The recorded tree species were found to be represented by 9 conservation categories, viz. Conservation Dependent (CD), Data Deficient (DD), Least Concern (LC), Not Evaluated (NE), Not Evaluated but seems to be rare (NE but seems rare), Near Threatened (NT), Vulnerable (VU), Endangered (EN) and Critically Endangered (CR). A total of 52% species (85 species out of 162) were found as Least Concern (LC) which represents maximum tree species

Table 1. Tree species composition and conservation status in Hazarikhil Wildlife Sanctuary.

Family	No.	Species no.	Local name	Scientific name	Conservation status
Anacardiaceae	1	1	Barela	*Holigarna caustica* (Dennst) Oken	DD[1]
		2	Jail bhadi	*Lannea coromandelica* (Houtt.) Merr.	LC[1]
		3	Chikki	*Buchnania lancifolia* Roxb.	NE[1]
		4	Civit	*Swintonia floribunda* Griff.	VU[2]
		5	Nala amshi	*Drimycarpus racemosus* (Roxb.) Hook. f.	VU[2]
		6	Miriam	*Bouea oppositifolia* (Roxb.) Meissn.	EN[1]
		7	Desi amra	*Spondias pinnata* (L. f.) Kurz	LC[1]
		8	Aam	*Mangifera indica* L.	LC[1]
		9	Uriam	*Mangifera sylvatica* Roxb.	CR[1]
Annonaceae	2	10	Kuchu kao	*Miliusa longiflora* (Hook.f. and Thom.) Finet and Gagnep.	EN[2]
		11	Aata	*Annona squamosa* L.	LC[1]
Apocynaceae	3	12	Chatim	*Alstonia scholaris* (L.) R. Br.	LC[1]
		13	Chhatim	*Alstonia neriifolia* D. Don	EN[2]
		14	Dud kuruch	*Wrightia arborea* (Dennst.) Mabb.	VU[2]
		15	Kuruz	*Holarrhena antidysenterica* (L.) Wall. Ex Decne	LC[1]
Araliaceae	4	16	Argoza	*Trevesia palmata* (Roxb.) Vis.	LC[1]
Arecaceae	5	17	Chau supari	*Caryota urens* L.	EN[4]
		18	Desi Khejur	*Phoenix sylvestris Roxb.*	LC[1]
		19	Narikel	*Cocos nucifera* L.	LC[1]
		20	Oil Palm	*Elaeis guineensis* Jacq.	NE[1]
		21	Taal	*Borassus flabellifer* L.	LC[1]
Bignoniaceae	6	22	Dharmara	*Stereospermum colais* (Buch.-Ham. ex Dillw.) Mabb.	NE but seems to rare[1]
		23	Barpatta	*Fernandoa adenophylla* (Wall. ex G.Don) vn Steenis	VU[4]
		24	Khona	*Oroxylum indicum* (L.) Benth. ex Kurz	LC[1]
Bombacaceae	7	25	Bonsimul	*Bombax insigne* Wall.	VU[4]
		26	Simul	*Bombax ceiba* L.	LC[1]
Boraginaceae	8	27	Bohal	*Cordia dichotoma* Forst. f.	VU[4]
Burseraceae	9	28	Silbhadi	*Garuga pinnata* Roxb.	LC[1]
		29	Dhup	*Canarium resiniferum* Brace ex king.	CR[4]
		30	Gutgutya	*Protium serratum* (Wall. ex. Colebr.) Engl.	VU[4]
Caesalpiniaceae	10	31	Asok	*Saraca asoca* (Roxb.) de Willd.	VU[4]
		32	Bansonalu	*Cassia nodosa* Buch.-Ham. *ex* Roxb.	LC[1]
		33	Minjiri	*Senna siamea* (Lamk.) Irwin and Barneby	LC[1]
