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Unlocking Wild Edible Fruits of Indo-Burma Biodiversity Hot Spot, Arunachal Pradesh, India, to Support Food Security and Sustainable Rural Livelihood

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Abstract: Forests inhabit a large number of trees, shrubs, climbers, non-timber forest products and a number of wild edible fruits. These wild edible fruits are an indispensable constituent of human life and rich in vitamins, minerals, fibres, antioxidants, alkaloids, and phenolics. Many of them are good source of medicines. The present study was undertaken to document wild edible fruits of Arunachal Pradesh, India, and their socioeconomic importance in the sustainable rural economy. The study revealed that altogether 50 wild edible fruits belonging to 31 families are used against a number of ailments. They have a number of uses in the socioeconomic life of rural people such as constructional timbers, firewood, charcoal, fodder, fish poisoning, dyes, oils, etc. Although these fruits play an important role in the life of tribal people, these valuable species have been vanishing at a very fast rate. Therefore, promoting their sustainable use and increasing their abundance in different landscapes through the agroforestry system must immediately be undertaken. The claimed therapeutic values are to be critically studied and dynamic conservation of associated indigenous knowledge among local tribal communities should be carried out through policy interventions, implementation of farmer's rights, and generation of awareness among the local people. Policy makers should immediately undertake strategic plans for both in situ and ex situ conservation of wild edible fruits that have ethno-medicinal values. In addition, the orally transmitted therapeutic values of wild edible fruits should be urgently documented to safeguard these valuable species from further extinction.

Keywords: ethno-medicinal value; food security; socioeconomic importance; sustainability; wild edible fruits

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1. Introduction

Forests are an integral part of global sustainable development and provide renewable raw material, maintain biological diversity, mitigate climate change, protect land and water resources, improve air quality, and help alleviate poverty. Rural people depend on these forests to fulfil their sustainable livelihood and as a source of income for economic prosperity [1]. These forests inhabit a large number of trees, shrubs, herbs, climbers, as well as non-timber forest products including medicinal and aromatic plants and a good number of wild fruit plants. These wild fruits have been an indispensable constituent of rural people since ancient times. They still play an important role when food crops are scarce, ensuring food sovereignty and food security, and potentially contribute to wellbeing in vulnerable households [2]. It is also reported that one in six people on the planet rely on these wild fruits for their sustenance [3] and they are an open-source supply of food and nutrition [4,5]. Several studies have suggested that these fruits possess significant

biologically active compounds, antioxidants, vitamins, and minerals [6]. In addition, the presence of secondary metabolites in these plants affords them a prominent place in traditional medicinal systems [7]. Some of these fruits are reported to have comparable or even higher nutritive values than so-called commercial fruits [8,9]. Due to the presence of a sufficiently high amount of minerals and vitamins, inclusion of these fruits in daily diet can reduce the risk of a number of diseases such as diabetes, cancer and coronary heart disease [10]. In addition, incorporation of these fruits in agricultural systems can also protect biological diversity as well provide adequate food security and boost the rural economy. Moreover, the world population is expected to surpass 9 billion by 2050, boosting global food demand by 50% compared to 2013 [11]. Thus, to meet the global food demand, proper identification, documentation, enumeration, and domestication of wild edible fruits become very much necessary [12].

Northeast India is one of the agrobiodiversity hot spots in the India gene centre and is full of ethnic and traditional diversity. Arunachal Pradesh, geographically the largest state in Northeast India, is commonly known as the Orchid state of India or paradise of the botanist, which translates to "land of the dawn-lit mountains". The state has more than 26 major tribes and over 100 subtribes, with differences in their traditions and customs. The tradition, sociocultural life and custom of each tribe mostly depend on the biodiversity, forest, and wildlife of the state. The state falls within the 12 mega diversity "Hot Spots" in the world, having 20% of the species of the country's fauna, 4500 species of flowering plants, 400 species of pteridophytes, 23 species of conifers, 35 species of bamboos, 20 species of canes, 52 rhododendron species and more than 500 species of orchids [13]. Most of the people in the state mainly depend on forests to earn their livelihood. The tribal people of the state depend on forests for food, fibre, fodder, in addition to ethnomedicines of the traditional healthcare system. In addition to other edible and non-edible plants in the forests, a number of wild fruits are also present, which the tribal people have been using since ancient times against a number of diseases in the traditional healthcare system. However, knowledge of the medicinal values of wild edible fruits has been transmitted from generation to generation orally without proper documentation [14]. In many villages, these fruits also offer a source of sustainable income and livelihood security [15]. As of now, with ever increasing population pressure and shrinkage of land as well as use of forest areas for development and constructional projects, these wild fruits are on the verge of extinction. Although these fruits have been used in folk medicines of the traditional healthcare system, traditional knowledge about the ethnomedicinal uses of these fruits have been losing their intrinsic value due to lack of proper documentation [16]. Therefore, it is high time for the scientific community to safeguard these valuable natural resources of forests by domestication as well as conservation efforts [17].

Keeping all this information in view, the present research work was carried out to enumerate the ethnomedicinal uses of the wild fruits in Arunachal Pradesh, India as well as of these fruits in the socioeconomic life of rural people.

2. Materials and Methods

Study Area

The present research was carried out to document the ethnomedicinal uses of wild fruits in the East Siang, Upper Siang, West Siang, and Lower Dibang valley districts of Arunachal Pradesh, India (Figure 1) in the traditional healthcare system of rural people as well as the uses of these species in the socioeconomic life of rural people. The study consists of survey, collection, identification, and enumeration of the species. The preliminary survey and collection of the wild edible fruits was conducted during 2017–2019. The method for the field work was followed as suggested by [18–20]. Questionnaires were prepared, and personal interviews were taken with the traditional healers of rural villages to collect the information about the ethnomedicinal uses of the fruits among rural people by following standard guidelines. A total of 38 individuals from 22 villages among different age groups (45–68 years) identified with the help of local administrators and community leaders were

interviewed. Information on wild edible fruits, parts used and ethnomedicinal values against different kinds of diseases, methods of preparation, dosages, and durations of treatment were collected. The collected specimens were identified with the help of the literature and by using various floras and monographs including regional flora, the data collected were compared and cross checked with other recommended literature [21–23], and after proper identification, the plant specimens were processed and dried and herbarium specimens were prepared. Voucher specimens of the collected plant species were deposited in the department of Horticulture, Aromatic and Medicinal Plants, Mizoram University.

