Assessment of non-timber forest products (NTFPs) in Behali Reserve Forest, Assam, Northeast India

Dipankar Borah, Sumpam Tangjang, Abhaya Prasad Das, Ankur Upadhaya, Puranjoy Mipun

Research

Abstract

Background: Non-timber forest products (NTFPs) are defined as all biological materials other than timber, which are extracted from forests for human use. Uses of various NTFPs have shown significant progress in cultural subsistence, commercial purposes, bioprospecting and sustainable support to forest biodiversity. The present research was conducted in a protected area to document NTFPs of plant origin with their relative importance, to record information for future investigation and discovery of novelty in drug use, and to edify the local communities on sustainable forest management.

*Methods :*The study was aimed to assess the Non-timber forest products of Behali Reserve Forest of Assam. Data was collected from 67 households belonging to two communities, the Karbi and Munda, covering almost 50% of the total households of the studied area using semi-structured questionnaires, personal interviews, group discussions and transect walks from 2017 to 2019.

Results: A total of 100 plants falling under 87 genera and 56 families were reported. Urticaceae with 6 species was the most dominant family. Trees with 35% were the most dominant group, followed by shrubs (28%), climbers (22%) and herbs (15%). Out of the reported NTFPs, 51 species (51%) were edibles, 23 species (23%) had ethnomedicinal importance, and 48 species (48%) are treated as having miscellaneous uses. Use value of all the reported species ranged from 0.01 to 0.13. *Zanthoxylum oxyphyllum, Hodgsonia macrocarpa, Aristolochia cathcartii* and *Aristolochia assamica* have high UV indicating that these species are most important for the studied population. Informant consensus factor was calculated for the different ailments recorded and a total of seven species were found to have above 70% fidelity level values, showing high reliance of the forest dependent people on these species.

Conclusions: The study illustrates a high diversity of NTFPs in the area as well as an intricate relation with the people residing in the fringes of the forest. Anthropogenic activities such as construction of roads, cutting of forests for jhum (shifting) cultivation, natural calamities like landslides etc., were observed to be serious threats to native biodiversity. It is recommended to provide skill development trainings and financial support for the installation of renewable and alternative energy technologies to minimize the use of forest resources in Behali Reserve Forest for better forest sustainability.

Key words: Assam, Assesment, Behali Reserve Forest, Non-timber forest products, quantitative approach, bio-resources

Correspondence

Dipankar Borah[1,2], Sumpam Tangjang[1,*], Abhaya Prasad Das[1], Ankur Upadhaya[1], Puranjoy Mipun[3]

[1]Department of Botany, Rajiv Gandhi University, Rono Hills, Doimukh 791112, Arunachal Pradesh, India
[2]Department of Botany, Goalpara College, Goalpara 783101, Assam, India
[3]Department of Botany, BN College, Dhubri 783323, Assam, India

[*]Corresponding Author: sumpam@gmail.com

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Background

Non-timber forest products (NTFPs) are defined as all biological materials other than timber, which are extracted from forests for human use, with exclusions made for sand, stones, water, and ecotourism (De Beer & McDermott M 1989, Chandrasekharan 1995). But with due course and time, many other definitions were proposed (Chamberlain & Hammett 2002, Grivins 2016, Leßmeister *et al.* 2016), still there is no single or definite definition of NTFPs; hence the concept or classification varies by use or by origin (Ahenkan & Boon 2011). Plants with its diverse use products have long played important roles in the emerging progress of human civilization. The explicit study of these plants has proven to be a powerful tool in understanding how different indigenous communities around the globe relate to natural resources, notably for medicine, food, shelter, additional income, fodder etc. (Albuquerque & Hanazaki 2009). NTFPs also come in handy in case of emergency situations and hardships such as crop failure, economic crisis, war conflicts, and floods as emergency sustenance measures (Sunderlin & Ba 2005). Uses of various NTFPs have shown significant progress in cultural subsistence, commercial purposes, bioprospecting and sustainable support to forest biodiversity (Cocksedge 2009).

India is counted in the countries with a growing market for aromatic and medicinal plants (Martinez 2004). The total number of NTFPs in India is accounted, for about 3000 plant species (Pradhan & Badola 2008, Pradhan & Singh 2019). Northeastern India, falling under the realm of two major biodiversity hotspots (The Himalayas and the Indo-Burma) is considered as one of the most diverse regions of the world in terms of its culture, people and biodiversity (Paul *et al.* 2005). And it holds the majority of the NTFP species, evident from the studies of Pandit *et al.* (2014). A total of 145 tribal communities reside in the terrains of Northeast (Vaiphei 2014). Being mainly forest dwellers the tribal population has a surplus amount of knowledge and is heavily dependent on the forest and its products (Dattagupta *et al.* 2010). Assam, the heart of the Northeastern region of India is a land of cultural, traditional, racial and ethnic diversity. The folk culture in the region is still alive and most tribal communities in the remote areas depend on NTFPs for their traditional system of medicine, household materials, cultural need, etc. (Saikia *et al.* 2017). Assam, on the other hand, is the most studied among the northeastern states in terms of Ethnobotanical knowledge but, a comprehensive study of the documentation of NTFPs wealth in different areas is still lacking.

Over the last century, quantitative approach in relation to people-plants in a multidisciplinary manner using not only ethnobotany, but also ecology, economics, public policy, pharmacology, public health, and other disciplines have gained considerable attention (Balick & Cox 1996, Reyes-García 2006). The advantage of using such method helps to produce quality information, which in turn supplies substantially to resource conservation and development (Hossain & Rahman 2018). The present research was conducted in a protected area to document NTFPs of plants origin with their relative importance, to record information for future investigation and discovery of novelty in drug use, and to edify the local communities on sustainable forest management.