		34	Sonalu	*Cassia fistula* L.	LC[1]
		35	Tetul	*Tamarindus indica* L.	LC[1]
Capparaceae	11	36	Barun	*Crataeva magna* (Lour.) DC.	LC[1]
Celastraceae	12	37	Raktan	*Lophopetalum wightianum* Arn.	VU[4]
Clusiaceae	13	38	Nageshwar	*Mesua ferrea* L.	LC[1]
		39	Kau	*Garcinia cowa* Roxb. *ex* DC.	VU[4]
Combretaceae	14	40	Bahera	*Terminalia bellirica* (Gaertn.) Roxb.	LC[1]
		41	Haritaki	*Terminalia chebula* Retz.	VU[1]
		42	Kat Badam	*Terminalia catappa* L.	LC[1]
		43	Sheori	*Anogeissus acuminata* (Roxb. *ex* DC.) Guill. et Perr.	VU[4]
Cycadaceae	15	44	Cycas	*Cycas pectinata* Hamilton	VU[4]
Datiscaceae	16	45	Chandul	*Tetrameles nudiflora* R. Br.	NE[1]
Dilleniaceae	17	46	Chalta	*Dillenia indica* L.	LC[1]
		47	Hargaza	*Dillenia pentagyna* Roxb.	VU[4]
Dipterocarpaceae	18	48	Baittya Garjan	*Dipterocarpus costatus* Gaertn.	CD[1]
		49	Boilam	*Anisoptera scaphula* (Roxb.) Pierre	CD[1]
		50	Dhullya garjan	*Dipterocarpus alatus* Roxb. ex G. Don	VU[4]
		51	Teliaa garjan	*Dipterocarpus turbinatus* Gaertn.	LC[1]
		52	Sal	*Shorea robusta* Roxb. *ex* Gaertn. f.	LC[1]
		53	Telsur	*Hopea odorata* Roxb.	LC[1]
Ebenaceae	19	54	Gab	*Diospyros malabarica* (Desr.) Kostel.	LC[1]
Elaeocarpaceae	20	55	Jalpai	*Elaeocarpus tectorius* (Lour.) Poir.	EN[4]
		56	Belphoi	*Elaeocarpus floribundus* Blume	EN[4]
Euphorbiaceae	21	57	Amloki	*Phyllanthus emblica* L.	LC[1]
		58	Kechchua	*Glochidion lanceolarium* (Roxb.) Voigt.	LC[1]
		59	Ban-naranga, Moricha	*Suregada multiflora* (A. Juss.) Bail.	NE[1]
		60	Banshiyalbuka	*Antidesma bunius* (L.) Spreng.	LC[1]
		61	Bura	*Macaranga denticulata* (Bl.) Muell.-Arg.	LC[1]
		62	Chamfata	*Sapium baccatum* Roxb.	VU[4]
		63	Kanjail bhadi	*Bischofia javanica* Blume	VU[4]
		64	Kaulla	*Aporosa wallichii* Hook. f.	NE[1]
		65	Patkhoi	*Bridelia* tomentosa Bl.	LC[1]
		66	Elena	*Antidesma ghaesambilla* Gaertn.	LC[1]
		67	Phata karoola	*Aporosa dioica* (Roxb.) Muell.-Arg.	NE[1]
		68	Bura	*Mallotus tetracoccus* (Roxb.) Kurz	LC[1]
		69	Bhubi	*Baccaurea ramiflora* Lour.	VU[4]
		70	Chhota bura	*Mallotus roxburghianus* Muell.-Arg.	NE[1]
		71	Pannyaturi	*Glochidion multiloculare* (Roxb. ex Willd.) Muell.-Arg.	LC[1]
		72	Mera gota	*Trewia nudiflora* L.	LC[1]
		73	Rubber	*Hevea brasiliensis* (Willd. *ex* A. Juss.) Muell.-Arg.	LC[1]
		74	Sinduri	*Mallotus phillippensis* (Lamk.).Muell.-Arg	CD[1]
Fabaceae	22	75	Miringa	*Derris robusta* (Roxb. *ex* DC) Benth.	LC[1]
		76	Padak	*Pterocarpus indicus* Willd.	LC[1]
		77	Mandar	*Erythrina stricta* Roxb.	LC[1]

