

Monitoring Forest Biodiversity in the Face of Urban Proximity: A Case Study in Nirjuli Highlighting the necessity for Ex-situ Conservation Imperative

Dipankar Borah

Department of Botany, Kaliabor College, Kaliabor-782137, Assam, India

Momang Taram

Rajiv Gandhi University

Millo Tasser

Department of Environment, Forests and Climate Change, Itanagar-791111, Arunachal Pradesh, India

Egam Basar

State Horticulture Research and Development Institute, Itanagar-791111, Arunachal Pradesh, India

Sumpam Tangjang

Rajiv Gandhi University

Tonlong Wangpan

twangpan@gmail.com

Rajiv Gandhi University

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Abstract

A verdant plot of land in Nirjuli, Papum Pare district of Arunachal Pradesh, is home to an impressive array of biodiversity. Within this modest expanse, 156 species of flowering plants, representing 129 genera and 57 families thrive astoundingly. Notably, 11 of these species are only found in North East India, with five (*Amomum arunachalense*, *Boeica arunachalensis*, *Henckelia collegii-sancti-thomasii*, *Pseuderanthemum arunachalense* and *Rhynchothecum nirjuliense*) of them being endemic to this particular area only. Regrettably, the relentless march of urbanization and rapid encroachments of human settlements has led to the extinction of its once-thriving microhabitats. This lamentable tale is not unique to this plot alone, it also applies to many other regions across the state. Faced with these alarming circumstances, ex-situ conservation efforts are imperative to safeguard these irreplaceable bioresources.

Introduction

The state of Arunachal Pradesh, also known as the "land of the dawn-lit mountains," holds a key location in the zone separating the Indo-Burma and Himalayan biodiversity hotspots. The state is bordered by Bhutan to the west, Tibet to the north, Myanmar to the east, and Assam and Nagaland to the south (Tsering et al., 2017; Myers et al., 2000). It is the largest state in Northeast India, covering an area of roughly 83,700 km², and is one of the 200 ecoregions that have gained international recognition (Olson and Dinerstein, 1998). The exceptional phytogeographical, topographical, and climatic conditions of the state offer the perfect environment and habitat for a variety of distinctive floral diversity (Chakravarty et al., 2012; Taram et al., 2018). Given that it is home to half of all flowering plant species in India, Arunachal Pradesh is frequently referred to as the "centre of evolutionary development" and the "cradle of flowering plants" (Takhtajan, 1969; Chowdhery, 2008). Numerous delicate ecosystems, a wide variety of endemic and native species, and a unique arrangement of various plant communities can be found on its territory (Biswas, 1966; Hajra and Mudgal, 1997; Saikia et al., 2017).

Despite having a forest cover of 66,964 km² (about 80% of its total area), Arunachal Pradesh only has a small number of protected areas, including two national parks, two tiger reserves, eleven wildlife sanctuaries, and a biosphere reserve (Kanwal and Lodhi, 2018). Owing to which, a sizeable portion of the state's biodiversity thrives in forests owned by local people, with many of these lands being held as a whole by the communities.

The forest resources serve as the primary livelihood source for rural communities in Arunachal Pradesh, with all plant species, from medicinal herbs to timber trees, intricately linked to the local economy and sustenance (Saikia et al., 2017). However, the region is facing multiple threats and biotic pressures, including shifting cultivation, grazing, forest fires, loss of pollinators, illegal extraction of forest products, diversion of forest land for developmental projects chiefly commercial monoculture plantations and establishment of new settlements (Kumar and Chaudhry, 2015; Kanwal and Lodhi, 2018). Some of which are depicted in Fig. 1. Consequently, the biodiversity of the area is under tremendous pressure, with

many species on the verge of extinction (Choudhury et al., 2007), and some disappearing even before being known to the scientific world (Myers et al., 2000; Pimm and Raven, 2000). Since the 18th century and continuing to the present day, numerous studies have been published shedding light on the bioculturally important floras and floristic diversity of the forest lands of Arunachal Pradesh (Burkill, 1924; Ward, 1929; Rao and Joseph, 1965; Chauhan et al., 1996; Hajra et al., 1996; Choudhary, 2008; Giri et al., 2008; Chowdhery et al., 2009; Choudhary et al., 2012; Ambrish, 2013). However, these studies were primarily focused on protected areas, neglecting the significance of research on unprotected plot of lands.

Recently, over 70 new taxa have been discovered in a few decades and added to the scientific world from various localities within the state, indicating an increasing rate of exploration as areas become more accessible to researchers, which was not the case earlier. Yet, the future existence of these plants remains closely tied to their specific localities. In this present study, we have provided a comprehensive checklist of all the native and endemic plants found within highly vulnerable and exploited Bage hills of Nirjuli, addressing the imperative need for conservation approaches required to safeguard areas of such ecological importance.