Materials and Methods

Study area

The study was conducted in the fringe villages of Behali Reserve Forest (BRF), the last remaining patch of pristine forest in the entire Biswanath district of Assam (Figure 1, Figure 2A). It is located between 26° 52' and 26° 57' North longitudes and 93° 15' and 93° 25' East latitudes. The total geographical area is about 140.16 km^2 and the elevation of the area ranges between 90 to 110 meters. The temperature ranges between 13°- 37°C and the mean annual rainfall is 1800 mm (Upadhaya 2016-17). The area is surrounded by Buroi River in the east, Singlijan Reserve Forest in the west, Papum Reserve forest in the north and several Tea plantations and human habitations in the south (Sarma *et al.* 2009). The forest type is identified as a tropical semi-evergreen as per Champion and Seth (Champion & Seth 1968). Agriculture is present in almost all sides of the reserve forest and degradation has severely hampered its boundaries. Shifting cultivation is seen in the North boundaries, whereas settled agriculture is predominant in the south and the east.

Data collection

For the present study, field investigation was conducted from 2017 to 2019 from four villages in the fringes of Behali reserve forest falling under Behali Development Block, namely:Serelia Bongaon, Sialmari Bongaon, Bihumari Bongaon and Rampur. These villages were purposively selected for their tendency to use both timber and non-timber forest resources from the reserve forest. Selection of respondents was done through purposive stratified sampling from those villagers who accepted the request for an interview voluntarily. A total of 67 households, covering almost 50% of the total households, present in these villages were covered for data collection. The selected respondents were

those who frequently accesses the forest, village heads, traditional healers, old folks etc., belonging to two tribal communities of the state, the Karbi and Munda. Information regarding NTFPs harvest were collected from the sample households through interviews by various participatory rural appraisal tools such as semi-structured questionnaires, personal interviews, group discussions and transect walk were organized with the core respondents for field validation (Martin 1995). Collection of plant species belonging to NTFPs was done in the company of respondents and was later processed following the methods of Jain & Rao (1977). It was then identified using relevant literatures (Kanjilal *et al.* 1934-1940, Hooker 1872−1897), and consulting voucher specimens present in regional herbaria (ARUN, ASSAM) and submitted in HAU (Herbarium of Rajiv Gandhi University, Arunachal Pradesh).

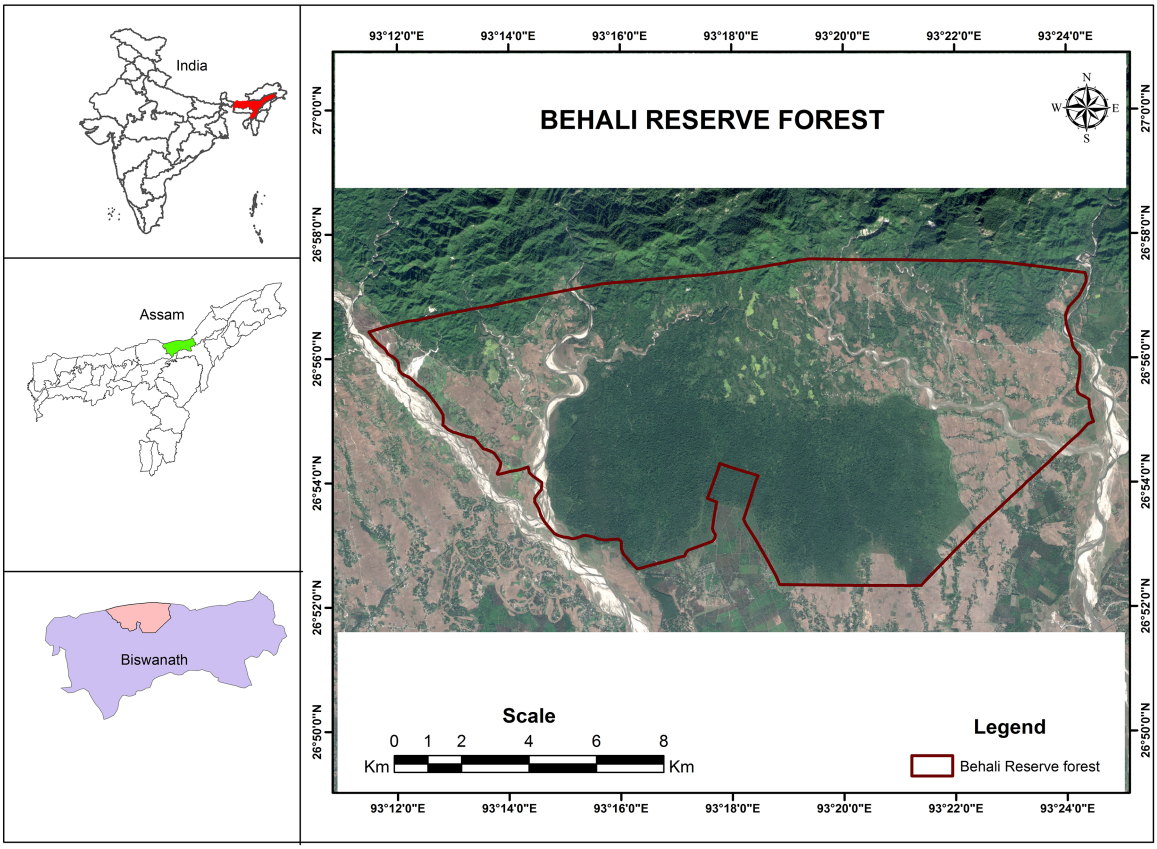

Figure 1. Location map of Behali Reserve forest, Assam, India

Data analysis

The collected data was analyzed using four quantitative indices:Use Value (UV), Use Report (UR), Informant Consensus factor (ICF), and Fidelity Level (FL).

Use Value (UV) is calculated using the following formula:

$$UV = U/n$$

Where, U is the number of use reports cited by every respondent for a given species and n is the total number of respondents interviewed.

The Informant Consensus Factor (ICF) was calculated as:

$$ICF = (Nur-Ns)/(Nur-1)$$

where 'Nur' is the number of use reports for a particular use category and 'Ns' is the number of species used, for each category mentioned by all respondents (Trotter & Logan 1986). ICF gives information about the consensus of respondents regarding the utilization of a certain use category.

