Research Square

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Ethnobotanical survey in Tampolo forest (Fenoarivo Atsinanana, Madagascar)

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Research

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Abstract

Background

Madagascar shelters over 14,000 plant species out of which 90% are endemic to the region. Some of the plants are very important for the socio-cultural and economic potential. Tampolo forest is one of the remnant littoral forests hinged on by the adjacent local communities for their daily livelihood. However, it has considerably shrunk due to anthropogenic activities forming forest patches. Thus, documenting the useful plants in and around the forest is important for understanding the ethnobotany in this area.

Methods

In this study, we 1) collected and identified useful plants utilized by local communities. Voucher specimens were collected following the information given by interviewees. 2) recorded the collection activities and the consumption methods through semi-structured interviews of the local inhabitants. 3) did a phytochemical screening to identify the active compounds and the potential healing metabolites of the medicinal plants.

Results

A total of 65 people between 25 to 75 years old were interviewed. Surveys recorded 123 species used as timber, food or medicine. Among them, 92 were forest species and 31 were ruderal species. Medicinal plants were mostly used to cure diarrhea, stomachache, and fever with leaves being the most used plant part. Phytochemical analyses of 20 endemic medicinal species showed the presence of compounds that could be responsible for the therapeutic effects of the plants.

Conclusions

Tampolo forest proves to be an important littoral forest highly utilized by the adjacent local communities due to the presence of high number of useful plants which are mostly endemic to the region. Hence, our investigation assessed the importance of these species in the locality and this can be used for further study on ecology, conservation and valorization of these species.

1. Background

Tropical forests harbor a rich diversity of species which have a high productive and protective natural values [1, 2]. They are also a driver of a significant social and economic development as a result of the exploitation of the existing natural resources [2, 3]. Additionally, humans also depend on the forests for food, shelter and medicines [4]. However, there is a rapid loss of tropical forests through deforestation driven by the increased land use change, natural resource overexploitation and climate change.

Madagascar has a remarkable wealth in terms of vegetation and endemic species. The Island is composed of a variety of natural environments, which harbor a unique and globally important assemblage of plant species. It is home to over 14,000 plants species, out of which 90% are endemic to the region [3, 5]. Among the 490 tree genera on the island, 161 are endemic [6]. However, the increasing intense population growth has led to rapid deforestation as land is cleared for agricultural fields and for fuel. The rainforest cover in Madagascar has recorded a gradual decrease from 5,254,306 hectares in the year 1990 to 4,489,248 hectares in the year 2005 [7], and a further loss of 4,345,000 hectares in the year 2013 [8], which translates to one million hectares loss in 15 years.

Tampolo forest is part of the eastern littoral forest remnants of Madagascar which have considerably shrunk due to anthropogenic activities hence forming forest patches [5]. The adjacent local communities majorly depend mostly on farming and fishing which generally do not generate enough income hence the improper exploitation of forest's natural resources to supplement the daily income. Due to this direct addition into the wellness of the adjacent community, there is a greater risk of extinction of many endemic animal and plant species such as *Daubentonia madagascariensis* Gmelin "Aye-Aye)" (Daubentoniidae) and *Dalbergia baronii* Baker (Fabaceae) which inhabit the forest. This biodiversity loss is greatly propelled by

the forestry sector which have since the colonial period, focused on the wood production potential of the sites, rather than focus on the region's plants and their practical uses through the traditional knowledge of the local culture and people's perspective [9–14].

As rural communities, local people of Tampolo depend on natural resources for their daily livelihood [13, 15, 16], especially for their healthcare [17]. In many parts of the world, traditional knowledge has always been transferred orally from generation to generation [18]. However, there is a risk of loss of information over the years, hence the importance of gathering them through ethnobotanical studies [4, 19–24]. In terms of traditional cures, despite the lack of written documents, forest medicinal plant species were used to treat various types of diseases. Unlike other parts of the island where works were completed [17, 21, 25, 26], no related works were available for this present area of study. Therefore, this paper is aimed at filling the gap of the previous literature available and to document the floristic list of useful forest plants with emphasis on medicinal endemic species. Additionally, to evaluate the significance of most salient plant families, genera and species and their uses among the participants for the conservation of the biological resources and their sustainable utilization.

2. Methods

2.1. Study area

Tampolo forest is located on the eastern coast of Madagascar covering 360 ha (Fig. 1). It is about 110 km from Toamasina, the capital district and 10 km from Fenoarivo Atsinanana, in Analanjirofo region [27]. It is bordered by Lake Tampolo and the village of Rantolava to the North, the village of Ampasimazava to the South, the Indian Ocean to the East and the National Road number 5 and the village of Tanambao Tampolo to the West. It is classified as low altitude dense evergreen humid forest belonging to the series of *Anthostema* and Myristicaceae by Humbert and Cours-Darne [28] and as coastal forest by DuPuy and Moat [29], recording over 360 plant species [30]. Three types of soils can be found in the forest station: South of the station, the ground sandy, In the North and West, the soil is generally clayey-loamy, on the hills, the soil is ferralitic in Nature.Tampolo region has an average annual temperature of 23°C with the coldest month being July with 19^{0}C and December is the hottest month with 26.5^{O}C. The region receives 3406mm of rain per year with average rainy days of 241 registered per year. In terms of human population, nearly 6,000 people are distributed within the following “fokontany”: Andapa II, Tanambao Tampolo, Rantolava and Takobola, which belong to the rural “commune” of Ampasina Maningory in 2014.