Methodology

Study area

Nirjuli lies between 27°7'N and 93°44'E (Fig. 2) covering an area of approximately 5 sq. km located at Papum Pare district of Arunachal Pradesh. The whole area is characterized by hilly ridges, and occasional plains, as the capital of the state Itanagar lies in the district hence, much of the forest lands have been converted into residential areas, and very small isolated patches of forests have been left interspersed as being the last left remnants of existing Itanagar Wildlife Sanctuary. The vegetation of the area is sub-tropical evergreen, deciduous and humid (Das et al., 2017). The Nyishi community, constituting a significant tribal group in the state, predominantly resides in the region and is native to the district. These individuals primarily belong to the Paleo-Mongoloid stock and communicate using the Tani language, a member of the Tibeto-Burmese language group (Toku et al., 2021).

Data collection

From April 2016 to August 2023, comprehensive data was gathered through repeated field surveys covering all seasons. The plant specimens were collected, photographed, press-dried, and mounted on herbarium sheets following Jain and Rao's standard methods (1977). Species nomenclature adhered to the references like POWO 2023 with classification according to the APG IV system. Identifications were cross-referenced with relevant literature (Kanjilal et al., 1934, Hooker 1872) and examination of herbarium specimens at ASSAM, ARUN, HAU, and virtual herbaria such as K, E and PE. Conservation status data adhered to IUCN's Red List (2020). Voucher specimens were deposited at the Herbarium of Rajiv Gandhi University, Arunachal Pradesh. Ethnobotanical information on the plants of the area was

collected through semi-structured interviews and questionnaires (Singh et al., 2019) involving 50 key informants (26 females and 24 males) from the region during the survey period of 2017–2021. The selected respondents represented diverse social roles and positions, ensuring a comprehensive assessment of local traditional knowledge.

Results and Discussion

A comprehensive survey of the area revealed a total of 156 species, distributed across 129 genera and 57 families (Table 1). Notably, 11 of these species were endemic to North East India, with four species exclusively found in the Nirjuli, yet to be reported in any other locations.

Table 1

Diversity of plants and its ethnobotanical uses in Nirjuli, Papum pare district, Arunachal Pradesh, India.