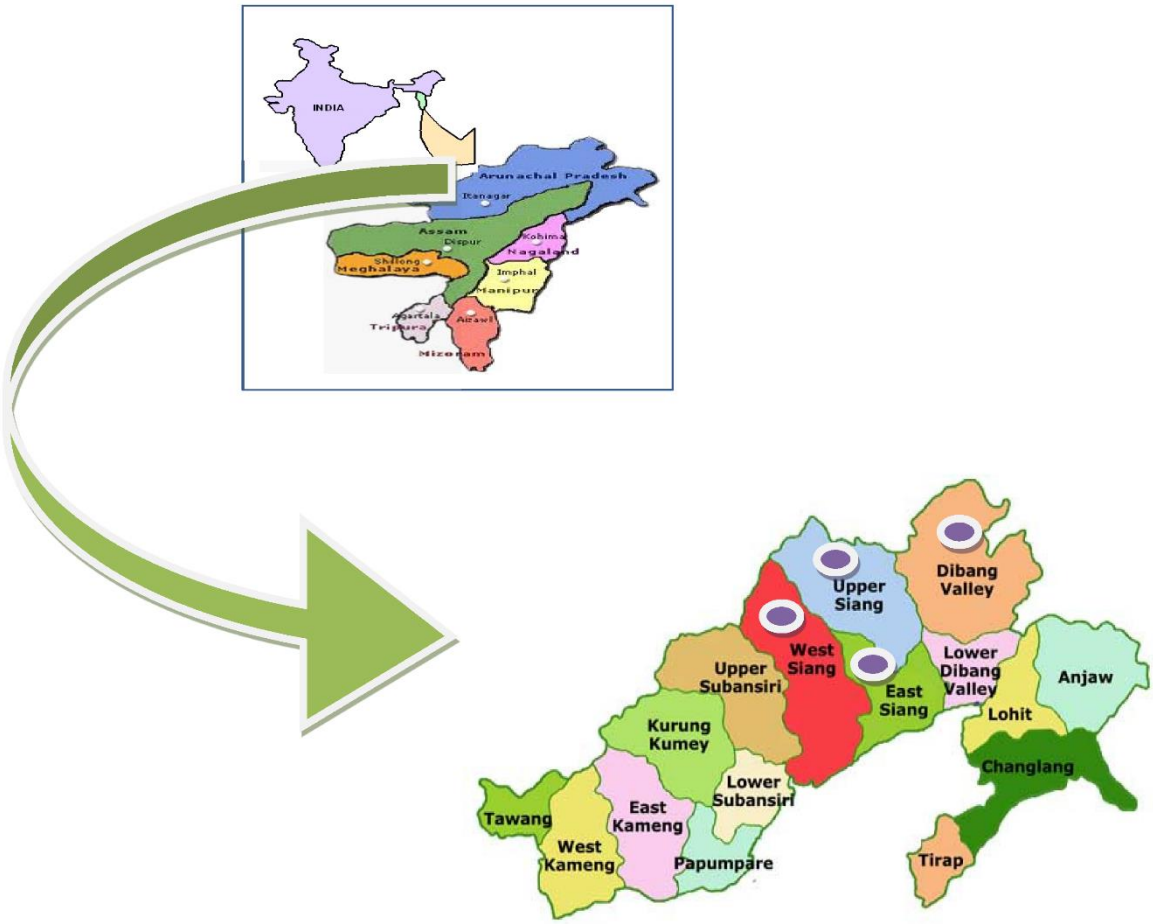

Figure 1. Map of Arunachal Pradesh showing the study area.

Regarding the use of these fruits in the socioeconomic life of rural people, such as constructional timber, firewood, charcoal, fodder, dye, etc., people of different age groups were interviewed with the help of prepared questionnaires. Market surveys were conducted at rural markets and sellers were asked about market price, demand, season of availability, etc.

3. Results and Discussion

3.1. Ethnomedicinal Evaluation

From the results of the present investigation, it is clear that a total of 50 wild edible fruits having ethnomedicinal uses exist (Figure 2). These fruits are represented by 31 families of which Moraceae and Rutaceae had the highest with five species, followed by Phyllantaceae with four species, Anacardiaceae and Rosaceae with three species, Arecaceae, Fabaceae, Fagaceae, Lauraceae, and Primulaceae each with two species and the rest were one all species each.

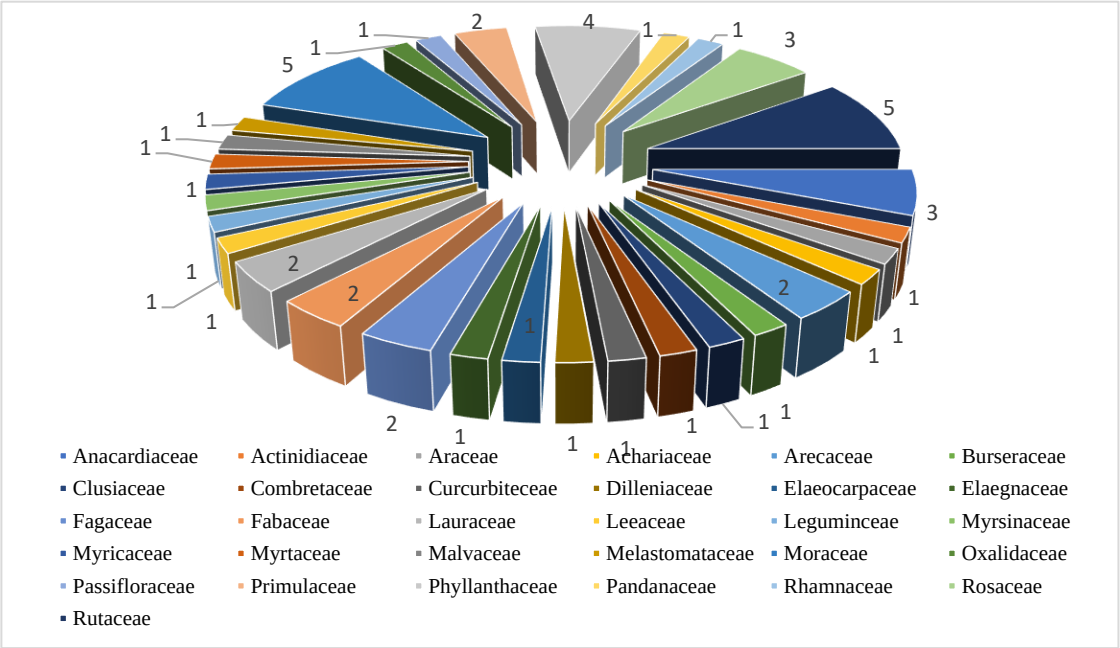

Figure 2. Family wise representation of wild edible fruits of Arunachal Pradesh, India.