2.2. Ethnobotanical data collection

Five fieldtrips for ethnobotanical and biological surveys were carried out from February to November, 2012. Ethnobotanical surveys were done by using the methods of Martin [31] to achieve open or semi-open interviews which means that questionnaires were asked in manner that could not influence the answers of the participants and by following the International Society of Ethnobiology (ISE) code of ethics [32]. Researchers started their interaction with each prospective respondent by first explaining the aims and objectives of the project in order to solicit their consent and co-operation before any ethnobotanical data were gathered. Interviews were conducted with the selected informants to determine and explore the ethnobotanical knowledge regarding the utilization of plant species, their usefulness, their utilized parts, mode of preparation, or method of processing the plants. The ethnobotanical data for this research were gathered from altogether 53 farmers, 3 traditional healers, 3 fishermen, 2 chiefs of Fokontany, 1 forest guard, 1 Tangalamena (traditional chief of the village), 1 retired nurse and 1 blacksmith. The participants were selected based on their consent to be interviewed and their affirmation on the use of or having knowledge on at least one of the uses of the forest plant species. At first before any interview, we introduced ourselves to those responsible for the village; after their agreement, participants were asked if they can be interviewed in the context of our study. They were free to participate or not i.e., voluntary. Preliminary engagement has shown that younger people are ignorant of traditional knowledge; in contrast, the elderly interviewees depend mostly or entirely on natural resources.

Investigations were conducted in the three villages surrounding the forest: Tanambao Tampolo, Andapa II and Rantolava where informants of the age 25 and above were interviewed and with their prior consent. The Nagoya protocol on access and benefit-sharing [33] has been followed.

The importance value of the use of each species by local population were assessed by calculating its Use Index by using the formula of Lance et *al*. [34]:

I (%) = n/N × 100,

where I (%) is the percentage index of use, n is the number of people citing the species, and N is the total number of people surveyed. The given species is heavily used if the value of I (%) is between 60 and 100% and moderately used if I (%) is between 30 and 60%; and if I (%) is less than 30%, it is rarely used.

2.3. Specimen collection and taxonimic identification

Voucher specimens were collected with the help of the field guides and following the information given by interviewees relying on the plant species vernacular names. Some of the plant species were identified in the field and the remaining ones identified at the Herbarium of Tsimbazaza Park (TAN), acronym according to the Index Herbariorum list [35]. Species names were checked using Tropicos, International Plant Name Index (IPNI), the Plants Of the World Online (POWO) and Plant List databases [36–39]. Duplicates were deposited at office of the "Association de Valorisation de l'Ethnopharmacologie en Regions Tropicales et Meditéranéenes (AVERTEM)" in Tampolo and at the herbarium of the "Département de Biologie et Ecologie Végétales (DBEV)" which is not yet listed at the Index Herbariorum, Faculty of Sciences Ankatso. A unique voucher specimen number was assigned to each herbarium specimen.

2.4. Phytochemical screening for medicinal plants

Clean leaf samples with no fungal or any other disease contaminations were collected from the selected medicinal plant species and were dried in a ventilated area under a shade.

An aqueous extract was prepared by mixing 1 g of leaf powder with 20 ml of distilled water, then the solution was boiled and cooled [40–42]. Four drops of salted gelatin 1% was mixed with 0.25 ml of the aqueous solution, the formation of a precipitate indicates the presence of tannins. On the other hand, phenolic compounds were detected when the color of the mixture switches to dark blue or blue-green by mixing four drops of ferric chloride in methanolic solution with 0.5 ml of the extract [42]. Then, Anthraquinones were detected by using the Bornträger reaction [43, 44], a 0.5 ml of the aqueous solution was mixed with 1 ml of benzene. After decantation, 0.5 ml of ammoniac 25% was added, the turn to red of the solution indicates the presence of Anthraquinones. The presence of desoxyoses were also detected by using 0.5 ml of the aqueous solution with consecutively 0.5 ml of cold acetic acid, 0.5 ml of ferric chloride 10% and 0.5 ml of sulfuric acid (H_2SO_4) 36 N where "N" is the number of particles in the substance (reaction of Keller-Kiliani [45]). The formation of a purplish ring at the interface of the tube confirms the presence of desoxyoses [46]. Iridoids were detected by adding some drops of hydrochloric acid (HCl) 12 N to 0.5 ml of the aqueous solution. The mixture was boiled in a water bath for 30 minutes, then a dark green or dark blue precipitate or color appears if these compounds are presents. For saponins, after dissolving in water, there should be a formation of a foamy solution after strongly shaking for 30 seconds. [40], if the convoluted foam persisted within 30 minutes, it contained Saponins.

Chloroform extract was used to detect the presence of steroids and terpens. One gram of leaf powder was mixed with chloroform, stored in cold place for one night, then filtered. The Libermann-Burchard test [47] was used by mixing 1 ml of the extract with 1 ml of acetic anhydride. After shaking, 1 ml of H_2SO_4 was then added. The formation of a purplish red ring indicates the presence of terpens while the presence of steroids was indicated by the formation of a green color at the upper level of the solution. Also, the presence of sterols was detected by using the reaction of Salkowski [48, 49], The phase at the bottom of the test tube turns in red if they were presents when 0.5 ml of H_2SO_4 34 N and three drops of anhydrous acetic were added to 0.5 ml of chloroformic extract.