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
	IUCN Conservation status*			
Acanthaceae				
1.	<i>Pseuderanthemum arunachalense</i> D. Borah, Taram, R.Kr. Singh, DB and MT 0064	Under shrub		
2.	<i>Pseuderanthemum latifolium</i> (Vahl) B.Hansen, DB and MT4223	Under shrub		
3.	<i>Strobilanthes oxycalycina</i> J.R.I.Wood, DB and MT4060	Shrub		
4.	<i>Strobilanthes secunda</i> T.Anderson, DB and MT4061	Shrub		
5.	<i>Thunbergia coccinea</i> Wall. ex D.Don, DB and MT4232	Climber		
6.	<i>Thunbergia grandiflora</i> Roxb., DB and MT4222	Climber		
Achariaceae				
7.	<i>Gynocardia odorata</i> R.Br., DB and MT4062	Tree	Fruit, Seed	The fruits are ground into a paste, which is then employed as fish poison. The seeds are consumed after being cooked
Actinidaceae				
8.	<i>Saurauia armata</i> Kurtz, DB and MT4063*	Small tree	Fruit	The fruits are consumed fresh and are characterized by their sweet taste
Amaranthaceae				
9.	<i>Deeringia amaranthoides</i> (Lam.) Merr., DB and MT4064	Perennial herb	Leaf	Tender shoots are a common choice for vegetable dishes in the local cuisine
Annonaceae				
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
	IUCN Conservation status*			
Acanthaceae				
10.	<i>Goniothalamus sesquipetalis</i> (Colebr. ex Wall.) Hook.f. and Thomson, DB and MT4065	Undershrub		
11.	<i>Milium dioeca</i> (Roxb.) Chaowasku and Kessler, DB and MT4066	Small tree		
Apiaceae				
12.	<i>Hydrocotyle javanica</i> Thunb., DB and MT4067	Herb		
Apocynaceae				
13.	<i>Dischidia bengalensis</i> Colebr., DB and MT4068	Epiphytic herb		
14.	<i>Hoya globulosa</i> Hook.f., DB and MT4069	Epiphytic herb		
15.	<i>Hoya verticillata</i> (Vahl) G.Don, DB and MT4070	Epiphytic herb		
Araceae				
16.	<i>Colocasia fallax</i> Schott, DB and MT4006*	Perennial herb	Leaf	Leaves are a common choice for vegetable dishes in the local cuisine
17.	<i>Homalomena aromatica</i> (Spreng.) Schott, DB and MT4682	Perennial herb		
18.	<i>Pothos scandens</i> L., DB and MT4081	Epiphytic herb	Whole plant	The entire part of the plant can be utilized for healing fractured bones
19.	<i>Raphidhopora decursiva</i> (Roxb.) Schott, DB and MT4082	Epiphytic herb		
20.	<i>Steudnera assamica</i> Hook.f., DB and MT4000	Perennial herb		
Araliaceae				
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
IUCN Conservation status*				
Acanthaceae				
21.	<i>Aralia armata</i> (Wall ex.Don) Seem., DB and MT4084 *	Small tree		
22.	<i>Trevesia palmata</i> (Roxb. ex Lindl.) Vis., DB and MT4085 *	Small tree	Fruit	As a culinary tradition, the consumption of immature fruits as a vegetable is widespread in this community
Areaceae				
23.	<i>Calamus flagellum</i> Griff. Ex Walp, DB and MT4087	Climbing shrub	Shoot, Fruit, Stem	Roasted tender shoots are used to make chutney, immature fruit acts as a substitute for betel nut, matured stems function as traditional grinders, and stem fibres are employed as construction rope
24.	<i>Caryota urens</i> L., DB and MT4086 *	Tree	Stem	Matured stem is for construction of local bridge, hunting and traditional handloom equipment
25.	<i>Pinanga gracilis</i> Blume, DB and MT4046	Small tree		
26.	<i>Wallichia oblongifolia</i> Griff., DB and MT4083	Small tree	Stem, Leaf	The black fibres extracted from the stem are employed in the weaving of traditional bags known as "Tali." Additionally, the veins of the leaves find use in crafting sturdy brooms.
Aristolochiaceae				
27.	<i>Aristolochia assamica</i> D.Borah and T.V.Do, DB and MT4088	Climber		
Asparagaceae				
28.	<i>Dracaena petiolata</i> Hook.f., DB and MT4001	Undershrub		
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
IUCN Conservation status*				
Acanthaceae				
29.	<i>Peliosanthes macrophylla</i> Wall. ex Baker, DB and MT4089	Perennial herb		
Balsaminaceae				
30.	<i>Impatiens laevigata</i> Wall. ex Hook.f. and Thomson, DB and MT4132	Herb		
31.	<i>Impatiens porrecta</i> Wall. ex Hook.f. and Thomson, DB and MT4003	Herb		
32.	<i>Impatiens tripetala</i> Roxb. ex DC., DB and MT4004	Herb		
Begoniaceae				
33.	<i>Begonia burkillii</i> Dunn, DB and MT4128	Perennial herb	Leaf	Petioles are ingested raw to relieve headaches and nausea
34.	<i>Begonia griffithiana</i> (A.DC.) Warb., DB and MT4629	Perennial herb		
Campanulaceae				
35.	<i>Lobelia nummularia</i> Lam., DB and MT4130	Herb		
36.	<i>Lobelia zeylanica</i> L., DB and MT4009 *	Herb		
Cannabaceae				
37.	<i>Trema orientale</i> (L.) Blume, DB and MT4129 *	Tree		
Commelinaceae				
38.	<i>Amischotolype hookeri</i> (Hassk.) H.Hara, DB and MT4118	Perennial herb		
39.	<i>Floscopa scandens</i> Lour., DB and MT4010 *	Perennial herb		
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
	IUCN Conservation status*			
Acanthaceae				
40.	<i>Polia subumbellata</i> C.B.Clarke, DB and MT6134*	Perennial herb		
41.	<i>Rhopalephora scaberrima</i> (Blume) Faden, DB and MT4060	Herb		
Convolvulaceae				
42.	<i>Argyreia nervosa</i> (Burm.f.) Bojer, DB and MT4119	Climber		
Cornaceae				
43.	<i>Alangium chinense</i> (Lour.) Harms, DB and MT4120	Small tree		
Costaceae				
44.	<i>Hellenia speciosa</i> (J.Koenig) S.R.Dutta, DB and MT4121 *	Perennial herb		
Cucurbitaceae				
45.	<i>Hodgsonia macrocarpa</i> (Blume) Cong., DB and MT4122	Climber	Seed	Endosperm of seeds are edible
46.	<i>Solena heterophylla</i> Lour., DB and MT4123	Climber		
47.	<i>Thladiantha cordifolia</i> (Blume) Cong., DB and MT4124	Climber		
48.	<i>Zehneria japonica</i> (Thunb.) H.Y.Liu, DB and MT6134	Climber		
Dilleniaceae				
49.	<i>Dillenia indica</i> L., DB and MT4051 *	Tree	Fruit	Fruits are served as vegetable in local cuisine
Dipterocarpaceae				