(*Continued*)

Table 1. (Continued).

Family	No.	Species no.	Local name	Scientific name	Conservation status
Fagaceae	23	78	Batna	*Quercus oxydon* Miq.	EN[1]
		79	Bara batna	*Lithocarpus elegans* var. *brevipetiolata* (A. DC.) Hook. f.	EN[4]
		80	Khooisa batna	*Quercus gomeziana* A. Camus	DD[1]
Flacourtiaceae	24	81	Chalmugra	*Hydnocarpus kurzii* (King) Warb.	VU[4]
Juglandaceae	25	82	Jhumka bhadi	*Engelhardtia spicata* Leschen ex Blume	VU[4]
Lauraceae	26	83	Madanmasta	*Actinodaphne angustifolia* Nees	NE[1]
		84	Sutrong	*Cryptocarya amygdalina* Nees	EN[1]
		85	Manda	*Litsea monopetala* (Roxb.) Pers.	NE[1]
		86	Menda	*Litsea glutinosa* (Lour.) C. B. Robinson	LC[1]
		87	Modon mosta	*Dehaasia kurzii* King	VU[3]
		88	Chibong	*Persea bombycina* (King *ex* Hook.f.) Kosterm.	NE[1]
		89	Tez matan	*Cinnamomum iners* Reinw. *ex* Blume	VU[4]
Leeaceae	27	90	Achilagach	*Leea indica* (Burm. f.) Merr.	LC[1]
Lythraceae	28	91	Jarul	*Lagerstroemia speciosa* (L.) Pers.	LC[1]
Magnoliaceae	29	92	Champa	*Michelia champaca* L.	LC[4]
Meliaceae	30	93	Ban lichi	*Walsura robusta* Roxb.	VU[1]
		94	Bokain	*Melia azedarach* L.	LC[1]
		95	Chikrassi	*Chukrasia tabularis* A. Juss.	LC[4]
		96	Mahagony	*Swietenia mahagoni* (L.) Jacq.	LC[1]
		97	Neem	*Azadirachta indica* A. Juss.	LC[1]
		98	Pitraj	*Aphanamixis polystachya* (Wall.) Parker.	VU[4]
		99	Rata	*Chisocheton cumingianus* (C. DC) Harms.	LC[1]
		100	Toon	*Toona ciliata* Roem	CD[1]
Mimosaceae	31	101	Akashmoni	*Acacia auriculiformis* A. Cunn *ex* Benth. et Hook.	LC[1]
		102	Rain tree	*Samanea saman* (Jacq.) Merr.	LC[1]
		103	Chakua koroi	*Albizia chinensis* (Osbeck) Merr.	LC[1]
		104	Kala koroi	*Albizia lebbeck* (L.) Benth.	LC[1]
		105	Sil Koroi	*Albizia procera* (Roxb.) Benth	LC[1]
		106	Tetua-koroi	*Albizia odoratissima* (L. f.) Benth.	LC[1]
		107	Kuramara	*Pithecellobium angulatum* Benth.	NE[1]
		108	Mangium	*Acacia mangium* Willd.	LC[1]
		109	Lohakat	*Xylia xylocarpa* Roxb. Taub.	LC[1]
		110	Rajkoroi	*Albizia richardiana* (Voigt) King and prain	LC[1]
Moraceae	32	111	Ashwathwa	*Ficus religiosa* L.	LC[1]
		112	Bara dumur	*Ficus auriculata* Lour.	LC[1]
		113	Jhiri bot	*Ficus benghalensis* L.	LC[1]
		114	Chapalish	*Artocarpus chama* Buch.-Ham.	NE but seems rare[1]
		115	Panidumur	*Ficus nervosa* Heyne *ex* Roth	LC[1]
		116	Dewa	*Artocarpus lacucha* Buch.-Ham.	LC[1]
		117	Dumur	*Ficus hispida* L.f.	LC[1]
		118	Joggya dumur	*Ficus racemosa* L. var. miquelli	LC[1]
		119	Kanthal	*Artocarpus heterophyllus* Lamk.	LC[1]
		120	Chokorgola	*Ficus semicordata* Buch.-Ham. *ex* Smith	NE[1]
		121	Dumur	*Ficus fistulosa* Reinw. *ex* Bl.	NE[1]
		122	Sheora	*Streblus asper* Lour.	LC[1]
Myristicaceae	33	123	Am barela	*Myristica linifolia* Roxb.	VU[4]
Myrsinaceae	34	124	Seea barela	*Ardisia colorata* Roxb.	VU[2]
		125	Moricha	*Maesa indica* (Roxb.) A.DC.	CD[1]
Myrtaceae	35	126	Painnya jam	*Cleistocalyx nervosum* (DC.) Koterm.	LC[1]
		127	Dhakijam	*Syzygium grande* (Wit.) Walp.	VU[1]
		128	Malaria gach	*Eucalyptus camaldulensis* Dehnn.	NE[1]
		129	Eucalyptus	*Eucalyptus citrodora* Hook.	LC[1]
		130	Hukuinna jam	*Syzygium* sp.	DD[1]
		131	Jam	*Syzygium cumini* (L.) Skeels	LC[1]
		132	Chalta jam	*Syzygium megacarpum* (Craib) Rathakr. et Nair	NE[1]
		133	Pannya jam	*Syzygium formosum* (Wall.) Masamune	LC[1]
		134	Putijam	*Syzygium fruticosum* DC.	LC[1]
Podocarpaceae	36	135	Banspata	*Podocarpus nerrifolius* D.Don	CR[1]
Rhamnaceae	37	136	Boroi	*Zizyphus mauritiana* Lamk.	LC[1]
		137	Bon boroi	*Zizyphus rugosa* Lamk.	NE[1]
Rhizophoraceae	38	138	Raskao	*Carallia brachiata* (Lour.) Merr.	LC[1]
Rubiaceae	39	139	Kadam	*Neolamarckia cadamba* (Roxb.) Bosser	LC[1]
		140	Kannyari	*Gardenia coronaria* Buch.-Ham.	VU[1]
		141	Harinarphul	*Morinda angustifolia* Roxb.	LC[1]
		142	Tulalodh	*Wendlandia tinctoria* (Roxb.) DC.	DD[1]
Rutaceae	40	143	Dulia morichaa	*Clausena excavata* Burm.	LC[1]
Sapindaceae	41	144	Chagaler leda	*Lepisanthes rubiginosa* (Roxb.) Leenhouts	LC[1]
		145	Lichu	*Litchi chinensis* Sonn.	LC[1]
Sapotaceae	42	146	Tali	*Palaquium polyanthum* (Wall. *ex* DC.) Engler.	NE but seems rare[1]
Sonneratiaceae	43	147	Bandarhula	*Duabunga grandiflora* (Roxb. Ex DC.) Walp.	VU[4]
Sterculiaceae	44	148	Fashya udal	*Sterculia villosa* Roxb. *ex* Smith.	LC[1]
		149	Lana assar	*Pterospermum semisagittatum* Buch.-Ham. *ex* Roxb.	VU[4]
		150	Ulat kambal	*Abroma augusta* (L.) L.f	NT[1]
Theaceae	45	151	Ramjani	*Eurya acuminata* DC.	CD[1]
Thymeliaceae	46	152	Agar	*Aquilaria malaccensis* Lamk.	LC[1]
Tiliaceae	47	153	Achar gulla	*Grewia nervosa* (Lour.) Panigrahi	LC[1]
		154	Moos	*Brownlowia elata* Roxb.	VU[1]