After that, 1 g of leaf powder was mixed with 10 ml of hydroethanol (75%) then stored in a cold place for one night. To detect the presence of flavonoids, the Wilstater procedures [50, 51] was used by adding 4 drops of HCl 12 N and 2 Magnesium turnings to 2 ml of the extract. The color change to red indicates the presence of flavonoid compounds. Then, the detection of anthocyanins followed the procedures of Bate-Smith [52]. A mixture of 2 ml of the plant extract and 0.5 ml of HCl 12 N was boiled for 30 minutes, and when cooling, a red color appeared.

Finally, 1 g of leaf powder was mixed with 10 ml of HCl 2 N and marinated for one night. Then, 1 ml of the acid extract were then mixed with four drops of reagent of Mayer [53], Wagner [54] or Dragendorff [55] and produced a white precipitate or a flocculation if Alkaloids were presents in the solution.

3. Results

3.1. Demographic Variables

During the study, 65 local inhabitants were surveyed, 41 (63.08%) were male and 24 (36.92%) were female. The age of the informants ranges from 25 and 75 years old (Table 1). The survey was done either by individual interviews (one-on-one consultations) or through focus groups. The interviewees consisted of 53 farmers, 3 traditional healers, 3 fishermen, 2 chiefs of Fokontany, 1 forest guard, 1 Tangalamena (traditional chief of the village), 1 retired nurse and 1 blacksmith. The participants were selected based on their consent to be interviewed and their affirmation on the use of or having knowledge on at least one of the uses of the forest plant species. At first before any interview, we introduced ourselves to those responsible for the village; after their agreement, participants were asked if they can be interviewed in the context of our study. They were free to participate or not i.e., voluntary. It was observed in the survey that their knowledge of useful plants mostly medicinal plants was passed down from their ancestors through oral traditions. Preliminary engagement has shown that younger people are ignorant of traditional knowledge; in contrast, the elderly interviewees depend mostly or entirely on natural resources.

Table 1
Repartition of the interviewees according to the age group and the gender.

Age (y)	Male	Female
25–35	23	8
36–45	5	3
46–55	3	8
56–65	8	4
66–75	2	1
Total	41	24
The use of traditional medicine is an important part of healthcare of the Tampolo community.		

3.2. Plant utilizations

The following ethnobotanical information are reported for each species: the scientific name, the family name, the growth form, the plant part used, and uses. During these interviews, 123 plant species distributed within 62 families and 112 genera, including ruderal species, were cited as useful in the locality of Tampolo of which 59 were medicinal (48%), 54 for timber and firewood (44%) and 10 were edible (8%) (Fig. 2). Among these useful plants, 92 species where exclusively from the forest where 78 (84.78%) of them were endemic (Table 2) then distributed within 49 families and 83 genera. Most of the forest-utilized plant families were represented by two or three species.

Table 2
List of useful plants of Tampolo with their use index. M: Medicinal; T: Timber; E: Edible.

	Family	Species	Collection Number	Local name	Use	Endemism	Life form	I (%)
1	Anacardiaceae	*Sorindeia madagascariensis* Thouars ex DC.	GE 109	Voantsirindrina	E	Not endemic	Liana	27.7
2	Anacardiaceae	*Campnosperma micranteium* Marchand	GE 034	Tarantana	T	Endemic	Tree	6.1
3	Anisophylleaceae	*Anisophyllea fallax* Scott-Elliot	GE 124	Hazomamy	M	Endemic	Tree	9.2
4	Annonaceae	*Xylopia buxifolia* Baill	GE 122	Hazoambo	M	Endemic	Tree	46.1
5	Annonaceae	*Fenerivia ghesquiereana* (Cavaco & Keraudren) R.M.K. Saunders	GE 096	Tsilongodongotra	T	Endemic	Tree	6.1
6	Apocynaceae	*Landolphia nitens* Lassia	GE 013	Voahena	E	Endemic	Liana	46.1
7	Apocynaceae	*Tabernaemontana retusa* (Lam.) Pichon	GE 126	Livoro	M	Endemic	Tree	9.2
8	Apocynaceae	*Stephanostegia capuronii* Markgr	GE 110	Hazon-dronono	T	Endemic	Tree	9.2
9	Araceae	*Pothos scandens* L.	GE 006	Ravin-tampina	M	Not endemic	Vine	9.2
10	Araliaceae	*Schefflera vantsilana* (Baker) Bernardi	GE 106	Voantsilana	T	Endemic	Tree	3
11	Arecaceae	*Dypsis fasciculata* Jum	GE 056	Amboza	T	Endemic	Shrub	9.2
12	Asclepiadaceae	*Secamone obovata* Decne	GE 090	Vahizahana	M,E	Endemic	Vine	21.5
13	Asteropeiaceae	*Asteropeia micraster* Hallier F.	GE 024	Tambônana	T	Endemic	Tree	24.6
14	Asteropeiaceae	*Asteropeia matrambody* (Capuron) G.E.Schatz, Lowry & A.-E.Wolf	GE 023	Matrambody	T	Endemic	Tree	6.1
15	Bignoniaceae	*Phyllarthron bojeranum* DC.	GE 093	Antohiravina	M,T	Endemic	Tree	27.7
16	Bignoniaceae	*Rhodocolea racemose* (Lam.) H.Perrier	GE 102	Velonavohitra	T	Endemic	Shrub	12.3
17	Bignoniaceae	*Colea tetragona* DC.	GE 042	Sifontsoy	M	Endemic	Shrub	6.1
18	Burseraceae	*Aucoumea klaineana* Pierre	GE 123	Akomea	T	Endemic	Tree	27.7