50.	<i>Vatica lanceifolia</i> (Roxb.) Blume, DB and MT4522	Tree		
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
	IUCN Conservation status*			
	Acanthaceae			
	Dioscoreaceae			
51.	<i>Dioscorea pentaphylla</i> L., DB and MT4126	Climber	Bulbil	The bulbils can be consumed as food after they are cooked
52.	<i>Tacca integrifolia</i> Ker Gawl., DB and MT4127	Perennial herb		
	Euphorbiaceae			
53.	<i>Croton caudatus</i> Geiseler, DB and MT4524	Climber		
	Fabaceae			
54.	<i>Albizia lucida</i> (Jacques) Benth., DB and MT4617	Tree		
55.	<i>Dalhousiea bracteata</i> (Roxb.) Graham ex Benth, DB and MT4117	Shrub		
56.	<i>Mastersia assamica</i> Benth., DB and MT4116	Climber		
57.	<i>Mucuna interrupta</i> Gagnep., DB and MT4324	Climber		
58.	<i>Pueraria montana</i> (Lour.) Merr., DB and MT5364	Climber		
59.	<i>Senegalia rugata</i> (Lam.) Britton and Rose, DB and MT4115	Shrub	Bark	The barks are pounded into a paste, which is then utilized as fish poison
60.	<i>Smithia ciliata</i> Royle, DB and MT4646	Herb		
61.	<i>Stylosanthes hamata</i> (L.) Taub., DB and MT4546	Herb		
	Fagaceae			
62.	<i>Castanopsis indica</i> (Roxb. Ex Lindl.) A.DC., DB and MT4114 *	Tree	Seed	Seeds are edible
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
IUCN Conservation status*				
Acanthaceae				
Gesneriaceae				
63.	<i>Aeschynanthus acuminatus</i> Wall. ex A.DC, DB and MT4111	Epiphytic herb		
64.	<i>Aeschynanthus gracilis</i> C.S.P. Parish ex C.B. Clarke, DB and MT6082	Epiphytic herb		
65.	<i>Boeica arunachalensis</i> D.Borah, Taram, A.P. Das and R.Kr. Singh, DB and MT0093	Undershrub	Shoot	Tender shoots are served as vegetable in local cuisine
66.	<i>Boeica filiformis</i> C.B.Clarke, DB and MT4110	Undershrub	Shoot	Tender shoots are served as vegetable in local cuisine
67.	<i>Henckelia collegii-sancti-thomasii</i> A.Joe, D.Borah, Taram and Sandhya, DB and MT4109	Perennial herb		
68.	<i>Lysionotus serratus</i> D.Don, DB and MT4108	Epiphytic herb	Leaf	Leaves are consumed raw to alleviate stomach ache
69.	<i>Rhynchotechum ellipticum</i> (Wall. ex D.Dietr.) A.DC., DB and MT4107	Undershrub	Shoot, Fruit	Tender shoots are served a vegetable in local cuisine. The fruits are eaten raw
70.	<i>Rhynchotechum nirijuliense</i> Taram and D.Borah, MT and DB 0157	Undershrub	Shoot	Tender shoots are served a vegetable in local cuisine. The shoots can be consumed raw
71.	<i>Stauranthera umbrosa</i> (Griff.) C.B.Clarke, DB and MT4106	Perennial herb	Leaf	The leaves are first pounded, then smoked, and subsequently transformed into a paste. The paste is applied to the affected area to facilitate the healing of bruises
Hypoxidaceae				
72.	<i>Curculigo capitulata</i> (Lour.) Kuntze, DB and MT4105	Perennial herb	Fruit, Leaf	The ripe fruit is edible, while the leaves are utilized for packaging
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
	IUCN Conservation status*			
Acanthaceae				
				purposes and in various rituals
73.	<i>Curculigo prainiana</i> (Deb) Bennet and Raizada, DB and MT4591	Perennial herb	Fruit, Leaf	The ripe fruit is edible, while the leaves are utilized for packaging purposes and in various rituals
Lamiaceae				
74.	<i>Clerodendrum colebrookeanum</i> Walp., DB and MT4104	Shrub	Leaf	The leaves have properties that help reduce hypertension and are also served as vegetable in local cuisine
75.	<i>Clerodendrum japonicum</i> (Thunb.) Sweet, DB and MT4011 *	Undershrub		
76.	<i>Gomphostemma melissifolium</i> Wall. ex Benth., MT 0201	Shrub		
Lauraceae				
77.	<i>Actinodaphne obovata</i> (Nees) Blume, DB and MT4102	Tree		
78.	<i>Cinnamomum bejolghota</i> (Bucc-Ham) Sweet, DB and MT4019 *	Tree		
79.	<i>Litsea cubeba</i> (Lours.) Pers., DB and MT4101*	Tree	Fruit	Fruits are utilized as spice or served as chutney in local cuisine
80.	<i>Litsea lancifolia</i> (Roxb. ex Nees) Fern.-Vill., DB and MT4012 *	Shrub		
81.	<i>Litsea monopetala</i> (Roxb.) Pers., DB and MT4103 *	Tree		
Lythraceae				
82.	<i>Duabanga grandiflora</i> (Roxb. ex DC.) Walp., DB and	Tree		
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
	IUCN Conservation status*			
	Acanthaceae			
	MT4669			
	Malvaceae			
83.	<i>Abroma augustum</i> (L.) L.f., DB and MT4100	Small tree		
84.	<i>Sterculia striatiflora</i> Mast., DB and MT4099	Small tree		
	Magnoliaceae			
85.	<i>Magnolia hodgsonii</i> (Hook.f. and Thomson) H.Keng, DB and MT4014 *	Tree		
	Marantaceae			
86.	<i>Phrynium pubinerve</i> Blume, DB and MT4098	Perennial herb	Seed, Leaf	Seed are edible and leaves are used in packaging
87.	<i>Stachyphrynium placentarium</i> (Lour.) Clausager and Borchs., DB and MT6028	Perennial herb		
	Moraceae			
88.	<i>Artocarpus lacucha</i> Buch.Ham., DB and MT4040	Tree	Fruit	Fruits are edible and consumed raw when ripe
89.	<i>Ficus auriculata</i> Lour., DB and MT4015 *	Tree	Fruit, Leaf	Ripe fruit are edible and young leaves are served as vegetable in local cuisine
90.	<i>Ficus fulva</i> Reinw. ex Blume, DB and MT4041 *	Small tree		
91.	<i>Ficus geocarpa</i> Teijsm. ex Miq., DB and MT4042	Small tree	Fruit	Ripe fruits are edible and are consumed raw
92.	<i>Ficus hispida</i> L.f., DB and MT4016 *	Tree		
93.	<i>Ficus semicordata</i> Buch-Ham ex Sm., DB and MT4017 *	Tree	Fruit	Fruits are edible and consumed raw
	Melastomataceae			
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
	IUCN Conservation status*			
Acanthaceae				
94.	<i>Melastoma malabathricum</i> L., DB and MT4097	Shrub	Fruit	Fruits are edible and consumed raw
95.	<i>Osbeckia nepalensis</i> Hook., DB and MT4096	Shrub		
96.	<i>Osbeckia nutans</i> Wall., DB and MT4095	Undershrub		
97.	<i>Pseudodissochaeta assamica</i> (C.B.Clarke) Nayar, DB and MT4094	Shrub		