(*Continued*)

Table 1. (Continued).

Family	No.	Species no.	Local name	Scientific name	Conservation status
Ulmaceae	48	155	Naricha	*Trema orientalis* (L.) Blume	LC[1]
Urticaceae	49	156	Sunnot gach	*Sarcochlamys pulcherrima* Gaud.	NE but seems rare[1]
Verbenaceae	50	157	Goda	*Vitex peduncularis* Wall. *ex* Schauer	VU[4]
		158	Baramala	*Callicarpa macrophylla* Vahl.	NE[1]
		159	Gamari	*Gmelina arborea* Roxb.	LC[1]
		160	Harina	*Vitex glabrata* R.Br.	LC[1]
		161	Arsol	*Vitex pinnata* L.	NE but seems rare[1]
		162	Teak	*Tectona grandis* L.f.	LC[1]

Abbreviations: CD – Conservation Dependent; CR – Critically Endangered; DD – Data Deficient; EN – Endangered; LC – Least Concern; NE – Not Evaluated; NE but seems rare – NotEvaluated but seems to be rare; NT – Near Threatened; VU – Vulnerable.
Superscripts: 1 – Ahmed et al. (2008); 2 – Rahman (2013); 3 – Ara et al. (2013); 4 – FieldObservation/Experience.

among all the categories (Table 1). Whatsoever, Vulnerable, Endangered, Near Threatened and Critically Endangered tree species were represented by 20% (32 species), 6% (9 species), 1% (1 species) and 2% (3 species) respectively (Figure 3).