	Family	Species	Collection Number	Local name	Use	Endemism	Life form	I (%)
19	Celastraceae	*Brexia madagascariensis (*Lam.*)* Thouars ex Ker Gawl.	GE 125	Maimboholatra	M	Not endemic	Shrub	9.2
20	Clusiaceae	*Symphonia fasciculata* (Noronha ex Thouars) Vesque	GE 112	Haziny	T	Endemic	Tree	18.5
21	Clusiaceae	*Garcinia* sp.	GE 065	Ravi-masina kakazo	M	Endemic	Shrub	6.1
22	Clusiaceae	*Calophyllum paniculatum* P.F.Stevens	GE 033	Vintanona	T	Endemic	Tree	3
23	Clusiaceae	*Symphonia* sp.	GE 130	Haziny be ravina	T	Endemic	Shrub	1.5
24	Combretaceae	*Terminalia catappa* L.	GE 116	Antafana	T	Not endemic	Tree	18.5
25	Connaraceae	*Agelaea pentagyna* (Lam.) Baill	GE 008	Vahimaintina	M	Not endemic	Liana	43
26	Dilleniaceae	*Tetracera madagascariensis* Willd. ex Schltdl.	GE 016	Vahimaragna	M	Endemic	Liana	12.3
27	Dilleniaceae	*Hibbertia coriacea* (Pers.) Baill.	GE 067	Anjavidy vavy	M	Endemic	Shrub	3
28	Ebenaceae	*Diospyros filipes* H.Perrier	GE 049	Hazomaintina	T	Endemic	Tree	12.3
29	Ebenaceae	*Diospyros* sp.	GE 050	Hazomaintina	T	Endemic	Epiphyte	1.5
30	Elaeocarpaceae	*Elaeocarpus alnifolius* Baker	GE 057	Aferonakavy	M	Endemic	Shrub	3
31	Ericaceae	*Erica* sp.	GE 059	Anjavidy lahy	M	Endemic	Shrub	40
32	Ericaceae	*Vaccinium* sp.	GE 121	Voantsirihitra	E	Endemic	Shrub	15.4
33	Euphorbiaceae	*Croton noronhae* Baill	GE 043	Fotsy avadika	M	Endemic	Shrub	18.5
34	Fabaceae	*Intsia bijuga* (Colebr.) Kuntze	GE 073	Hintsina	T	Not endemic	Tree	86
35	Fabaceae	*Dalbergia Baronii* Baker	GE 047	Hazovola	T	Endemic	Tree	77
36	Fabaceae	*Dialium unifoliolatum* Capuron	GE 048	Zahana (zana)	M	Endemic	Tree	15.4
37	Fabaceae	*Cynometra capuronii* Du Puy & R.Rabev.	GE 046	Mampay	M	Endemic	Tree	6
38	Fabaceae	*Hymenaea verrucosa* Gaertn.	GE 071	Mandrofo	T	Not endemic	Tree	6
39	Gentianaceae	*Tachiadenus carinatus* (Desr.) Griseb.	GE 003	Rangilo	M	Endemic	Herb	3

	Family	Species	Collection Number	Local name	Use	Endemism	Life form	I (%)
40	Gentianaceae	*Anthocleista madagascariensis* Baker	GE 064	Dindemo	M	Endemic	Tree	1.5
41	Hypericaceae	*Psorospermum chionanthifolium* Spach	GE 098	Harongam-panihy	T	Endemic	Shrub	3
42	Lauraceae	*Ocotea racemosa* (Danguy) Kosterm.	GE 086	Tafononana	T	Endemic	Tree	6.1
43	Lauraceae	*Cryptocarya* sp.	GE 045	Tavolo	T	Endemic	Tree	6.1
44	Lauraceae	*Cryptocarya acuminata* Merr.	GE 044	Tavolomalama	T	Not endemic	Tree	3
45	Liliaceae	*Dracaena reflexa* Lam.	GE 052	Felana	T	Not endemic	Shrub	1.5
46	Liliaceae	*Dracaena* sp.	GE 053	Felana	T	Not endemic	Shrub	1.5
47	Melastomataceae	*Medinilla parvifolia* Baker	GE 004	Ravi-masina	M	Endemic	Epiphyte	9.2
48	Melastomataceae	*Memecylon thouarsianum* Naudin	GE 082	Tsimahamasatokina	T	Endemic	Tree	6.1
49	Melastomataceae	*Medinilla quadrangularis* Jum. & H. Perrier	GE 005	Ravi-masina	M	Endemic	Epiphyte	1.5
50	Melastomataceae	*Memecylon* sp.	GE 132	Tsimahamasatokina	T	Endemic	Tree	1.5
51	Menispermaceae	*Burasaia madagascariensis* DC.	GE 032	Hazon-dahy	M	Endemic	Tree	15.3
52	Menispermaceae	*Tinospora* sp.	GE 017	Andanitrehy	M	Endemic	Liana	9.2
53	Monimiaceae	*Tambourissa religiosa* (Tul.) A. DC	GE 114	Ambora	T	Endemic	Shrub	3
54	Moraceae	*Trilepisium* sp.	GE 028	Tsopatika	T	Endemic	Tree	12.3
55	Moraceae	*Streblus dimepate* (Bureau) C.C. Berg	GE 127	Maherihely	T	Endemic	Tree	9.2
56	Moraceae	*Ficus lutea* Vahl	GE 062	Amontana	M	Not endemic	Tree	3
57	Myristicaceae	*Brochoneura acuminata* (Lam.) Warb	GE 030	Rara	M	Endemic	Tree	15.3
58	Myrsinaceae	*Oncostemum botryoides* Baker	GE 088	Hazontoho	T	Endemic	Shrub	6
59	Myrtaceae	*Syzygium bernieri* (Baill. ex Drake) Labat & Schatz	GE 113	Hompa	T	Endemic	Tree	21.5
60	Ochnaceae	*Campylospermum obtusifolium* (DC.) Tiegh	GE 089	Menahihy	M	Endemic	Shrub	9.2