The uses of wild edible fruits of Arunachal Pradesh, India in the traditional healthcare system of rural people presented in Table 1.

Table 1. Ethnomedicinal uses of wild edible fruits of Arunachal Pradesh, India.

Sl. No.	Fruit Used	Vernacular Name	Family	Diseases	Part Used	Formulation
1	*Artocarpus heterophyllus.* Lam	Belang	Moraceae	Skin disease, ringworm infestation, cracking of feet	Roots, latex, leaves	(i) Latex from the stem is collected and applied in skin diseases. (ii) Paste made from leaves is applied externally against ringworm and cracking of feet.
2	*Ardisia crenata* Sims.	So-Bumlo	Myrsinaceae	Skin disease	Leaf	(i) Leaves are crushed, the juice extracted and used against skin diseases such as acne.
3	*Averrhoa carambola* L.	Tador	Oxalidaceae	Chicken pox, ringworms, fever, throat inflammation	Leaves, seed, fruits	(i) Leaves are crushed and are externally applied against chicken pox, ringworm infestation. (ii) The juice of ripe fruits is ingested to provide relief from fever and throat inflammation.
4	*Antidesma bunius* (L.) Spreng.	Kompong-Perong	Phyllanthaceae	Indigestion, cough, stomach-ache, insomnia	Bark, leaves, fruits	(i) Bark and leaf extracts are ingested orally for treatment of cough, indigestion, and stomach-ache. (ii) Fruit juice is used against insomnia.
5	*Bischofia javanica* Blume	Sitiil	Phyllanthaceae	Cholera, skin diseases	Leaves, bark	(i) Decoction of bark is taken internally for the treatment of cholera. (ii) The leaves are ground and applied externally on the affected part of skin to cure eczema.
6	*Bauhinia variegate* L.	Ogok	Fabaceae	Stomach-ache, diarrhoea, dysentery	Leaves, flower	(i) The juice of the flower is drunken against diarrhoea and dysentery. (ii) The leaves are boiled or chewed raw against stomach-ache.
7	*Baccaurea ramiflora* Lour.	Bureng	Phyllanthaceae	Constipation	Bark, fruit	(i) Fresh bark is chewed, or fruit juice is taken orally against constipation.
8	*Castanopsis hystrix* Hook. f. & Thomson ex A. DC.	Sirang-Raaye	Fagaceae	Chest pain	Bark	(i) Bark paste is applied on the chest to control chest pain.
9	*Calamus tenuis* Roxb	Esong	Arecaceae	Stomach disorder	Shoot	(i) Young shoots are consumed raw for stomach disorder.