Fidelity Level (FL) was calculated as:

$$FL\ \% = Np/Nx100$$

Where, 'Np' is the number of respondents that claim to use a plant species for treating a particular disease and N is the number of respondents that use the plants as a medicine to treat any given disease (Alexiades & Sheldon 1996)

Results

The study reported a total of 100 plants falling under 87 genera and 56 families used by the Karbi and the

Munda communities settled in the fringe villages of BRF (Table 2). Among the 56 recorded families, Urticaceae with 6 species was the most dominant, followed by 5 families (Fabaceae, Lamiaceae, Moraceae, Phyllanthaceae, Rutaceae) with 4 species each, 5 families (Acanthaceae, Asteraceae, Cucurbitaceae, Lauraceae, Malvaceae) with 3 species each, 14 families with 2 species each, and the rest 31 families with 1 species each. As per the habit groups, the plants were broadly divided with trees being most dominant (35%), followed by shrubs (28%), climbers (22%) and herbs (15%). Out of the reported 100 NTFPs, 51 species (51%) were edibles, 23 species (23%) had ethnomedicinal importance, and 48 species (48%) are treated as having miscellaneous uses (rituals and customs, construction, utensils etc.), with cross linked uses. Table 2 presents the plants with validated names using (http://www.theplantlist.org/, https://www.tropicos.org/home, http://www.worldfloraonline.org/) along with their families, voucher numbers, local names, habit, uses, parts used as well as use values. It has been seen that among the four villages, a total of 76 species has been used by the people of Serelia Bongaon, 25 species by Sialmari and Bihumari Bongaon each and 24 species by Rampur (Table 1). The number of native plants reported here is 91, 8 were exotic and 1 is doubtful (POWO 2019).

Table 1. Relative number of plants used by people of different fringe villages recorded in the study area.

Name of the fringe village	Number of plants used
Serelia Bongaon	76
Sialmari Bongaon	25
Bihumari Bongaon	24
Rampur	24

Use value (UV) of all the 100 reported species ranges from 0.01 to 0.13. The species like *Zanthoxylum oxyphyllum, Hodgsonia macrocarpa, Aristolochia cathcartii* and *Aristolochia assamica* have high UV indicating that these species are most important for the studied population (Table 2). The ICF value for traditional medicine used in BRF varied from 0.57 to 1.00, with an average value of 0.91 (Table 3). Among the ailments, eight of them have the highest ICF value of 1 viz., Antidote against dog bite, Antidote against leech bite, Antidote against stings of wasp and nettle leaves, Blood dysentery, Vomiting, Internal injuries, Jaundice and Loss of hearing due to single number of reported species. Dental infections have the ICF of value 0.98 with 60 use-reports for 2 species, followed by Stomach pain (ICF=0.96; 62 use-reports, 3 species), Cut-wounds (ICF=0.95; 64 use-reports, 4 species), Malaria (ICF=0.92; 57 use-reports, 5 species), Dysentery (ICF=0.92; 55 use-reports, 5 species) etc. (Table 3). The highest ICF value with more than a species reported for a particular ailment, is for Dental infections (*Acmella paniculata* & *Croton caudatus*). Similarly, species responsible for the high consensus for Stomach pain are *Aristolochia assamica*, *Aristolochia cathcartii* and *Garcinia xanthochymus*; Cut-wounds are *Chromolaena odorata*, *Clerodendrum infortunatum*, *Mikania micrantha* and *Thunbergia grandiflora*; Malaria are *Alstonia scholaris*, *Hodgsonia macrocarpa*, *Zanthoxylum oxyphyllum*, *Aristolochia cathcartii* and *Aristolochia assamica*; Dysentery are *Aristolochia cathcartii*, *Aristolochia assamica*, *Dillenia indica*, *Hodgsonia macrocarpa* and *Zanthoxylum oxyphyllum*. The least agreement between the informants was observed for plants used for Cough, Swells, Urinary tract infections etc.

A total of seven species were found to have above 70% FL values, showing the cultural importance of these species (Table 4). The high value of FL (%) is taken for selecting the most preferred plant species that have one or more species responsible for treating that particular ailment category (Uddin & Hassan 2014). The result revealed that a single species, *Clerodendrum colebrookeanum* was responsible for treating high blood Pressure showing highest FL value of 97% with 65 use reports. Whereas, out of the 4 species with high values of ICF for treating cut-wounds, *Chromolaena odorata* is the most commonly used species in the study area (ICF=0.95) with 62 use report and FL value (92%). Similarly, *Aristolochia assamica* is the most widely used species for treating stomach pain with 61 use report and FL value (91%), followed by *Croton caudatus* with 59 use report and FL value (88%) for dental infections, *Solanum myriacanthum* with 55 use report and FL value (82%) for antidote against leech bite, and *Aristolochia cathcartii* with 55 use report and FL value (82%) for malaria (Table 4).

Discussion

Edible plants

A large number of edible species has been recorded from the present study. It was perceived that majority of the people living in those fringe areas yield some kind of edible plant products in most of their visits to the forest. Plants like *Gnetum gnemon, Lepionurus sylvestris, Dillenia indica, Diplazium esculentum,* etc. were the most preferred wild edible plants.

Among the reported plants, *Gnetum gnemon*, is in great demand during the flowering season i.e. the summers. One hundred gram of *G. gnemon* cones can price up to 100 Indian rupees (INR). Fruits of *Dillenia indica*, young fronds of *Diplazium*

esculentum are also sold in the markets throughout the year fetching minimal price (INR 20/kg and INR 20/bundle). The local market price of such wild edible plant products somehow ranges the same in the entire North eastern part of the country, indicating the abundance and high suitability areas for introduction of those underutilized plants in the homegardens of these regions (Terangpi *et al.* 2013). Documentation of the wild edible plants, along with the study of their availability and preference in an area can act as a reserve zone for large scale production in future to support food shortage calamities.