98.	<i>Sarcopyramis napalensis</i> Wall., DB and MT4093	Herb		
Menispermaceae				
99.	<i>Pericampylus glaucus</i> (Lam.) Merr., DB and MT4697	Climber		
100.	<i>Stephania japonica</i> (Thunb.) Miers, DB and MT4092	Climber		
101.	<i>Stephania rotunda</i> Lour., DB and MT4091	Climber		
Musaceae				
102.	<i>Musa balbisiana</i> Colla	Herb		
Olacaceae				
103.	<i>Erythralum scandens</i> Blume, DB and MT4043 *	Climber		
Orchidaceae				
104.	<i>Cymbidium aloifolium</i> (L.) Sw., DB and MT5021	Epiphytic herb		
105.	<i>Bulbophyllum delitescens</i> Hance, DB and MT6021	Epiphytic herb		
106.	<i>Dendrobium lituiflorum</i> Lindl., DB and MT5085	Epiphytic herb		
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
IUCN Conservation status*				
Acanthaceae				
107.	<i>Goodyera procera</i> (Ker Gawl.) Hook., DB and MT4044	Herb		
108.	<i>Papilionanthe teres</i> (Roxb.) Schltr., DB and MT5088	Epiphytic herb		
109.	<i>Spiranthes sinensis</i> (Pers.) Ames, DB and MT4002	Herb		
Phyllanthaceae				
110.	<i>Phyllanthus reticulatus</i> Poir., DB and MT4045 *	Shrub		
Piperaceae				
111.	<i>Piper pedicellatum</i> C.DC, DB and MT4023 #	Shrub	Leaf	Leaves are served as vegetable in local cuisine
Primulaceae				
112.	<i>Ardisia solanacea</i> Roxb., DB and MT4047	Shrub	Shoot, Fruit	Tender shoots are a popular vegetable in local cuisine, while ripe fruits are commonly consumed raw.
113.	<i>Maesa indica</i> (Roxb.) Sweet, DB and MT4018 *	Shrub	Shoot, Fruit	Tender shoot and fruits are consumed raw
114.	<i>Maesa macrophylla</i> (Wall.) A.DC., DB and MT4457	Shrub		
Ranunculaceae				
115.	<i>Clematis zeylanica</i> (L.) Poir., DB and MT4048	Climber		
Rosaceae				
116.	<i>Rubus acuminatus</i> Sm., DB and MT4049	Shrub	Fruit	Fruits are consumed raw
Rubiaceae				
117.	<i>Chassalia curviflora</i> (Wall.) Thwaites, DB and MT4050	Undershrub		
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
IUCN Conservation status*				
Acanthaceae				
118.	<i>Dimetia scandens</i> (Roxb.) R.J.Wang, DB and MT4125	Climber	Leaf	Leaves served as vegetable in local cuisine
119.	<i>Ixora polyantha</i> Wight, DB and MT4052	Undershrub		
120.	<i>Morinda angustifolia</i> Roxb., DB and MT4543	Undershrub		
121.	<i>Mussaenda roxburghii</i> Hook.f, DB and MT4053	Shrub		
122.	<i>Mycetia mukerjiana</i> Deb and Ratna Dutta, DB and MT4054	Undershrub		
123.	<i>Ophiorrhiza brunonis</i> Wight and Arn., DB and MT4055	Herb		
124.	<i>Ophiorrhiza lurida</i> Hook.f., DB and MT4056	Herb		
125.	<i>Ophiorrhiza pectinata</i> Arn., DB and MT4057	Herb		
126.	<i>Paederia foetida</i> L., DB and MT4058	Climber	Leaf	The leaves are utilized as a vegetable in local cuisine and are known for their effectiveness against gastrointestinal disorders
127.	<i>Spiradiclis bifida</i> Kurz, DB and MT4071	Herb		
128.	<i>Uncaria macrophylla</i> Wall., DB and MT4072	Climber		
Rutaceae				
129.	<i>Citrus medica</i> L., DB and MT4073 *	Shrub	Fruit	Fruits are consumed raw to alleviate headaches
Sabiaceae				
130.	<i>Sabia lanceolata</i> Colebr., DB and MT4075	Climber		
Salicaceae				
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
	IUCN Conservation status*			
	Acanthaceae			
131.	<i>Casearia vareca</i> Roxb., DB and MT4074	Shrub		
	Sapindaceae			
132.	<i>Allophylus chartaceus</i> (Kurz) Radlk., DB and MT4005	Undershrub		
133.	<i>Lepisanthes senegalensis</i> (Poir.) Leenh. DB and MT4695	Undershrub		
	Smilacaceae			
134.	<i>Smilax ovalifolia</i> Roxb. ex D.Don, DB and MT4076	Climber		
135.	<i>Smilax zeylanica</i> L., DB and MT4077	Climber		
	Solanaceae			
136.	<i>Lycianthes biflora</i> (Lour.) Bitter, DB and MT4677	Herb		
	Stemonaceae			
137.	<i>Stemona tuberosa</i> Lour., DB and MT4078	Climber		
	Theaceae			
138.	<i>Pyrenaria khasiana</i> var. <i>lakhimpurensis</i> Odyuo and D.K.Roy, MT 0234	Small Tree		
	Urticaceae			
139.	<i>Boehmeria penduliflora</i> Wedd. ex D.G.Long, DB and MT4079	Shrub		
140.	<i>Dendrocnide sinuata</i> (Blume) Chew, DB and MT4030	Shrub		
141.	<i>Elatostema sessile</i> J.R.Forst. and G.Forst., DB and MT4032	Herb	Shoot	Tender shoots are commonly served as a vegetable in local cuisine
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
IUCN Conservation status*				
Acanthaceae				
142.	<i>Girardinia diversifolia</i> (Link) Friis, DB and MT4633	Herb		
143.	<i>Gonostegia hirta</i> (Hassk.) Miq., DB and MT4031	Herb	Shoot	Tender shoots are commonly served as a vegetable in local cuisine
144.	<i>Poikilospermum suaveolens</i> (Blume) Merr., DB and MT4033	Climber	Shoot	Tender shoots are commonly served as a vegetable in local cuisine
145.	<i>Pouzolzia zeylanica</i> (L.) Benn., DB and MT4034	Herb	Leaf	Fresh leaves are into paste and applied on the cut wound
146.	<i>Urtica dioica</i> L., DB and MT4020 *	Herb		
Vitaceae				
147.	<i>Leea indica</i> (Burm.f.) Merr., DB and MT4021 *	Small tree		
148.	<i>Tetrastigma leucostaphylum</i> (Dennst.) Alston, DB and MT4029	Climber		
Zingiberaceae				
149.	<i>Alpinia nigra</i> (Gaertn.) Burtt, DB and MT4022 *	Perennial herb	Fruit, Leaf	Ripe fruit are consumed raw and leaves are used for packaging
150.	<i>Amomum arunachalense</i> Hareesh and M. Sabu, DB and MT4035	Perennial herb	Inflorescence	Inflorescences are served as vegetable in local cuisine
151.	<i>Amomum subulatum</i> Roxb., DB and MT4565	Perennial herb	Shoot, Fruit	Tender shoots are served as vegetable in local cuisine and fruit are consumed raw
152.	<i>Etlingera linguiformis</i> (Roxb.) R.M.Sm., DB and MT6027	Perennial herb		
153.	<i>Globba multiflora</i> Wall. ex Baker, DB and MT4037 *	Perennial herb		
*Least concern, #Vulnerable				