Table 1. *Cont.*

Sl. No.	Fruit Used	Vernacular Name	Family	Diseases	Part Used	Formulation
10	*Castanopsis indica* Roxb	Koyu -Korang Raaye	Fagaceae	Stomach disorder, skin disease, indigestion, headache	Leaves, bark	(i) Decoction of leaves is applied against stomach disorder and skin diseases such as warts and acne. (ii) Powdered leaves are mixed with water and administered to cure indigestion. (iii) Paste prepared from the leaves is applied against headache.
11	*Citrus grandis* (L.)	Rebab	Rutaceae	Swelling, constipation	Fruit, Leaf	(i) Hot leaf decoctions are made and applied externally to swelling area. ii) Fruit juice is used against constipation.
12	*Citrus medica* L	Sipa-Yegra	Rutaceae	Constipation, backpain	Root, Leaves	(i) Root decoction is applied externally for back pain. (ii) Fruit juice is used against constipation.
13	*Citrus limon* Burm.f	Singkom	Rutaceae	Dysentery, cuts, indigestion	Fruit, leaves and stem	(i) Bark of fruits and leaves are chewed raw and applied externally on cuts and wounds. (ii) Fruit is used against indigestion and dysentery.
14	*Canarium strictum* Roxb	Hilum/Tikok	Burseraceae	Insect bite, Fever, cough, chicken pox	Bark, Leaf	(i) Juice extracted from bark is used against insect bites. (ii) Bark and resin are burnt around the household for the prevention of chicken pox.
15	*Dillenia indica* L.	Sompa	Dilleniaceae	Dysentery, diarrhoea, Fever	Fruits, Leaf	(i) The fruits are a tonic; taken orally against dysentery and diarrhoea. (ii) Fruit juice is used as a cooling beverage against fever. (iii) Leaves are directly consumed for treatment of dysentery.
16	*Epipremnum pinnatum* (L.) Engl.	Talo	Araceae	Fracture, chest pain	Leaves	(i) Decoction of leaf paste is applied externally to cure fracture and chest pain.
17	*Elaeagnus latifolia* L.	Raapgam	Elaeagnaceae	Anaemia	Roots, leaf	(i) Fruit's juice is used against anaemia.
18	*Emblica officinalis* G.	Amloki	Phyllanthaceae	Scurvy	Fruits	(i) Fruits are used against the opening of previously healed wounds.
19	*Elaeocarpus floribundus* Blume.	Jolpai	Leguminoceae	Inflamed gums	Leaves, bark	(i) Infusion of bark and leaves is used as mouthwash against inflamed gums.
20	*Entada pursaetha* DC.	Pyopa	Elaeocarpaceae	Fever, cold	Bark, leaves	(i) Bark powders are used against fever. (ii) The leaf juice is ingested orally to cure common colds.
21	*Ficus auriculata* Lour.	Tapang	Moraceae	Diarrhoea, dysentery, cuts, wounds, vomiting, cholera	Stem, fruits	(i) The fruits are roasted and used to cure diarrhoea and dysentery. (ii) The stem's latex is widely used in cuts and wounds.
22	*Ficus semicordata* Buch.-Ham	Takuk	Moraceae	Boils, constipation, headache, indigestion	Latex, fruits, leaf, root	(i) Latex is directly applied to boils. (ii) Fruit's juice is drunken for headache. (iii) Leave and root juice are used against constipation and indigestion.
23	*Ficus hirta* Reinw.ex Blume	Siipop	Moraceae	General weakness	Root	(i) The extracted root juice is drunken for the treatment of body weakness.
24	*Garcinia cowa* Roxb	Tabi-Tarak	Clusiaceae	Dysentery, fever, constipation	Fruits	(i) Fruit is cut into slices, sundried, and are used against dysentery and fever.
25	*Gynocardia odorata* Roxb.	Sibeng-Tulpii	Achariaceae	Sprains, skin diseases, jaundice	Seeds, young shoot	(i) Seeds are crushed and oil is extracted, which is applied externally in the treatment of acne and sprains. (ii) Young shoots are grinded and the juice is drunken to combat jaundice.
26	*Melastoma malabathricum* L.	Kesi-Yayi	Melastomataceae	Dysentery, diarrhoea, cuts, wounds	Leaves	(i) Decoction of leaves is orally ingested in treatment of dysentery and diarrhoea. (ii) Leaves are chewed raw and applied to cuts and wounds.
27	*Myrica esculenta* Buch.-Ham	Ketir	Myricaceae	Diarrhoea	Bark, flower	(i) Decoction of bark and flower are drunken to treat diarrhoea
28	*Morus alba* L.	Eeyum-Tayin	Moraceae	Fever	Leaves	(i) Decoction of leaves used against fever.
29	*Maesa japonica* (Thunb.) Moritzi & Zoll.	Ko-Kebung	Primulaceae	Itching	Leaves	(i) Leaf paste is applied externally to cure itch.
30	*Mangifera sylvatica* Roxb	Monaam-Tagung	Anacardiaceae	Diarrhoea	Seed	(i) Kernels make powder and are mixed with water and drunken to treat diarrhoea.
31	*Litsea cubeba* (Lour.) Pers.	Raayil	Lauraceae	Cough, Indigestion	Seed	(i) Seeds are eaten raw to promote digestion and to treat coughs.
32	*Livistona jenkinsiana* Griff.	Taek	Arecaceae	Stomach ailment	Seed, fruits	(i) Seeds and fruits are used to cure some stomach ailments.
33	*Leea indica* (Burm.f.) Merr.	Talu	Leeaceae	Dysentery, fever, headache, sprain	Leaves, roots	(i) The leaf's juice is taken orally to treat dysentery and mild fever. (ii) A paste of leaves and roots is externally applied to treat headache, sprain, etc. (iii) A decoction of the leaf is consumed by women during pregnancy to control bodily pain.
34	*Phoebe cooperiana* P. C. Kanj. & Das	Tapil	Lauraceae	Itching	Bark	(i) Bark paste is applied externally to cure itch.
35	*Passiflora edulis* Sims.	Marsang-Riiyong	Passifloraceae	Dysentery, constipation	Leaves, fruits	(i) Leaves are boiled and the extract is drunken against dysentery. (ii) Fruits are eaten raw for relief from constipation.

Table 1. *Cont.*

Sl. No.	Fruit Used	Vernacular Name	Family	Diseases	Part Used	Formulation
36	*Pandanus odoratissimus* L.	Taku	Pandanaceae	Skin diseases	Leaf	(i) Paste of the leaves is externally applied on skin diseases such as warts ringworm.
37	*Rhus chinensis* Mill.	Tagmo	Anacardiaceae	Cough, fever, dysentery	Fruit, leaf	(i) Fruits are mixed with common salt and soaked in water, which are eaten and drunken to cure indigestion. (ii) Decoction of leaves is used against dysentery.
38	*Rubus calycinoides* Hayata ex KoidZ.	Pasi-Payi	Rosaceae	Wound	Leaf	(i) Crushed leaves are applied externally for wounds.
39	*Rubus ellipticus* Smith.	Tayin	Rosaceae	Gastric, fever, wound, dysentery	Fruit, roots, young shoot	(i) A paste of the roots is applied externally to treat wounds. (ii) Juice of the root is taken to treat gastric problems, fever, and dysentery.
40	*Rubus niveus* Thunb.	Inmin-Tayin	Rosaceae	Dysentery	Fruits, roots	(i) The juice of the fruits and the roots are taken for the treatment of dysentery.
41	*Saurauia roxburghii* Wall.	Taan	Actinidiaceae	Fever, boils	Leaves, Bark	(i) Decoction of bark is orally administered for fever. (ii) Infusion of leaves is used to treat boils.
42	*Syzygium cumini* Lam.	Jongkeng	Myrtaceae	Dysentery, diarrhoea,	Bark	(i) Decoction of bark is used to treat dysentery.
43	*Spondias pinnata* Kurz	Belum/Dorgeng	Anacardiaceae	Cough, joints pain, diarrhoea, sour throat	Leaves, fruits, bark	(i) Paste of the bark is used externally in joint pain. (ii) Decoction of bark is administered for severe coughs. (iii) Unripe fruits are consumed for sore throat. (iv) Juice of leaves is used for common cough remedy, diarrhoea, etc.
44	*Sterculia lanceifolia* Roxb	Aanggom-Bayom	Malvaceae	Fever	Pod	(i) Pod decoction is administered to cure fever.
45	*Trichosanthes dunniana* Levl.	Pak-Sung gal	Cucurbitaceae	Wound, Diarrhoea	Fruits	(i) Fruit juice is extracted and drunken to cure diarrhoea.
46	*Terminalia citrina* Roxb.ex	Hilika	Combretaceae	Fever, stomach aches, kidney problem	Seed, bark, fruits	(i) Decoction of bark is ingested orally for kidney problems. (ii) Fruit is directly consumed for stomach-aches.
47	*Tamarindus indica* L.	Imli	Fabaceae Fabaceae	Cough, cold, asthma, Fever	Fruits, leaf, Bark	(i) Decoction of bark is used for asthma. (ii) The decoction of leaves is used against cough and fever. (iii) Leaves are made into paste and applied externally for joint pains.
48	*Zanthoxylum rhetsa* (Roxb) DC.	Onger	Rutaceae	Wart, jaundice, stomach pain, snake bite, asthma, toothache	Bark, leaves, seeds, fruits	(i) Bark pounded and mixed with oil, used externally as remedy for stomach pains. (ii) Leaves are boiled for the treatment of jaundice and warts. (iii) Bark is chewed and applied to snake bites. (iv) The paste of the seed is used to treat asthma, toothache.
49	*Zanthoxylum armatum* DC.	Ombey	Rutaceae	Cuts, wounds, stomach pain	Leaves, bark	(i) A paste of the leaves is applied externally to cuts and wounds. (ii) An infusion of the leaves is drunken to relieve stomach pains.
50	*Ziziphus mauritiana* Lam.	Bogori	Rhamnaceae	Fever, old wounds, indigestion	Bark, root, fruits	(i) The roots are dried and make powder that is very effective in the case of fevers and old wounds. (ii) Fruits are mixed with salt and chilli peppers. Fruits are consumed as a digestant. (iii) Decoction of roots is also good for treatment for fever.