	Family	Species	Collection Number	Local name	Use	Endemism	Life form	I (%)
61	Olacaceae	*Olax emirnensis* Baker	GE 087	Famelondriaka	M	Endemic	Tree	1.5
62	Oleaceae	*Noronhia boivinii* Dubard	GE 084	Tsilaitra	M	Endemic	Tree	9.2
63	Oleaceae	*Noronhia* sp.	GE 131	Tsilaitra be ravina	T	Endemic	Tree	1.5
64	Phyllanthaceae	*Bridelia tulasneana* Baill	GE 009	Roihavitra	M	Endemic	Tree	15.3
65	Phyllanthaceae	*Cleistanthus capuronii* Leandri	GE 039	Lohendry	T	Endemic	Tree	6.1
66	Phyllanthaceae	*Uapaca thouarsii* Baill	GE 120	Voapaka	M,T,E	Endemic	Tree	98.5
67	Phyllanthaceae	*Wielandia mimosoides* (Baill.) Petra Hoffm. & McPherson	GE 027	Beando	T	Endemic	Shrub	3
68	Physenaceae	*Physena madagascariensis* Steud.	GE 094	Fanavimangoaka	M	Endemic	Shrub	9.2
69	Pittosporaceae	*Pittosporum ochrosiifolium* Bojer	GE 095	Maimbovitsika	M	Endemic	Shrub	6.1
70	Putranjivaceae	*Drypetes madagascariensis* (Lam.) Humbert & Leandri	GE 054	Tsivavegny	M	Endemic	Shrub	15.3
71	Rhamnaceae	*Bathiorhamnus louvelii* (H.Perrier) Capuron	GE 026	Menavahatra	M	Endemic	Tree	1.5
72	Rhizophoraceae	*Macarisia pyramidata* Thouars	GE 080	Hazomalagny	M	Endemic	Tree	15.3
73	Rosaceae	*Magnistipula tamenaka* (Capuron) F.White	GE 128	Tamenaka	T	Endemic	Tree	6.1
74	Rubiaceae	*Saldinia axillaris* (Lam. ex Poir.) Bremek.	GE 103	Valavelona	M	Endemic	Shrub	6.1
75	Rubiaceae	*Pyrostria media* (A.Rich. ex DC.) Cavaco	GE 101	Tsifo madini-Dravina	T	Endemic	Shrub	6.1
76	Rubiaceae	*Breonia madagascariensis* A.Rich. ex DC.	GE 029	Molo-pangady	M	Endemic	Tree	3
77	Rubiaceae	*Pyrostria major* (A.Rich. ex DC.) Cavaco	GE 100	Tsifobe	M	Endemic	Tree	3
78	Rubiaceae	*Hyperacanthus poivrei* (Drake) Rakotonas. & A.P.Davis	GE 072	Voantalanina	T	Endemic	Tree	3

	Family	Species	Collection Number	Local name	Use	Endemism	Life form	I (%)
79	Rubiaceae	*Gaertnera* sp.	GE 064	Sadôdôka	M	Endemic	Tree	3
80	Salicaceae	*Homalium erianthum* (Tul.) Baill	GE 068	Hazom-bato	T	Endemic	Tree	9.2
81	Salicaceae	*Ludia madagascariensis* Clos	GE 077	Fanenton'akoholahy	M	Endemic	Shrub	3
82	Sapindaceae	*Pseudopteris decipiens* Baill	GE 097	Hazomananjara	M	Endemic	Shrub	6.1
83	Sapindaceae	*Filicium thouarsianum* (DC.) Capuron	GE 063	Elatrangidina	T	Endemic	Tree	3
84	Sapotaceae	*Mimusops coriacea* (A.DC.) Miq	GE 083	Voaranto	E	Not endemic	Tree	61.5
85	Sapotaceae	*Faucherea glutinosa* Aubrév	GE 061	Nanto	O	Endemic	Tree	46
86	Sapotaceae	*Labramia bojeri* A.DC.	GE 074	Nanto vasihy	T	Endemic	Tree	6.1
87	Sapotaceae	*Chrysophyllum boivinianum* (Pierre) Baehni	GE 038	Famelona	M	Not endemic	Tree	3
88	Sarcolaenaceae	*Leptolaena abrahamii* G.E.Schatz & Lowry	GE 075	Amanin'aombilahy	T	Endemic	Tree	21.5
89	Sarcolaenaceae	*Schizolaena rosea* Thouars	GE 107	Tsiariagnarany	T	Endemic	Tree	9.2
90	Sarcolaenaceae	*Sarcolaena grandiflora* Thouars	GE 104	Helana	T	Endemic	Tree	6
91	Sarcolaenaceae	*Schizolaena* sp.	GE 108	Voandroza	T	Endemic	Tree	6
92	Simaroubaceae	*Quassia indica* (Gaertn.) Noot.	GE 129	Bemafaitra	M	Not endemic	Tree	1.5