Table 2. List of NTFPs used by the people residing in fringe villages of Behali Reserve Forest. (Abbreviations used:Ba - Bark, Fl - Flowers, Fr - Fruits, I - Inflorescence, L - Leaves, P - Petiole, R - Roots, Re - Resin, Rh - Rhizome, Se - Seeds, St - Stem, Tu - Tuber, Tw - Twigs, WP - Whole Plant; S - Shrub, T - Tree, C - Climber, H - Herb)

Species	**Family**	**Voucher number**	**Vernacular name**	**Habit (Parts used)**	**Use and application**	**Use value**
Phlogacanthus curviflorus (Wall.) Nees	Acanthaceae	3011	Bam chouk, Tita phul	S (Fl, Tw)	Edible: Flowers are boiled then fried; Medicine: High blood Pressure (29): Eaten after boiled: Oral; Miscellaneous: Chujun	0.044
Strobilanthes paniculiformis J.R.I.Wood	Acanthaceae	1015	Mehek sou	S (Fl)	Miscellaneous: Aesthetic value	0.014
Thunbergia grandiflora (Roxb. ex Rottler) Roxb.	Acanthaceae	3022	Nonong	C (Tw)	Medicine: Cut-wounds (10): Topical: Paste, with Phil it (Clerodendrum infortunatum)	0.014
Miliusa dioeca (Roxb.) Chaowasku & Kessler	Annonaceae	4011	Thenglang kung	T (St)	Miscellaneous: Firewood	0.014
Polyalthia simiarum (Buch.-Ham. ex Hook. f. & Thomson) Benth. ex Hook. f. & Thomson	Annonaceae	5010	Mengsuri, Kaari	T (St, Ba)	Miscellaneous: Construction (Rope), Firewood, Rongker	0.014
Hoya verticillata (Vahl) G.Don	Apocynaceae	6655	Methan adei	C (L)	Medicine: Loss of hearing (2), Antidote against dog bite (2): Paste: Topical	0.029
Alstonia scholaris (L.) R. Br.	Apocynaceae	1088	Thengnu (Sotian), Thengnu	T (Tw, L, Ba)	Medicine: Jaundice (2), Malaria (12): Paste: Topical; Miscellaneous: Dwi Krai	0.044
Lasia spinosa (L.) Thwaites	Araceae	7091	Sengmora	H (L,I)	Edible: Young leaves and spathes are fried	0.014
Rhaphidophora glauca (Wall.) Schott	Araceae	1136	Lolap	C (L)	Edible: Young leaves are boiled; Miscellaneous: Plates	0.029
Eleutherococcus trifoliatus (L.) S.Y. Hu.	Araliaceae	1023	Ingsu so	S (WP)	Miscellaneous: Fence	0.014
Pinanga gracilis Blume	Arecaceae	1022	Koibi enlo, Koibi ir	T (Fr, L)	Edible: Fruits are eaten raw with beetle leaves; Miscellaneous: Construction (Roofing)	0.029
Aristolochia assamica D. Borah & T.V. Do	Aristolochiaceae	3013	Rui etso/ Pet bix lota	C (Tu)	Medicine: Stomach pain (61), Malaria (54), Dysentry (50), High blood pressure (17), Body pain **(12)**, Urinary tract infections (4), Headache (13), Cough (2): Paste (with Hanthar, Jajur, Rui etpi) are mixed with Porcupines pit to make a tablet of the normal size: Oral	0.119
Aristolochia saccata Wall.	Aristolochiaceae	1112	Rui etpi	C (Tu)	Medicine: Stomach pain (59), Malaria (55),	0.119

					Dysentry (49), High blood pressure (16), Body pain **(12)**, Urinary tract infections (4), Headache (19), Cough (2): Paste (with Hanthar, Rui etso, Jajur) are mixed with Porcupines pit to make a tablet of the normal size: Oral	
Dracaena petiolata Hook.f.	Asparagaceae	3033	Chorleng	S (Tw)	Miscellaneous: Chujun	0.014
Diplazium esculentum (Retz.) Sw.	Aspleniaceae	7088	Dungkek, Dhekia	H (Sh)	Edible: Young shoots are boiled	0.014
Acmella paniculata (Wall. ex DC.) R.K.Jansen	Asteraceae	3039	Bap suki	H (Fl)	Medicine: Dental infections (28): Applied after chewed: Oral	0.014
Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae	7021	Bap jarman	S (L)	Medicine: Cut-wounds (62): Paste: Topical	0.014
Mikania micrantha Kunth	Asteraceae	3018	Babro ket, Mekani lota, China lota	C (Tw)	Medicine: Cut-wounds (60): Paste: Topical	0.014
Begonia silhetensis (A.DC.) C.B.Clarke	Begoniaceae	3025	Suat	H (P, R)	Edible: Petioles are eaten as chutney; Medicine: Antidote against stings of wasp and neetle leaves (12): Paste: Topical	0.029
Oroxylum indicum (L.) Kurz	Bignoniaceae	3024	Nopak ban	T (Ba, Fl)	Edible: Flowers are fried; Medicine: Headache (18): Paste: Topical	0.029
Stereospermum chelonoides (L.f.) DC.	Bignoniaceae	1034	Inghet, Paroli	T (St)	Miscellaneous: Firewood	0.014
Canarium resiniferum Bruce ex King	Burseraceae	4036	Hijung	T (Re)	Miscellaneous: Fragrance	0.014
Trema orientalis (L.) Blume	Cannabaceae	3044	Rampaat	T (St)	Miscellaneous: Construction (Poles)	0.014
Chloranthus elatior Link	Chloranthaceae	1147	Jok ansu	S (Tw)	Miscellaneous: Fodder	0.014
Garcinia xanthochymus Hook.f. ex T.Anderson	Clusiaceae	3017	Phe champreng, Thei champre, Thekera tenga	T (Fr)	Edible: Fruits are eaten raw; Medicine: Stomach pain (12): Eaten directly: Oral	0.029
Amischotolype hookeri (Hassk.) H.Hara	Commelinaceae	3034	Chehe lubor	H (WP)	Miscellaneous: Chujun	0.014
Cheilocostus speciosus (J.Koenig) C.D.Specht	Costaceae	3002	Ai oppo, Ai eupou	H (Rh)	Medicine: Vomiting (4): Paste: Oral	0.014
Solena heterophylla Lour.	Cucurbitaceae	1077	Khrai khruk, Khrai khrup Akibi	C (Fr)	Edible: Fruits are fried	0.014
Hodgsonia macrocarpa (Blume) Cogn.	Cucurbitaceae	4045	Han thar	C (Se)	Edible: Roasted seeds are eaten; Medicine: Malaria (20), Dysentry (23), High blood pressure (18), Body pain (2), Urinary tract infections (2), Headache (12), Cough (2): Paste (with Rui-etso, Jajur, Rui-etpi) are mixed with Porcupines pit to make a tablet of the normal size: Oral	0.119
Momordica sp.	Cucurbitaceae	1092	Han pinu, Khrai khrut	C (L, Fl, Fr, Se)	Edible: Young leaves are boiled, flower and fruits are fried; Medicine: Swells	0.029