The data regarding the uses of different parts of the wild fruits plants in the traditional healthcare system are presented in Figure 3. The figure reveals that among the different plant parts, the most abundant part used was the leaf with 33 uses (35.48%), followed by fruits and bark with 20 (21.51%), roots with 10 (10.75%), seeds 7 (7.53%), latex 2 (2.15%) and shoot with 1 use (1.08%).

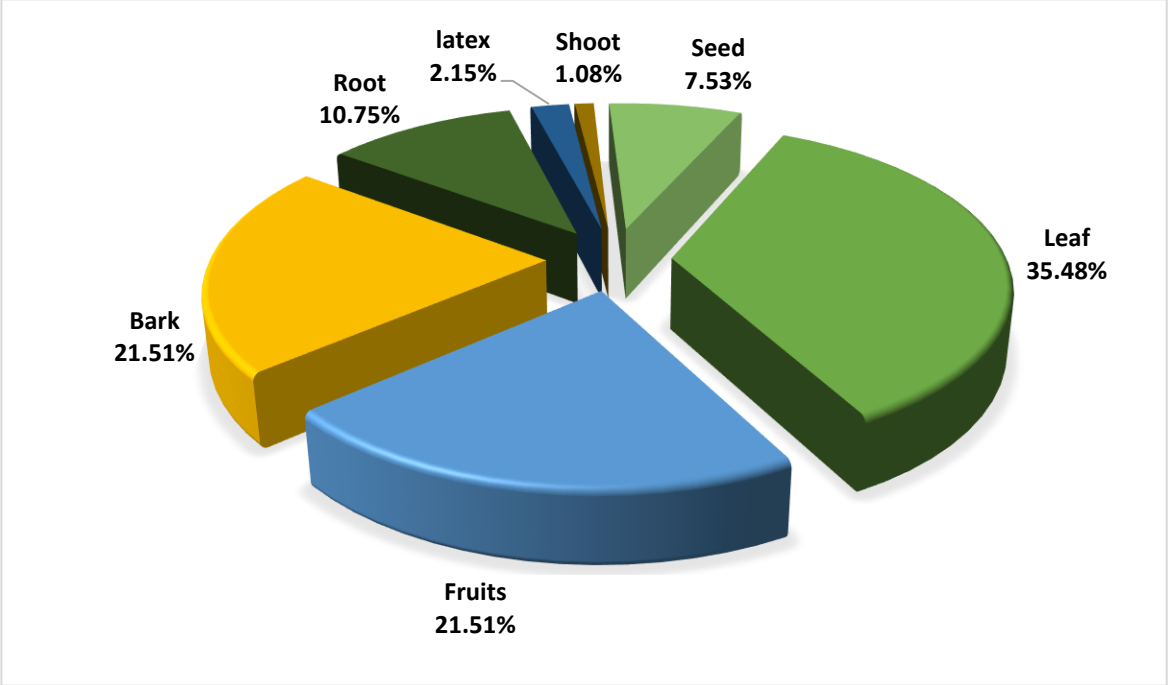

Figure 3. Parts used percentage of wild edible fruits.

The therapeutic classification of wild fruits is presented in Table 2. The data presented in the table reveals that most of the wild fruits have ethnomedicinal uses in the traditional healthcare system of tribal people in Arunachal Pradesh, India. Among the different species studied in the present investigation, the greatest number of species were used in gastrointestinal disorders (31 spp.), followed by allergies (18 spp.), dermatological problems (7 spp.), respiratory ailments (7 spp.), minor ailments (5 spp.), cardiovascular disorders, mental and nervous disorders (4 spp. each), jaundice (3 spp.), ENT, antivenom/insect bites/stings/snake bites, bone diseases, food poisoning (2 spp. each), and urogenital problems and cancers (1 sp. each).

Table 2. Therapeutic categorization of wild edible fruits.

Classes of Disease	Fruits Used
Dermatological problems	*Artocarpus heterophyllus, Ardisia crenata, Averrhoa carambola, Bischofia javanica, Castanopsis indica, Gynocardia odorata, Pandanus odoratissimus.*
Gastrointestinal disorders	*Averrhoa carambola, Antidesma bunius, Bischofia javanica, Bauhinia variegate, Baccaurea ramiflora, Calamus tenuis, Castanopsis indica, Citrus grandis, Citus medica, Citrus limon, Dillenia indica, Ficus auriculata, Ficus semicordata, Garcinia cowa, Melastoma malabathricum, Myrica esculenta, Mangifera sylvatica, Litsea cubeba, Livistona jenkinsiana, Leea indica, Passiflora edulis, Rhus chinensis, Rubus ellipticus, Rubus niveus, Syzygium cumini, Spondias pinnata, Trichosanthes dunniana, Terminalia citrina, Zanthoxylum rhetsa, Zanthoxylum armatum, Ziziphus mauritiana.*