Discussion

The present study revealed HWS as a diverse and well stratified natural forest being represented by 162 tree species. The tree composition of HWS (133 tree species under 104 genera and 45 families) is quite greater than 85 tree species reported from Bamu reserve forest of Cox's Bazar (Hossain, Hossain, & Alam, 1997); 92 tree species from Chunati Wildlife Sanctuary (Rahman & Hossain, 2003); 102 tree species from Boroitoli forest (Rahman, Hossain, Hoque, & Alam, 2004); 62 tree species from Tankawati natural forest (Motaleb & Hossain, 2011); 77 tree species from Dudhpukuria Natural forest (Hossain, Hossain, & Hossain, 2012); 18 tree species from Satchari National Park (Hossain, Hossen, & Akhter, 2018). But, it is quite lower in comparison to the 153-tree species reported from tropical forests of Eastern Ghats India (Reddy, Babar, Amarnath, & Pattanaik, 2011); 162 tree species from primary forests of Garo Hills, India (Kumar, Marcot, & Saxena, 2006).

Protected Areas (PAs) play a key role to reduce deforestation, habitat loss and biodiversity loss. The primary aim of establishing HWS was to strengthen the conservation of the existing flora and fauna of the area. Unfortunately, the population of few species is so poor that natural regeneration seems to be impossible. Most of the tree species recorded from the forest are degraded one. Some keystone tree species, e.g., Boilam, Garjan, Civit, Champa are very rare in the forests. Exceptionally few individuals are only available in the office compound.

At present extraction of all kinds of forest products, trespass, etc., are that disturbs the natural habitat is strictly prohibited in Hazarikhil WS. Community is involved in protecting the remnant natural resources of this forest. The group works under a Co-management Committee (CMC) is formed involving the local leaders. As a result, the adjacent people who are generally used to cut and collect the timber, fuelwood, bamboos, fence posts and house posts from the forests are not allowed to do the same. Local people became conscious and trying to protect their forests from deforestation. The Forest Department also extended their responsibilities to strengthen the conservation measures of the remnant forest resources.

Conclusion

HWS is rich in tree composition and diversity as represented with 162 tree species including some threatened and rare plant species. Physical observation during the study indicated that the vegetative resources are degrading rapidly. The main issues in the loss of tree diversity

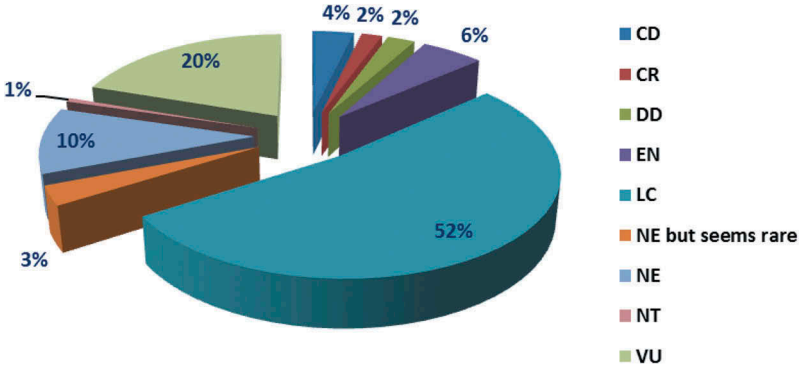

Figure 3. Percentage (%) of the recorded tree species under different conservation categories.

Abbreviations: CD – Conservation Dependent; CR – Critically Endangered; DD – Data Deficient; EN – Endangered; LC – Least Concern; NE – Not Evaluated; NE but seems rare – NotEvaluated but seems to be rare; NT – Near Threatened; VU – Vulnerable.

in HWS are degradation of habitat, e.g., change in land use, conversion of forest lands to agricultural lands, haphazard introduction and priority of alien invasive species, expansion of road networks and other anthropogenic activities that have damage most of the forest resources of HWS. Over exploitation of resources, e.g., illicit felling, encroachment, indiscriminate harvesting of tree species and Non-Timber Forest products, hunting and trafficking exerts a significant negative impact on the biodiversity of HWS. The process of conserving native tree species can be divided into three phases: i) identification – determining which species are in danger of extinction, ii) protection – determining and implementing the short-term measures necessary to halt species from extinction, iii) recovery – determining and implementing the long-term measures necessary to rebuild the population of the species to the point at which it is no longer in danger of extinction.

The present findings provide an assessment on tree species density, diversity, dominance and composition which will be helpful for preparing a sustainable management plan. The study results will also help in adopting appropriate conservation and protection measures for the HWS. The study also reveals the advancement of gradual restoration process that initiated after massive anthropogenic disturbances through both artificial and natural means.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Saddam Hossen http://orcid.org/0000-0002-9734-8075
Anisur Rahman http://orcid.org/0000-0001-8408-849X

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