Sl. No.	Family, species, and collection number	Habit	Useful parts	Ethnobotanical uses
IUCN Conservation status*				
Acanthaceae				
154.	<i>Hedychium stenopetalum</i> G.Lodd., DB and MT4038	Perennial herb		
155.	<i>Hornstedtia arunachalensis</i> S.Triphathi and V.Prakash, DB and MT4039	Perennial herb	Inflorescence, Fruit	Both the inflorescence and fruits are utilized in preparing chutney
156.	<i>Larsenianthus careyanus</i> (Benth. and Hook.f.) W.J.Kress and Mood, DB and MT4028	Perennial herb		
*Least concern, #Vulnerable				

The dominant life form in the region is represented by herbs (31%, 48 species), followed by trees (19%, 30 species), climbers (17%, 27 species), shrubs (15%, 23 species), undershrubs (10%, 15 species) and epiphytic herbs (8%, 12 species). Among the families, Rubiaceae stands out with 12 species, followed by Gesneriaceae (9 species), and Zingiberaceae, Fabaceae and Urticaceae with 8 and Orchidaceae, Moraceae and Acanthaceae with 6 species each (Table 1). When considering genera, *Ficus* takes the lead with 5 species, followed by *Impatiens*, *Litsea* and *Ophiorrhiza* (3 species each) (Table 1).