Table 2. *Cont.*

Classes of Disease	Fruits Used
Cardiovascular disorders	*Castanopsis hystrix, Epipremnum pinnatum, Elaegnus latifolia, Zanthoxylum rhetsa.*
Respiratory problems	*Averrhoa carambola, Bischofia javanica, Canarium strictum, Litsea cubeba, Rhus chinensis, Tamarindus indica, Zanthoxylum rhetsa.*
Urogenital problems	*Terminalia citrina.*
ENT diseases	*Ficus glomerata, Averrhoa carambola.*
Antivenom/insectbites/stings/snake bites	*Canarium strictum, Zanthoxylum rhetsa.*
Mental and nervousdisorders	*Bischofia javanica, Entada pursaetha, Ficus hirta, Tamarindus indica.*
Minor ailments	*Antidesma bunius, Bischofia javanica, Bauhinia variegate, Baccaurea ramiflora, Castanopsis indica.*
Bone diseases	*Epipremnum pinnatum, Leea indica.*
Allergies	*Averrhoa carambola, Antidesma bunius, Bischofia javanica, Castanopsis indica, Canarium strictum, Dillenia indica, Entada pursaetha, Ficus auriculata, Ficus semicordata, Garcinia cowa, Morus alba, Maesa japonica, Leea indica, Phoebe coperiana, Rhus chinensis, Suarauia roxburghii, Tamarindus indica, Ziziphus mauritiana.*
Cancers	*Melastoma malabathricum.*
Food Poisoning	*Citrus medica, Garcinia cowa.*
Jaundice	*Gynocardia odorata.*

3.2. Socio Economic Characterisation

3.2.1. Plants for Timber, Fodder, and Other Miscellaneous Purposes

Table 3 reveals the data regarding the socioeconomic uses of wild fruits of Arunachal Pradesh, India for constructional timber, firewood, charcoal, and fodder. In the state, most of the houses in the villages are made of wood and each household depends on trees available in forests or home gardens to construct their houses. Some of the wild fruit trees produce very good timbers for construction of houses in the villages. Among the different species of fruits, *Phoebe cooperiana* produces the best quality timber. In addition, timbers of *Castanopsis hystrix, Syzygium cumini, Spondias pinnata*, and *Terminalia citrina* are extensively used by the tribal people of the state. Moreover, timbers made from *Saurauia roxburghii, Castanopsis indica*, and *Canarium strictum* are moderately used by rural people for constructional works.

In addition to use as constructional timbers as well as for making furniture, in the villages that are far from the city, people still cook their daily meals as well as pig feed with firewood. Since each and every family have a good number of pigs, they need a sufficient quantity of firewood every day to prepare pig feed. In villages, a significant quantity of firewood is consumed (4000–6000 kg/family/year). During the daytime, the men and women go to nearby forests and their home gardens to collect firewood. In addition to other forest trees, wild fruits are also a very good source of firewood. Fruits such as *Castanopsis hystrix, Castanopsis indica*, and *Saurauia roxburghii* produce the best quality firewood. *Bischofia javanica* and *Syzygium cumini* also produce very good quality firewood extensively used by rural people.

The livelihood of rural people still depends on domestic animals. Each and every household has different types of domestic animals including cows and goats. All these animals need fodder every day. Average fodder needed per family varies around 5000–8000 kg per year and these fodders come from agricultural fields, agroforestry trees and agricultural by-products. The leaves of wild fruits serve the purpose of fodder of each family. The leaves of *Artocarpus heterophyllus*, *Ficus auriculata*, and *Ficus semicordata* are very good fodder for these domestic animals.

Table 3. Wild edible fruit tree species used for constructional timbers (CT), firewood (FW), charcoal (C) and fodder (F).

Plant Species	Family	Local Name	CT	FW	C	F
Artocarpus heterophyllus. Lam.	Moraceae	Belang	+	++	+	++++
Antidesma bunius (L.) spreng.	Phyllanthaceae	Kompong –Perong	-	++	-	+
Bischofia javanica Blume.	Phyllanthaceae	Sitiil	+	+++	+	-
Bauhinia variegate L.	Fabaceae	Ogok	-	++	-	-
Baccaurea ramiflora Lour.	Phyllanthaceae	Bureng	-	+	-	+
Castanopsis hystrix Hook. f.& Thompson ex A.DC.	Fagaceae	Sirang-Raaye	++	++++	++++	-
Castanopsis indica Roxb	Fagaceae	Koyu-Korang	++	++++	++++	-
Canarium strictum Roxb	Burseraceae	Hilum/Tiikok	++	+	+	-
Dillenia indica L.	Dilleniaceae	Sompa	+	++	+	-
Elaeocarpus floribundus Blume.	Elaeocarpaceae	Jolpai	-	++	+	-
Ficus auriculata Lour.	Moraceae	Tapang	-	+	+	++++
Ficus semicordata Buch-Ham.	Moraceae	Takuk	-	+	+	++++
Gynocardia odorata Roxb	Achariaceae	Sibeng-Tulpii	-	+	+	-
Phoebe cooperiana PC Kan-jilal and Das.	Lauraceae	Tapil	++++	++	++	-
Saurauia roxburghii Wall.	Actinidiaceae	Taan	+++	++++	+++	-
Syzygium cumini Lam.	Myrtaceae	Jongkeng	+++	+++	++++	-
Spondias pinnata (L.f) Kurz	Anacardiaceae	Belum/Dorgeng	+++	++	++	-
Sterculia lanceifolia Roxb	Malvaceae	Aanggom-Bayom	+	++	+	-
Terminalia citrina Roxb.ex	Combretaceae	Hilika	+++	++	++	-
Tamarindus indica L.	Fabaceae	Imli	-	++	++	-
Ziziphus mauritiana Lam.	Rhamnaceae	Bogori	-	++	++	-

+ = fairly used; ++ = moderately used; +++ = extensively used; ++++ = best quality and - = not used.

People in this region still also use charcoal for different purposes such as for cooking and other needs. Some families even earn their livelihood by selling charcoal prepared from different trees. Fruit trees such as *Tamarindus indica*, *Syzygium cuminii*, *Castanopsis hystrix,* and *Castanopsis indica* produce the best quality charcoal used by rural people for various purposes.