					(2): Paste with a fish called Okanbup: Topical	
Dillenia indica L.	Dilleniaceae	7087	Plim plam, Chalta tenga, ou tenga	T (Fr)	Edible: Fruits are fried; medicine: Dysentery (29): Eaten directly: Oral	0.029
Tetracera sarmentosa (L.) Vahl	Dilleniaceae	1036	Samphat	C (St)	Miscellaneous: The stem after cut is used to drink water inside the forest	0.014
Elaeocarpus rugosus Roxb. ex G.Don	Elaeocarpaceae	3006	Mir choubey	T (St)	Miscellaneous: Construction (Poles)	0.014
Sloanea sterculiacea var. assamica (Benth.) Coode	Elaeocarpaceae	2266	Phongrong ke-er	T (St)	Miscellaneous: Firewood	0.014
Croton caudatus Geiseler	Euphorbiaceae	1124	Su ik	S (St)	Medicine: Dental infections (59): Exudate: Tropical	0.014
Macaranga denticulata (Blume) Müll.Arg.	Euphorbiaceae	1074	Lopoklok, Lobonglong	T (L)	Miscellaneous: *Chomongkan*	0.014
Bauhinia variegata L.	Fabaceae	7084	Koina saag/ Kanchan	T (L)	Edible: Young leaves are boiled	0.014
Dalhousiea bracteata (Roxb.) Benth.	Fabaceae	1117	Lou jangthu	S (L)	Miscellaneous: Plates	0.014
Bauhinia scandens (L.)	Fabaceae	5006	Sarai lata	C (St)	Miscellaneous: Ropes	0.014
Caesalpinia enneaphylla Roxb.	Fabaceae	3007	Sir hup, Sulu	C (Tw)	Miscellaneous: Death ceremony	0.014
Castanopsis indica (Roxb. ex Lindl.) A.DC.	Fagaceae	1098	Phongrong kemong	T (L, Se)	Edible: Nuts are eaten raw and roasted; Miscellaneous: Wrappers (Biri)	0.014
Castanopsis lanceifolia (Oerst.) Hickel & A.Camus	Fagaceae	4012	Phongrong jamphru	T (Tw)	Miscellaneous: Chujun	0.014
Rhynchotechum ellipticum (Wall. ex D.Dietr.) A.DC.	Gesneriaceae	3038	Mehek tarkong	S (L)	Edible: Young leaves are boiled	0.014
Gnetum gnemon L.	Gnetaceae	3020	Han thu, Letera, Letra	S (L, I, Se)	Edible: Young leaves are eaten with pulses, Inflorescences are fried, and seeds are roasted; Medicine: Blood dysentery (10): Eatenafter boiled: Oral	0.029
Molineria crassifolia Baker	Hypoxidaceae	3045	Bati long	H (L)	Miscellaneous: Construction (Roof)	0.014
Clerodendrum glandulosum Lindl.	Lamiaceae	5003	Cler klum, Poto saag	S (L)	Edible: Young leaves are boiled; Medicine: High blood pressure (65): Eaten after boiled: Oral	0.029
Callicarpa arborea Roxb.	Lamiaceae	3043	Arhi	T (St)	Miscellaneous: Construction (Poles), Firewood	0.014
Callicarpa vestita Wall. ex C.B.Clarke	Lamiaceae	1065	Arhi kelok	T (Tw)	Miscellaneous: Chujun, Dwi krai	0.014
Clerodendrum infortunatum L.	Lamiaceae	3037	Phil it, Phler ik	S (L)	Medicine: Cut-wounds (61): Paste: Topical	0.014
Cinnamomum bejolghota (Buch.-Ham.) Sweet	Lauraceae	4020	Tezpat	T (L)	Edible: Used as spice in curries	0.014
Litsea khasyana Meisn.	Lauraceae	1113	Tingkrong, Pong aatso	S (Sh)	Edible: Used as spice in curries	0.014
Litsea monopetala (Roxb.) Pers.	Lauraceae	1024	Pongket	T (St)	Miscellaneous: Firewood	0.014
Magnolia hodgsonii (Hook.f. & Thomson) H.Keng	Magnoliaceae	2240	Borhom thari	T (St)	Miscellaneous: Firewood	0.014