Ethnobotanical uses of plants

The tribal communities of Arunachal Pradesh have a deep-rooted connection with wild edible plants in their daily lives. Out of the total 156 species, 56 have been identified as ethnobotanically useful in the region. The commonly utilized plant parts were fruits (29%), followed by tender shoots (28%) and leaves (25%). The total number of ethnobotanically useful plants in this region appeared relatively low when compared to other regions of Arunachal Pradesh, where a dominant community typically resides in a semi-urban to rural set-up (ENI, 2020). However, due to the migration of villagers to the urban centres of Nirjuli, Naharlagun, and Itanagar, a substantial portion of this indigenous knowledge is at risk. Presently, local vendors are playing a crucial role in this supply chain by imparting wild edible plant resources that are preferred by the majority of the urban population.

Among the species listed in Table 1, a few are commonly consumed as well as used and frequently found in the local markets of Nirjuli, Doimukh, Naharlagun, and Itanagar. Examples of such frequently traded species include *Clerodendrum colebrookeanum*, *Litsea cubeba*, *Dillenia indica*, *Pouzolzia zeylanica*, *Gonostegia hirta*, and *Phrynium pubinerve*.

On the other hand, several plants from the list, like *Boeica filiformis*, *Boeica arunachalensis*, *Rhynchoetechum ellipticum*, *Rhynchoetechum Nirjuliense*, *Pseudodissochaeta assamica*, *Piper*

pedicellatum, *Elatostema sessile*, *Amomum arunachalense*, and *Hornstedtia arunachalensis*, are selectively preferred by only one or two communities (Fig. 3). Due to limited demand, these plants are challenging to find in the markets as they do not fetch a reasonable price.

Nirjuli, being a relatively new settlement, is surrounded by businesses and people with jobs, reducing the dependence of the residents on the forest for food. Instead, specific collectors now gather wild edibles and sell them to the vendors who, in turn, make these products available to the public. This shift in the gathering and trading patterns reflects the changing lifestyle and economy of the region.

Threat status and assessment

The issue stems from inadequate biodiversity assessments and data collection concerning the abundance and distribution of species in the geographical area. Out of the species studied, 31 have been evaluated by the IUCN Red List, with *Piper pedicellatum* being categorized as Vulnerable, *Sterculia striatiflora* as Data Deficient, and the remaining species as Least Concern. Moreover, among the listed plants, *Pseuderanthemum arunachalense*, *Aristolochia assamica*, *Boeica arunachalensis*, *Henckelia collegii-sancti-thomasi*, *Rhynchoetechum nirjuliense*, and *Amomum arunachalense* are specifically described within this forest patch. It is worth noting that *P. arunachalense* and *A. arunachalense* have not been recorded outside this particular forest area. *A. assamica* is assessed as endangered in a separate study (Borah et al., 2019), while *B. arunachalensis*, *H. collegii-sancti-thomasi* and *R. nirjuliense* have been observed by a few workers in a few other locations, necessitating further study and confirmation, and hence they can be considered as Data Deficient.

The plant diversity of Arunachal Pradesh remains relatively balanced in both protected and non-protected areas. The accessibility of new species in unprotected regions is primarily due to their proximity to human settlements, resulting in their discovery and documentation. Conversely, protected areas are less readily available for study. Whereas, a significant portion of Arunachal Pradesh's plant species have yet to undergo evaluation for their regional or global threat status, due to the challenging terrains they inhabit. To address these issues and promote proper utilization and management of regional biodiversity, it is essential to adhere to the guidelines established by the National Biodiversity Authority in forming the Biodiversity Management Committee, which is mandated to implement the Biological Diversity Act (2002). This act introduces a new institutional structure with three tiers, facilitating decision-making on access, conservation, and commercial utilization of biological resources. By following these measures, local communities can effectively utilize bioresources while also conserving them to maintain ecological balance and sustainability. However, in the case of Nirjuli, the implementation of such measures is yet to be observed, highlighting the need for increased efforts in this area.

People's perceptions about the loss of plant diversity

A significant contributing factor to the problem is the prevailing lack of awareness among the general public regarding the importance of these plant species and the imminent threats they face. Many local communities remain insufficiently informed about these critical issues, often assuming that these plant

species can be found abundantly elsewhere in the vast forests of the state. This misconception poses a substantial obstacle to conservation efforts, as it belies the true uniqueness and ecological significance of the plant species found in these threatened microhabitats. It is imperative to convey the vital role that these plants play in maintaining ecological balance, food and nutritional security and preserving the region's biodiversity.

Mitigation through Conservation initiatives and future prospective

Currently, protected areas cover only 13.9% of the global land area, which is insufficient to accommodate the existing biodiversity. These areas also face significant pressure, making their protection more challenging. Considering this scenario, relying solely on such a small patch of land for conservation is not commonly seen as a viable option, as it contradicts complex social and economic factors tied to forest use. Moreover, there is no individual incentive for conservation among landholders, leading to a negative response and reluctance to participate in conservation strategies.

Developed countries have made early efforts to conserve private lands, but developing countries like India may miss the opportunity to do so in the long run (Kamal et al., 2015). Thus, the local scientific institutes, Universities, and concerned departments of the state should take the lead in conserving the exquisite but vanishing plant diversity of these forest areas in urban proximities. The continuous destruction of the diverse flora in the Itanagar Capital Complex region and other townships in Arunachal Pradesh underscores the need for policymakers to consider planning an ex-situ approach to conservation by establishing permanent structures such as botanic gardens or biodiversity parks, herbal gardens etc., which seems to be the most practical option for preserving the rich biodiversity of these unique microhabitats. This will not only safeguard the rich assemblage of plants but also enhance the region's aesthetic value and support research endeavours.