3.2.2. Plants for Fish Poisoning

Arunachal Pradesh is a state that is crisscrossed by numerous rivers, riverine, and streams. Most of the villagers in rural areas generate their income by selling the fishes collected from the rivers. A good number of wild fruits have been used by rural people to catch fishes (Table 4). The freshly crushed or powered plant component is put into running streams and the toxic chemicals present in the plant kills the fishes present in the rivers. The quantities of plant material applied vary from species to species. Fruit species such as *Gynocardia odorata*, *Myrica esculenta*, and *Zanthoxylum rhetsa* were extensively used as fish poison. These species are mainly used to catch small-sized fishes in rivers as well as small streams and ponds. It is reported that chemicals present in the fruits affect the respiratory system of fishes [24]; however, there is no report available on the effect of such poisoning on the flesh quality of fish.

Table 4. Wild fruits used for Fish poisoning.

Plant Species	Family	Local Name	Part Used
Gynocardia odorata Roxb	Achariaceae	Sibeng-Tulpii	Fruit
Myrica esculenta Buch-Ham.	Myricaceae	Ketir	Bark
Zanthoxylum rhetsa (Roxb) DC.	Rutaceae	Onger	Bark, leaves

3.2.3. Wild Fruits for Making Dyes

The handicraft industry of Arunachal Pradesh is very rich. The rural people mostly prepare handicrafts by using locally available materials. Some wild fruits in Arunachal Pradesh are also used for making dyes used in the local handicraft industries to colour traditional dresses of men and women (Table 5). The colour of such dyes has no negative effects on health and is long lasting. Wild fruits such as *Baccurea ramiflora Bischofia javanica, Garcinia cowa, Myrica esculenta*, and *Ziziphus mauritiana* produce very good-quality dyes used by rural people to make dyes in the handicraft industry.

Table 5. Wild plant species used as dyes.

Plant Species	Family	Local Name	Part Used
Baccurea ramiflora Lour.	Phyllantaceae	Bureng	Bark, Leaves
Bischofia javanica Blume.	Phyllanthaceae	Sitiil	Bark
Garcinia cowa Roxb	Clusiaceae	Tabi-Tarak	Bark
Myrica esculenta Buch-Ham.	Myricaceae	Ketir	Bark
Ziziphus mauritiana Lam.	Rhamnaceae	Bogori	Bark

3.2.4. Wild Fruits and Their Value-Added Products

A large number of wild fruits are borne from the trees and most of the household have 2–3 wild fruit trees of. Because of this reason, during the peak season of fruiting, wild fruits are available in glut in the villages. Additionally, due to less market demand for raw fruits, most of them spoil during their fruiting season. To get rid of this problem, a number of value-added products can be prepared from these fruits and thus can save them from spoilage, and additionally the farmer can earn extra income. Table 6 represents the various value-added products prepared from the wild fruits of Arunachal Pradesh, India.

Table 6. Locally prepared value-added products.

Plant Species	Food/Beverages	Local Name	Part Used	Preparation
Artocarpus heterophyllus Lam.	Pickle	Belang	Fruit	Unripe fruits are sliced into pieces and mixed with spices, oil, and vinegar
Dillenia indica L.	Pickle	Sibeng-Tulpi	Fruit	Ripe or unripe fruits are sliced into pieces and mixed with spices, oil, and vinegar.
Elaeocarpus floribundus Blume.	Pickle	Jolpai	Fruit	Fruits are cut into pieces and mixed with spices, oil, and vinegar.
Mangifera sylvatica Roxb	Pickle	Moonam-Tagung	Fruit	Unripe fruits are sliced into pieces and mixed with spices, oil, and vinegar
Emblica officinalis G.	Pickle	Amloki	Fruit	Fruits are boiled, dried, and mixed with spices, oil, and vinegar.
Ziziphus mauritiana Lam.	Pickle	Bogori	Fruit	Ripe fruits are boiled and mixed with spices, oil, and vinegar.
Tamarindus indica L.	Pickle	Imli	Fruit	Unripe pods are mixed with spices, oil, and vinegar.
Bischofia javanica Blume.	Wine	Sitiil	Fruit	Fruits are mixed with sugar and kept in an airtight container and fermented for 1 month.

3.2.5. Miscellaneous Uses of Wild Edible Fruits

Table 7 depicts that most of the wild fruits have miscellaneous uses. Rural people use different plant parts of these fruits in their day-to-day life for various purposes. Leaves of *Livistona jenkinsiana* are used in making roofs of houses, which is a good replacement for thatch. Similarly, leaves of *Saurauia roxburghii* are used for some local ritual purposes. Wood of *Phoebe cooperiana* and *Artocarpus heterophyllus* is used for making homemade furniture.

Phoebe cooperiana is used to make wooden containers that are generally used for the feeding of pigs and cows.

Table 7. Wild plants of miscellaneous use.

Plant Species	Family	Local Name	Uses
Livistona jenkinsiana Griff.	Arecaceae	Taek	Leaves for making roofs of homes.
Saurauia roxburghii	Actinidiaceae	Taan	Leaves for ritual purposes.
Artocarpus heterophyllus Lam.	Moraceae	Belang	Wood used for making furniture.
Phoebe cooperiana PC Kanjilal and Das.	Lauraceae	Tapil	Wood used for furniture and containers.

3.2.6. Marketing Status of Wild Fruits

In Arunachal Pradesh, among 3–4 villages there is one local market or rural *hat* (a place used to sell various items by the owner). Rural people sell and buy their paddy, home garden produce, and other essential needs in these markets. Most of these *hats* are weekly. Observations were taken at five important local markets (*hats*) in the East Siang and Upper Siang districts to ascertain the availability and market prices of wild edible species (Table 8). A weekly survey revealed the simultaneous availability of an individual species in two markets; however, market prices varied between markets. In general, the wild fruits are collected by the rural men and women one day before market day from the forests as well as from home gardens and bring them to market by themselves or sell them through middlemen. Most of the fruits have good demand in the rural *hats*, which people buy either to consume raw or to produce value-added products. The availability of these fruits varies from fruit to fruit and their market price also varies from INR 20 to 40 per kg (USD 0.125–0.25 per pound) depending upon the type of fruit. Interviews with shop owners revealed that the availability of wild fruits has decreased compared to previous years.

Table 8. Some wild edible fruits available at the weekly markets.