3.3. Growth form of the plants

Trees (56 Species) and shrubs (25 species) were cited by the participants to be the most exploited (Fig. 3) while climbers (7 species), Epiphytes (3 species) and Herbs (1 specie) were least cited. Four species such as *Uapaca thouarsii* Baill., *Intsia bijuga* Kuntze, *Dalbergia baronii* Baker and *Mimusops coriacea* Miq. had their use index greater than 60% because they were highly valued by the local people as timber. Moreover, *U. thouarsii* was used as medicinal plant. Few forest species were edible and fruits were the major part that were eaten by the local people. Furthermore, these species were also eaten by lemurs and birds.

3.4. Medicinal plants

Among the useful forest plants, 43 species were medicinal having therapeutical values, However, among the 43 species, 3 species were also used as timber as well as food while 37 of them were endemic to Madagascar (Table 2). The most frequent diseases that are treated with plants were diarrhea, stomachache, oral, dental, genital infections and non-malaria fever (Table 3). In the case of malaria, all of the interviewees affirmed that they consult a doctor. However, leaves were the most frequently used parts

(68%) that were used in the cure of most of the diseases as shown in the Fig. 4. The other parts or components of the plant such as stem, root, bark and latex or mixture of two or more of them were also used in low proportions.

Table 3
Method of use of the forest medicinal plant species.

Family	Species	Healing properties	Part used	method of preparation
Anisophylleaceae	*Anisophyllea fallax* Scott-Elliot	Anti-fever	Leaf	Decoction
Annonaceae	*Xylopia buxifolia* Baill.	Antidiarrheal Anti-fatigue.	Leaf	Decoction
Apocynaceae	*Tabernaemontana retusa* (Lam.) Pichon	Against toothache	Latex	Poultice
Asclepiadaceae	*Secamone obovata* Decne	Anti-yellow fever	Leafy branch	Decoction
Bignoniaceae	*Colea tetragona* DC.	Anti-genital infections	Leaf	Decoction, infusion
Bignoniaceae	*Phyllarthron bojeranum* DC.	Anti-stomach ache Anti-fatigue	Leaf	Decoction
Clusiaceae	*Garcinia sp.*	Anti-prolonged cough for kid	Leaf	Decoction
Dilleniaceae	*Hibbertia coriacea* (Pers.) Baill.	Anti-fever	Leafy branch	Decoction
Dilleniaceae	*Tetracera madagascariensis* Willd. ex Schltdl.	Child anti-oral candidiasis. Anti-asthma	Leaf	Poultice. Decoction
Elaeocarpaceae	*Elaeocarpus alnifolius* Baker	Anti-flu	Leaf	Decoction
Ericaceae	*Erica* sp.	Anti-fever	Leafy branch	Decoction
Euphorbiaceae	*Croton noronhae* Baill	Antidiarrheal, Anti-fatigue	Leaf	Decoction
Fabaceae	*Cynometra capuronii* Du Puy & R.Rabev.	Anti-yellow fever	Leaf	Decoction
Fabaceae	*Dialium unifoliolatum* Capuron	Anti-stomach ache	Leaf	Decoction
Gentianaceae	*Anthocleista madagascariensis* Baker	Antidiarrhoeal	Leaf	Decoction
Gentianaceae	*Tachiadenus carinatus* (Desr.) Griseb	Aerial part: Anti-fever Root: deworming	Leaf, stem, root	Decoction
Hypericaceae	*Psorospermum chionanthifolium* Spach	Antidiarrheal	Leaf	Decoction
Melastomataceae	*Medinilla parvifolia* Baker	Anti-prolonged cough for adults	Leaf	Decoction
Melastomataceae	*Medinilla quadrangularis* Jum. & H. Perrier	Anti-prolonged cough for adults	Leaf	Decoction
Menispermaceae	*Burasaia madagascariensis* DC.	Anti-fatigue against hernia face mask (masonjoany).	Bark	Decoction, Poultice