Pterospermum acerifolium (L.) Willd.	Malvaceae	2374	Mukchun	T (St)	Miscellaneous: Construction (Poles), Firewood	0.014
Sterculia hamiltonii Adelb.	Malvaceae	3004	Konkilo	S (Se)	Edible: Seeds are roasted	0.029
Sterculia villosa Roxb.	Malvaceae	2570	Jintekong	T (St, Ba)	Miscellaneous: Construction (Rope), Firewood	0.014
Phrynium pubinerve Blume	Marantaceae	2232	Loru	H (L)	Miscellaneous: Plates	0.029
Melastoma malabathricum L.	Melastomataceae	7092	Bik bik	S (T, Fr)	Edible: Young twigs are boiled, Fruits are eaten raw	0.014
Parabaena sagittata Miers	Menispermaceae	3,010	Han risang, Hangrisai	C (L)	Edible: Young leaves are eaten with pulses	0.014
Stephania rotunda Lour.	Menispermaceae	3036	Rikang bonglong	C (St)	Miscellaneous: Construction (Rope)	0.014
Artocarpus chama Buch.-Ham.	Moraceae	7082	Saam kothal, Phong	T (Fr)	Edible: Fruits are eaten raw	0.014
Artocarpus lacucha Buch.-Ham.	Moraceae	7083	Dahok	T (Fr)	Edible: Fruits are eaten raw	0.014
Ficus auriculata Lour.	Moraceae	4025	Thebok er	T (L)	Edible: Young leaves are boiled	0.029
Ficus hederacea Roxb.	Moraceae	4039	Chiri So	C (L)	Miscellaneous: Dwi Krai	0.014
Musa velutina H.Wendl. & Drude	Musaceae	2379	Lorop	H (WP)	Miscellaneous: Chujun	0.014
Horsfieldia kingii (Hook.f.) Warb.	Myristicaceae	7090	Detok (Ramtamul)	T (Fr)	Edible: Fruits are eaten raw with beetle leaves	0.014
Syzygium cumini (L.) Skeels	Myrtaceae	4019	Karabeng	T (Fr)	Edible: Fruits are eaten raw	0.014
Erythropalum scandens Blume	Olacaceae	1107	Han pilu	C (L)	Edible: Young leaves are boiled; Miscellaneous: Plates	0.014
Lepionurus sylvestris Blume	Opiliaceae	4032	Han Botar, Han votar, Rimil ful, Rimil Baha, Rimil saag	S (L, Fl)	Edible: Leaves and Flowers are boiled	0.014
Baccaurea ramiflora Lour.	Phyllanthaceae	3032	Dampijuk, Dampijuk athe, Letku	T (Fr)	Edible: Fruits are eaten raw	0.014
Sauropus androgynus (L.) Merr.	Phyllanthaceae	3026	Han woti, Munga saag, Jangli Munga	S (L)	Edible: Leaves are boiled	0.014
Bridelia stipularis (L.) Blume	Phyllanthaceae	1126	Thebi e	C (St)	Miscellaneous: Fire wood	0.014
Phyllanthus assamicus Müll.Arg.	Phyllanthaceae	1085	Phongrong su, Tamsir	T (Sh)	Miscellaneous: Fire wood	0.014
Oplismenus burmanni (Retz.) P.Beauv.	Poaceae	1120	Tipli	H (WP)	Miscellaneous: Fodder	0.014
Persicaria hydropiper (L.) Delarbre	Polygonaceae	4022	None hiru	H (WP)	Miscellaneous: Fishing	0.014
Persicaria praetermissa (Hook.f.) H.Hara	Polygonaceae	3035	Oksimor okpo, Pisol saag, Okhima Rokpo	H (L, Fl)	Edible: Leaves and flowers are boiled, fruits are eaten raw	0.029
Rhamnus napalensis (Wall.) M.A.Lawson	Rhamnaceae	1115	Thengki ik	S (St)	Miscellaneous: Fire wood	0.014
Rubus buergeri Miq.	Rosaceae	1032	Sumohar, Sarpi sarhi	S (Fr)	Edible: Fruits are eaten raw	0.014
Paederia foetida L.	Rubiaceae	3012	Akai nangthu/ Rikang angthu, R. nengtho, Padri Lata	C (L)	Medicine: Swells (2): Paste: Topical: Edible: Leaves are fried	0.014
Mussaenda roxburghii Hook.f.	Rubiaceae	1102	Uso bibang, Osopi Ban	S (L)	Edible: Young leaves are boiled	0.014
Citrus indica Yu.Tanaka	Rutaceae	7085	Kamla tenga, Jangli Kamla	S (Fr)	Edible: Fruits are eaten raw	0.029

Zanthoxylum rhetsa DC.	Rutaceae	7094	Jabrang	T (Se)	Edible: Seeds are used as spice	0.014
Citrus medica L.	Rutaceae	4016	Tumeng, Nimbu tenga	S (Fr)	Edible: Fruits are eaten raw	0.014
Zanthoxylum oxyphyllum Edgew.	Rutaceae	3023	Jajur	C (L, R, Ba)	Edible: Leaves are used as spice; Medicine: Malaria (19), Dysentry (21), High blood pressure (13), Body pain (4), Urinary tract infections (2), Headache (7), Cough (2): Paste (with Hanthar, Rui etso, Rui etpi) are mixed with Porcupines pit to make a tablet of the normal size: Oral; Miscellaneous: Fishing	0.134
Meliosma simplicifolia (Roxb.) Walp.	Sabiaceae	1038	Theng kangduk, Thengpi koba	T (L)	Edible: Young leaves are boiled	0.014
Meliosma pinnata (Roxb.) Maxim	Sabiaceae	3016	Thengsi kobu, Thengpi koba	T (L)	Edible: Young leaves are boiled; Miscellaneous: Dwi Krai	0.029
Lepisanthes senegalensis (Poir.) Leenh.	Sapindaceae	5007	Khranti ek, Thengsu, Bandardima, Jamun, Thekang Tang	S (Fr)	Edible: Fruits are eaten raw	0.014
Picrasma javanica Blume	Simaroubaceae	4051	Chabalu	T (St)	Miscellaneous: Firewood	0.014
Smilax aspera L.	Smilacaceae	1007	Phri langphung	C (L)	Edible: Young leaves are boiled	0.014
Solanum myriacanthum Dunal	Solanaceae	3021	Hipi duai, Bengna	S (R, Fr)	Medicine: Internal injuries (2), Antidote against leech bites (30): Paste, with Kochu (Colocasia sp.)and gul moris (Piper longum): Oral	0.029
Solanum stramoniifolium Jacq.	Solanaceae	3030	Theso rongman, Theso kumbang	S (Fr)	Edible: Fruits are boiled and made into chutney	0.014
Dalrympelea pomifera Roxb.	Staphyleaceae	2391	Thekejoi	T (St)	Miscellaneous: Firewood	0.014
Pyrenaria khasiana var. *lakhimpurensis* Odyuo & D.K. Roy	Theaceae	2393	Jangli chah	S (St)	Miscellaneous: Firewood	0.014
Boehmeria penduliflora Wedd. ex D.G. Long	Urticaceae	3041	Seram hou	S (L)	Edible: Young leaves are boiled	0.014
Dendrocnide sinuata (Blume) Chew	Urticaceae	7086	Bap kansam, Kulkuli, Surat paat	S (L)	Edible: Young leaves and flowers are boiled	0.014
Elatostema parvum (Blume) Blume ex Miq.	Urticaceae	7089	Longle mehek	H (L)	Edible: Young leaves are eaten with pulses	0.014
Laportea interrupta (L.) Chew	Urticaceae	8977	Termei, Tinipotia	H (L)	Edible: Young leaves are boiled	0.014
Poikilospermum suaveolens (Blume) Merr.	Urticaceae	1088	Arlong sirim	C (T, L, St)	Edible: Young twigs and leaves are boiled; Miscellaneous: Construction (Rope), The stem cut is used for drinking water	0.029
Pouzolzia sanguinea (Blume) Merr.	Urticaceae	1006	Han thai	C (L)	Edible: Young leaves are boiled	0.014
Alpinia nigra (Gaertn.) Burtt	Zingiberaceae	7081	Tara, Tarani, Torani, Bororu	H (L, Tw)	Edible: Young shoots are boiled; Miscellaneous: Used in Rongker;	0.029