Plant Species	Local Name	Time of Availability	Price/kg
Artocarpus heterophyllus Lam.	Belang	June–September	INR 20/-
Averrhoa carambola L.	Tador	Nov–January	INR 40/-
Baccaurea ramiflora Lour.	Bureng	June–August	INR 30/-
Canarium strictum Roxb	Hilum/Tiikok	November–January	INR 40/-
Citrus grandis (L.)	Rebab	June–December	INR 20/-
Citrus medica L	Sipa-yegra	June–September	INR 20/-
Citrus limon Burm.f	Singkom	July–August	INR 20/-
Dillenia indica L.	Sompa	July–August	INR 20/-
Elaeagnus latifolia L.	Raapgam	January–May	INR30/-
Emblica officinalis G.	Amloki	August–December	INR 40/-
Elaeocarpus floribundus Blume.	Jolpai	June–November	INR 40/-
Garcinia cowa Roxb	Tabi-Tarak	May–June	INR 40/-
Myrica esculenta Buch.-Ham	Ketir	May–Aug	INR 40/-
Mangifera sylvatica Roxb	Moonam-Tagung	May–June	INR 30/-
Passiflora edulis Sims.	Marsang –Riiyong	August–December	INR 40/-
Syzygium cumini Lam.	Jongkeng	April–July	INR 20/-
Tamarindus indica L.	Imli	July–December	INR 40/-
Ziziphus mauritiana Lam.	Bogori	December–February	INR 20/-

Wild edibles are collected from natural forests in the form of fruits, leaves, stems, roots, etc., and these plants still make up a good proportion of tribal diets throughout the

world [25,26]. Traditionally, these species have met the nutritional requirements of local inhabitants [27]. In northeast India, a major portion of the population depends on a number of plants for their survival. They depend on wild edibles as a source of ethnomedicines as well as for use in their socioeconomic life such as the construction of houses, fuel wood, as well as miscellaneous uses [28–30].

In the present investigation, 50 wild edible fruits belonging to 31 families having medicinal values were altogether reported. Among the different families, Moraceae and Rutaceae were dominant with five species, followed by Phyllanthaceae, Anacardiaceae and Rosaceae, Arecaceae, Fabaceae, Lauraceae, Primulaceae, and Fagaceae. In terms of parts used, the most used were leaves (35.58%), followed by fruits and bark (21.51%), roots (10.73%), seeds (7.53%), latex (2.15%) and shoots (1.07%). Therapeutically, the reported wild edible fruits are used against 14 classes of diseases. Our present study is in close conformity with previous studies conducted in Arunachal Pradesh where the researchers proved that a number of plants in the state have been used as ethnomedicine by the tribal people of the state [31].

The local inhabitants of Arunachal Pradesh consume a large number of wild edible fruits as important parts of their diets. Most of the species are used for their fruits, seeds, leaves, shoots, flowers, and roots or rhizomes. Similar ratios and trends of usage for different plant parts are reported for the country of India [8,32]. Tribal people of the state collect these wild edible fruits from primary and secondary forests and most of these fruits are sold in the local markets or *hats*. These wild fruits, therefore, are helpful in alleviating a subsistence economy [27]. In addition to use as a source of medicine, a number of these species are also processed into value-added products, which reduce their spoilage during the on-season and can be stored for use in a lean period, also helping farmers maximise their income [33]. Consumption of wild plants provides substantial nutritional dietary benefits to tribal populations in remote areas. Some wild edible plants are rich in nutrient content and may even be superior to cultivated ones in this respect [34]. A varied diet of wild edible plants may also increase one's sense of food palatability, which in turn may lead to an increase in food intake [35,36]. Due to the inaccessibility of many regions, wild plants can serve as an important supplement to conventional, domesticated crops.

The population density of these wild species is progressively decreasing, and their natural regeneration is often poor in natural habitats due to intense biotic and abiotic pressure. The pressure is further aggravated, as they are collected freely in large quantities from the backyard/forest for sale in the markets and used as fuel wood. Such uncontrolled exploitation of these naturally occurring wild genetic resources has led them to become rare to very rare and many may become extinct in the near future. Furthermore, this may lead to a narrowing of the genetic diversity and variability of these wild species. With the ever-increasing population, there is a great need to popularize and conserve these genetic resources in order to meet the future demand for human food, nutrition, medicine, and gene(s) sources for adapting to climate change.

Utilization of wild edible plants is an effective tool for the restoration of traditional knowledge systems inherent in tribal people. This can easily be achieved by a government-launched programme involving the local community on a care and share basis for the conservation of genetic resources of wild edible fruits. The necessary steps should also be taken for cultivation of important wild edibles in agroforestry systems. Undoubtedly, the traditional wisdom of controlled exploitation will constitute the traditional heritage of the people of Arunachal Pradesh, India. There is ample scope for studies on regeneration behaviour, population structure, and the status of such biological resources. Studies on the phonological characteristics of different species must be afforded due importance. The outcome of such studies will be useful in determining an appropriate conservation strategy.

4. Conclusions

Humans are the most intelligent species on the planet, as they devour plants and animals for their sustenance. Plants have long been a source of food, medicine, and other

necessities for humankind. The tribal people of northeast India rely heavily on forests and the products they provide for their daily sustenance. This economically backward region of India is a treasure trove of wild edible fruit crops in India. Wild fruit species in northeast India have diverse social, economic, and scientific importance. Policymakers should conceive an extensive plan for the sustainable management of wild edible fruits and documentation, domestication, and value addition of all the available species. To safeguard the existing genetic diversity of these valuable species, sincere in situ conservation efforts are urgently required. Dynamic conservation of associated indigenous knowledge among local tribal and farmer communities can be carried out through policy interventions, implementation of farmer's rights, and generating awareness among local people. Researchers, scientists, farmers, and entrepreneurs should work together to make these valuable species commercial crops for future. The phytochemical and nutritional profiles of the species in question can therefore constitute basic knowledge of food pairing with other ingredients to improve nutritional and sensory qualities, allowing key molecules responsible for functional properties to be enhanced. Bioprospecting and value addition of these valuable genotypes would further enhance the possibilities of utilizing rare genes to mitigate the challenges of climate change and biological stresses. Detailed research is also very much necessary to know the complete defence mechanisms of these wild edible fruits against several disease-causing pathogens. The present investigation is appropriate for encouraging researchers, pharmaceuticals, and policymakers to develop a plan for properly managing and utilizing these highly important wild edible fruits.

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