Family	Species	Healing properties	Part used	method of preparation
Menispermaceae	*Tinospora* sp.	Invigorating; anti-stomach ache; against hernia	Stem	Decoction
Myristicaceae	*Brochoneura acuminata* (Lam.) Warb.	Child anti-oral candid; anti-stomach ache	Bark, latex	Poultice
Ochnaceae	*Campylospermum obtusifolium* (DC.) Tiegh	Teeth care	Bark	Poultice
Olacaceae	*Olax emirnensis* Baker	Limitation of severe bleeding during delivery; anti-flu	Bark	Decoction
Oleaceae	*Noronhia boivinii* Dubard	Anti-fatigue; against swelling of the feet	Leaf	Decoction
Phyllanthaceae	*Bridelia tulasneana* Baill.	Anti-yellow fever, anti-oedema, Dietetic	Leaf, stem	Decoction
Phyllanthaceae	*Uapaca thouarsii* Baill.	Aphrodisiac	prop roots	Decoction
Physenaceae	*Physena madagascariensis* Steud.	Antidote emetic; anti-stomach ache	Leaf	Decoction
Pittosporaceae	*Pittosporum ochrosiifolium* Bojer	Against eye infection	Leaf	Poultice, Infusion
Putranjivaceae	*Drypetes madagascariensis* (Lam.) Humbert & Leandri	Revitalizing	Leaf	Decoction
Rhamnaceae	*Bathiorhamnus louvelii* (H.Perrier) Capuron	Anti-fever; antidiarrheal.	Root	Decoction
Rhizophoraceae	*Macarisia pyramidata* Thouars	Antidiarrheal	Leaf	Decoction
Rubiaceae	*Breonia madagascariensis* A.Rich. ex DC.	Against toothache	Latex	Poultice
Rubiaceae	*Pyrostria major* (A.Rich. ex DC.) Cavaco	Used for abortion	Bark, Leaf	Decoction, Infusion
Rubiaceae	*Saldinia axillaris* (Lam. ex Poir.) Bremek.	Anti-stomach ache	Leaf	Decoction
Salicaceae	*Ludia madagascariensis* Clos	Anti-hemorrhagic Anti-fatigue	Leaf	Decoction
Sapinfdaceae	*Pseudopteris decipiens* Baill	Antidiarrheal; Anti-stomach ache	Leaf	Decoction

3.5. Phytochemical screening for medicinal plants

Leaves of 20 species were used for the analysis (Table 4). The result revealed that polyphenols, deoxy-sugar, steroids, and unsaturated sterols were the most frequently present in the analyzed medicinal plants. In contrast, alkaloids, iridoids and flavonoids were only present in a few species.

Table 4
Secondary metabolites present in the leaf samples. (+: Present; -: Absent; ±: Trace).

Species	Alkaloid	Polyphenols	catechic tannins	Gallotannins	Saponin	Iridoid	Deoxy-sugar
Brexia madagascariensis (Lam.) Thouars ex Ker Gawl.	-	±	+	-	+	±	-
Bridelia tulasneana Baill.	-	+	+	+	+	-	+
Brochoneura acuminata (Lam.) Warb	-	+	-	+	+	-	+
Burasaia madagascariensis DC.	+	+	+	-	-	-	+
Cynometra capuronii Du Puy & R.Rabev	-	+	-	+	+	-	-
Dialium unifoliolatum Capuron	+	+	-	-	-	-	-
Drypetes madagascariensis (Lam.) Humbert & Leandri	-	+	+	-	+	-	-
Elaeocarpus alnifolius Baker	-	+	-	-	-	-	-
Ludia madagascariensis Clos	-	+	+	+	-	-	+
Macarisia pyramidata Thouars	-	+	-	+	-	-	±
Noronhia boivinii Dubard	-	+	-	-	-	-	-
Olax emirnensis Baker	-	±	-	-	-	-	+
Physena madagascariensis Steud.	+	+	+	-	+	-	-
Pittosporum ochrosiifolium Bojer	-	+	+	-	+	-	-
Pseudopteris decipiens Baill.	-	+	-	-	-	-	±
Pyrostria major (A.Rich. ex DC.) Cavaco	-	+	+	-	-	-	-
Saldinia axillaris (Lam. ex Poir.) Bremek.	-	+	+	+	-	+	-
Secamone obovata Decne	-	+	+	+	-	-	-
Tachiadenus carinatus (Desr.) Griseb.	-	±	-	-	+	-	-
Tetracera madagascariensis Willd. ex Schltdl.	-	+	+	+	-	-	±

Table 4
Secondary metabolites present in the leaf samples. (+: Present; -: Absent; ±: Trace) (*Continued*).

Species	Anthraquinone	Flavonoid	Leucoanthocyanins	steroid	Triterpene	Unsaturated sterols
Brexia madagascariensis (Lam.) Thouars ex Ker Gawl.	-	-	+	+	+	+
Bridelia tulasneana Baill.	-	-	-	+	+	+
Brochoneura acuminata (Lam.) Warb	+	-	+	-	+	+
Burasaia madagascariensis DC.	-	-	-	+	+	+
Cynometra capuronii Du Puy & R.Rabev	±	-	+	+	-	-
Dialium unifoliolatum Capuron	-	+	-	+	+	+
Drypetes madagascariensis (Lam.) Humbert & Leandri	+	-	-	+	-	-
Elaeocarpus alnifolius Baker	+	-	+	+	-	+
Ludia madagascariensis Clos	+	-	-	+	-	-
Macarisia pyramidata Thouars	+	-	+	+	+	+
Noronhia boivinii Dubard	-	-	-	+	+	+
Olax emirnensis Baker	-	-	+	+	+	-
Physena madagascariensis Steud.	-	-	-	+	-	-
Pittosporum ochrosiifolium Bojer	-	-	-	+	+	+
Pseudopteris decipiens Baill.	-	-	-	+	-	+
Pyrostria major (A.Rich. ex DC.) Cavaco	-	-	+	+	-	+
Saldinia axillaris (Lam. ex Poir.) Bremek.	-	-	-	+	-	-
Secamone obovata Decne	-	-	+	+	+	+
Tachiadenus carinatus (Desr.) Griseb.	-	-	+	+	+	+
Tetracera madagascariensis Willd. ex Schltdl.	-	-	+	+	+	+

4. Discussion

All the informants who participated in this study were over 25 years old, mostly dwelling in Tampolo which is a rural area. Rural communities have been known to utilize the natural resources to satisfy their daily needs [56]. This is due to the low income, lack of alternative sources of income and lack of modern healthcare facilities within the regions [57, 58].