Table 3. Consensus of agreement on the uses of medicinal plants among informants

Category of indigenous use	Number of use report (Nur)	Number of species (Ns)	Consensus factor (ICF)
Antidote against dog bite	2	1	1
Antidote against leech bite	30	1	1
Antidote against stings of wasp and nettle leaves	12	1	1
Blood dysentery	10	1	1
Body pain	30	4	0.896
Cough	8	4	0.571
Cuts-wounds	64	4	0.952
Dental infections	60	2	0.983
Dysentery	55	5	0.925
Headache	30	5	0.862
High blood pressure	65	6	0.921
Internal injuries	2	1	1
Jaundice	2	1	1
Loss of hearing	2	1	1
Malaria	57	5	0.928
Stomach pain	62	3	0.967
Swells	4	2	0.666
Urinary tract infections	12	4	0.727
Vomiting	4	1	1

Table 4. Fidelity level (FL %) of frequently cited plant species with major uses

Botanical name	Categories	Citation for particular disease (use report)	Fidelity level (%)
Clerodendrum colebrookeanum	High blood Pressure	65	97
Chromolaena odorata	Cut-wounds	62	92
Aristolochia assamica	Stomach pain	61	91
Croton caudatus	Dental infections	59	88
Solanum myriacanthum	Antidote against leech bite	55	82
Aristolochia cathcartii	Malaria	55	82
Aristolochia assamica	Dysentery	50	74

Traditional medicine

Traditional medicine plays an important role in the forest fringe communities of BRF. But due to the quick access to modern health facilities provided by the government lately, the reliance on traditional medicine is seen to be diminishing for any forest community. Hence, the number of plants reported to be used as medicine as well as people's knowledge on it is low as compared to other studies conducted on the Karbi's of Karbi-Anglong district of Assam (Mipun *et al.* 2019). Among the 23 reported ethnomedicinal plants, 14 (*Alstonia scholaris*, *Aristolochia assamica*, *Aristolochia cathcartii*, *Begonia silletensis*, *Clerodendrum colebrookeanum*, *Croton caudatus*, *Dillenia indica*, *Garcinia xanthochymus*, *Gnetum gnemon*, *Hoya verticillata*, *Momordica sp.*, *Phlogacanthus curviflorus*, *Solanum myriacanthum*, *Zanthoxylum oxyphyllum*) were new ethnobotanical records for the Karbi community (Terangpi *et al.* 2014, Mipun *et al.* 2019, Teron 2019), which might be due to the isolation of the tribal population in different pockets of the region.

The study on such traditional knowledge by the indigenous communities in different geographical zone can serve as a base line research for many new discoveries of important drugs (Shakya 2016). Furthermore, such new and continuous study can improve and help survive the concept of traditional knowledge, which is under threat, and its protection

is the need of the hour. The factors that pose threat on the survival of traditional communities and knowledge are commercialization of biodiversity, disruption of the interrelationship between traditional knowledge generators and their resources, industrialization and many more (Bala 2011). Moreover, lack of documentation of traditional knowledge and non-technical documentation also leads to bio piracy.

Plants used in other uses

The people's daily dependency on the forest can be mainly seen in terms of firewood. Generally, firewood are collected from the dominant trees in the accessible areas, such as Borhom thari (*Magnolia hodgsonii*), Chabalu (*Picrasma javanica*), Inghet (*Stereospermum chelonoides*), Jangli Chah (*Pyrenaria khasiana* var. *lakhimpurensis*), etc. Plants which are rare in the forest are sparsely collected and find no names in their dialect.

Community fishing was known to be a favorite game and time pass for the locals in off seasons and is known to be a part and parcel of life apart from agriculture (Yumnam & Tripathi 2013). Apart from using nets and other modern techniques, some of the tribal populations were still seen using the indigenous techniques for fishing. In the present study, two plants have been reported to be used:whole plants of Nune hiru (*Persicaria hydropiper*) and bark of Jajur (*Zanthoxylum oxyphyllum*). They are smashed and spread in blocked rivulet, and the fishes are either stupefied or killed in response. These environmently friendly techniques are seen to be lost in due time.

Even two species of lianas Samphat (*Tetracera sarmentosa*) and Arlong Sirim (*Poikilospermum suaveolens*) were used to drink water within the dense forests, where there is no other water source. Cuts are made and then the water within them is used as they are believed to be pure. Spiny plants such as Ingsu-so (*Eleutherococcus trifoliatus* var. *trifoliatus*) are used as fence, which is quite evident.