Conclusion

The rate of deforestation and habitat destruction in the Nirjuli has surpassed the critical point, eradicating nearly 80% of the habitats where the reported plant species were originally found. The expansion of settlements for local migrants from various districts of the state has contributed to the widespread clearing of native vegetation, causing the loss of endemic and endangered species in the region. With states like Arunachal Pradesh exhibiting substantial endemism and facing extensive habitat loss, the imperative solution to protect the plants beyond protected areas is ex-situ conservation methods.

Declarations

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Author Contribution

Dipankar Borah: conceptualization and research design
Momang Taram: field study and data collection
Millo Tasser: Contributed data
Egam Basar: Contributed data
Sumpam Tangjang: Editing and Proof reading
Tonlong Wangpan: Editing, compilation and communication

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Figures



Figure 1

Urban encroachment in biodiversity rich forest of Nirjuli, Papum pare district, Arunachal Pradesh, India

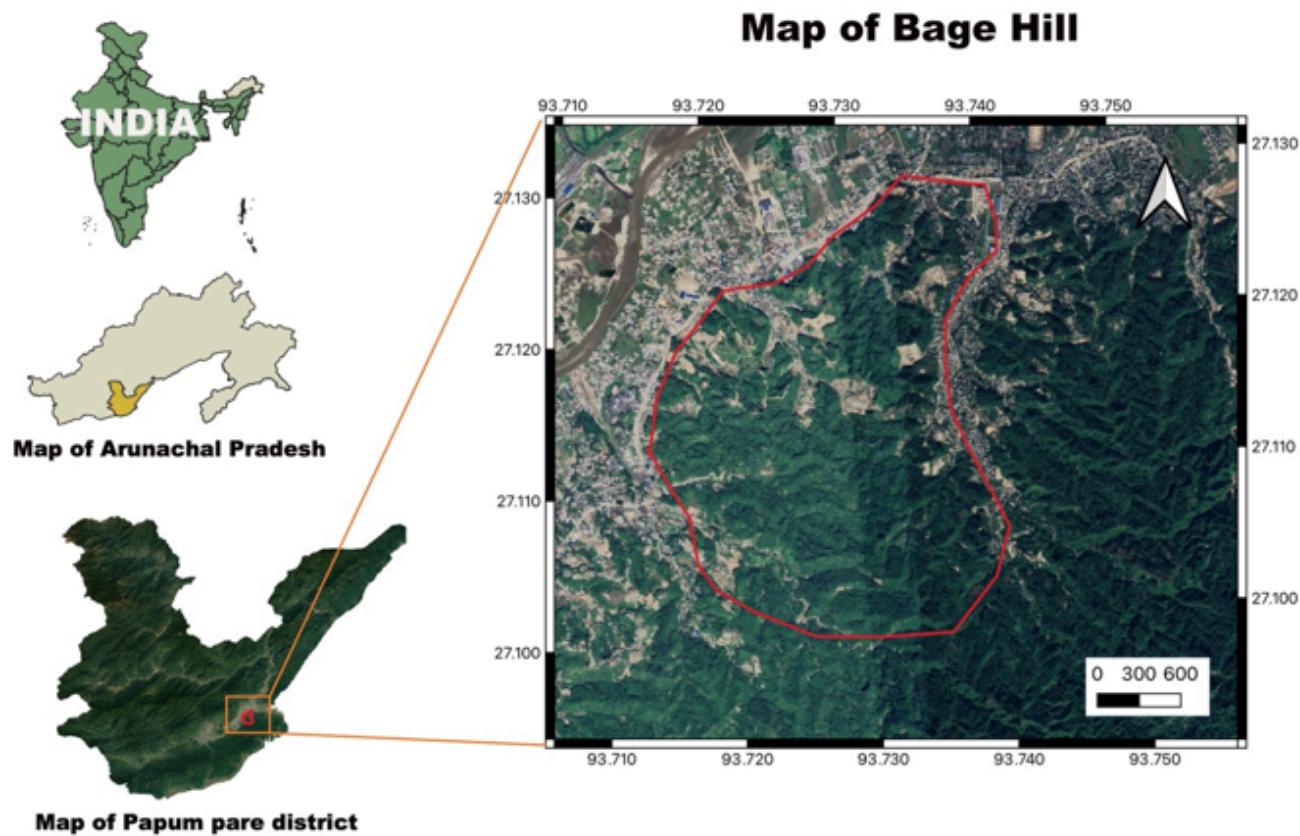


Figure 2

Map of Study area: Nirjuli, Papum pare district, Arunachal Pradesh, India



Figure 3

Some noteworthy and rare species of the forest patch of Nirjuli, Papum pare district, Arunachal Pradesh, India. A. *Amomum arunachalense*; B. *Henckelia collegii-sancti-thomasi*; C. *Peliosanthes macrophylla*; D. *Rhynchotechum nirijuliense*; E. *Goniothalamus sesquipedalis*; F. *Begonia burkillii*