Plants used in Rituals and Festivals

The Karbi's of BRF celebrates many festivals and rituals in accordance to their customs. Even this isolated population from the mainland stock maintain the original fragrance of their rites. *Rongker*, *Chujun*, *Arnam Pharo*, *Dwi Krai* and *Chomangkan* are some of them. Most of their rituals are related to elimination of the evil spirits in a single household or for the community. *Rongker* celebrated in the month of December is a community festival. Whereas, *Chujun* (Figure 2C) and *Chomangkan* (Death ceremony) are hosted by a single family, and the whole community participates. *Arnam Pharo* (Figure 2B) and *Dwi Krai,* on the other hand, are restricted within few individuals of the family. The importance of plants in these rituals are manifold, either the ones procured from the wild or the household commons. Plants of Fagaceae, Zingiberaceae, Poaceae and Piperaceae are found to be common in used for religious festivals and offerings by different communities of the Northeast (Nongbri *et al.* 2017).

Knowledge of the Karbi and the Munda on medicinal plant uses and its quantitative analysis

In the Karbi and the Munda, almost every family have a rich traditional knowledge on the use of medicinal plant species due to remoteness. The knowledge of traditional medicinal plants of these two groups was similar and most of the medicinal plant species reported were used to treat the prevalent diseases. Thus, the two group not only share the ecological area but are living in a symbiotic relation. Data obtained using quantitative based studies have shown the significance of these plants among the tribes. The plants (*Aristolochia assamica, Aristolochia cathcartii, Hodgsonia macrocarpa* and *Zanthoxylum oxyphyllum*) with the highest UV are considered most important for the local people due to their multiple use reports and are therefore specifically conserved (Albuquerque 2006). The ICF value for each of the 20 ailment categories ranged from 0.57 to 1.00. Categories like antidote against dog bite, leech bite, stings of wasp and nettle leaves, blood dysentery, vomiting, internal injuries, jaundice and loss of hearing shows ICF value of 1. It is because only one species for each category were used by the respondents.The plants associated with higher ICF value of ≥0.80 (*Aristolochia assamica, Aristolochia cathcartii, Chromolaena odorata, Clerodendrum infortunatum, Croton caudatus, Mikania micrantha, Solanum myriacanthum,* etc.) are mostly used by both the communities, suggesting that they have diverse and useful medicinal plants within the particular locality for treating different ailments (Solomon 2016). Most of the respondents used specific species for particular ailments as shown by the seven species having FL above 70%. The variation in ICF value and high value of FL suggests that though the local people have access to government health care system, for common ailments, they tend to use traditional medicine and traditional medicinal plants have not lost their values among the local people (Bibi *et al.* 2014).

For plants with high ICF and FL value such as *Clerodendrum colebrookeanum, Chromolaena odorata, Aristolochia assamica, Croton caudatus, Solanum myriacanthum, Aristolochia cathcartii,* etc., phytochemical investigations and nutritive analysis need to validate their uses as traditional medicines and to check their bioactive constituents. This type of

studies could potentially guide the development of new nutraceutical products and broaden the scope of bioprospecting in the future (Shaanker 2004, Ong & Kim 2014).

Figure 2. A- Landscape of Behali Reserve Forest; B- *Arnam Pharo*; C-*Chujun*; D-Preparation of *Gnetum gnemon*, in Rongker; E,F,G- Key respondents; H. *Aristolochia cathcartii*; I. *Aristolochia assamica*; J. *Strobilanthes paniculiformis*; K. *Citrus indica;* L. *Monoon simiarum* "Mengsuri".

In fact, the number of NTFP's reported here is far more when compared to the Garo hills of Meghalaya, 50 species (Sangma & Lalnundanga 2019), Namdapha National Park, Arunachal Pradesh, 63 species (Sarmah 2010), Cachar district, Assam, 67 species (Dattagupta *et al.* 2014), East Siang district, Arunachal Pradesh, 34 species (Kumar *et al.* 2015), Sonitpur district, Assam, 40 species (Sarma *et al.* 2016) and slightly less than Jaldapara Wildlife Sanctuary of West Bengal, 132 species, Pandit *et al.* 2004), Ziro valley, Arunachal Pradesh, 112 species, (Jha 2015), Buxa Tiger Reserve, West Bengal, 112 species, (Sarkar & Das 2015).

Threats status of some plants and guidance to sustainable forest management

The people are seen to use the common species more, probably due to their high availability, and wide occurrence. Among the reported plants, only nine plants were accessed by IUCN (2020), among which (*Alstonia scholaris, Diplazium esculentum, Bauhinia variegata, Gnetum gnemon* (Figure 2D), *Cinnamomum bejolghota, Baccaurea ramiflora, Persicaria hydropiper* and *Rhamnus napalensis*) are listed as least concern, and *Elaeocarpus rugosus* as vulnerable. Among the collected ones, some species were found to be rare in BRF such as *Aristolochia assamica* (Figure 2I), *Hodgsonia macrocarpa*, *Artocarpus chama*, *Zanthoxylum rhetsa* and *Citrus indica* (Figure 2K). The current population shows significant decline in BRF which may be perhaps due to unregulated collection and exploitation. Some conservative measures are being taken for these plants, starting with studying the population structure (Borah *et al.* 2018), conducting awareness programmes in those selected villages to aware the present and the future scenario of those plant species to the villagers by referring the local name of the plants and later towards germination and *in situ* approaches.

Conclusions

With an ever-increasing population, the demand for forest products is at a rise due to the collection of NTFPs and timber, leading to loss of biodiversity and threatening the native endemic and threatened flora. Anthropogenic activities such as construction of roads, cutting of forests for jhum (shifting) cultivation, natural calamities like landslides etc., were observed to be serious threats to native biodiversity. It is recommended to provide skill development trainings and financial support for the installation of renewable and alternative energy technologies to minimize the use of forest resources in BRF for better forest sustainability.

Declarations

List of abbreviations: NTFP-Non-timber forest products; BRF-Behali Reserve Forest.

Ethical approval and consent to participate: The necessary permissions to conduct this study was provided by the forest department of Assam as well as the village heads of the respective villages. Written consents were obtained from all the respondents during the interview process.

Consent for publication: Not applicable.

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Authors' contributions: DB and AU participated in data collection; ST and APD participated in drafting the manuscript. PM analyzed the data using quantitative approaches. All the authors approved the final version of the manuscript.

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