Despite its small size of about 1/6500 (0.015%) of the total cover the Malagasy Rainforests, the flora of Tompolo forest is highly diverse having 360 plant species [30] which represents 2.6% of the flora of Madagascar [3]. The assumption that local communities use forest plant species as timber, firewood and especially for medicinal purpose was demonstrated in this work. We found out that most of the illness encountered with these regions have been treated with plant materials. Their dependence on natural resources for their livelihood and their basic healthcare were due to their economic, lack of health facilities in the remote

regions of the country and their socio-cultural situation [59–61]. These species are utilized by the local adjacent communities to fulfill their daily livelihood needs [9, 12, 15, 62, 63].

Our findings were in sync with other botanical surveys that showed the importance of forest species to the local communities [13]. Non-severe health problem such as fever and digestive disorder were the most commonly treated with medicinal plants. Similarity in the mode of use and the recorded healing properties of several species were observed in different areas across Madagascar [64]. For example, leaves of *Phyllarthron bojeranum* DC (Bignoniaceae) were also used as treatment of fatigue in Analangazaha Farafangana [26, 65], in Ambalabe Vatomandry [21], in Antananarivo [25, 66] and in Tampolo. This is also the case of *Anthocleista madagascariensis* Baker which were an antidiarrheal [25]. Phytochemical analysis revealed the presence of active secondary metabolites which have been linked to treatment of various diseases [67] in the 20 selected forest species. However, more studies need to be undertaken to test their efficacy. The healing properties of the medicinal plants are in part due to the presence of the secondary metabolites such as alkaloids, saponins, flavonoids, tannins, glycosides, anthraquinones, steroids and terpenoids [68]. Phytochemical screening was used to detect the presence of them following the procedure of Cordell [41], Hemingway and Karchesky [42] and Bruneton [40]. Some secondary metabolites such as phenols, tannins, flavonoids and quinones show antidiarrheal effects [69–72]. Compounds such as alkaloids, phenols, tannins, iridoids, flavonoids, steroids and terpenes have been shown to have anti-inflammatory, antioxidant, antiseptic properties [69–74]. Based on these previous literatures, their presence can justify the specified therapeutic properties of the plant. In this study, *Saldinia axillaris* (Lam. ex Poir.) Bremek., indicated as antidiarrheal contains polyphenols, also *Tetracera madagascariensis* Willd. ex Schltdl., used to treat oral candidiasis, contains polyphenols and tannins which are antiseptics. However, further analysis should be done to prove an indepth understanding into their efficacy.

While the medicinal plant gathering by local people are non-destructive because the quantity of the collected leaves is relatively small and it is only for daily dose and for family use. The same holds true for the need of firewood because only the dead woods can be collected and that is under the control of the protected area managers. Moreover, although most of the population did not exceed the elementary school, awareness campaigns have been implemented by the ESSA-Forêt (Ecole Supérieure des Sciences Agronomiques-Forêt) and their partners, allowing the raise of awareness of these people of the ecological, environmental and socio-economic importance of the biodiversity that Tampolo forest shelters and that their participation in conservation acts have been noticed. However, due to the increasing demand for wood products, exploitation of the forest species focused more on the timber harvesting rather than the medicinal uses or the edibles, essentially to feed the markets of certain cities such as Fenoarivo Atsinanana and Ampasina Maningory, promoting the non-selective and illegal logging which worsen the pressures weighing heavily on the protected area. In Addition, the lack of written documents from the herbalists and the traditional healers [20] and the lack of interest from young generation to the tradition has led to the decrease of the traditional medicine and medicinal plants knowledge. This loss of knowledge were reported by Ravelonanosy in 2018 [63] while only 53 medicinal species were documented instead of 59 in 2012.

5. Conclusion And Recommendations

This survey showed that one third of the whole forest species which is about 360 species were useful plants, while 84.78% of them were endemic. This documentation of ethnobotanical knowledge provides a catalog of useful plants of the Tampolo, and will serve as a physical record of their culture for the education of the future generation. It will also strengthen their culture by recognizing their traditional knowledge on medicinal plants and providing scientific basis for it. However, the overexploitation may disturb the ecological balance of the area which subsequently can lead to the disappearance of these species. Hence, further efforts on environmental education still should be provided because Tampolo is one of the last remnant littoral forests of the East of Madagascar thus this could help conserve this area/forest. Necessary measures should also be taken to protect these most exploited species to avoid their future extinction. The current finding can be used as a reference point for various studies within the forest to help reconcile the local livelihood needs with forest conservation. Based on the findings, we recommend further studies regarding ecology, conservation and chemistry of the remaining species which constitute the flora of the littoral forest of Tampolo.

Declarations

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Author Contributions

G.E.O. conducted the interviews and completed the data analysis. C.S. and M.B.R. offered technical supports in the field, C.S., V.H.J. and G.-W.H. supervised the work, reviewed the analyzed data, and gave constructive comments. B.M.R.R. drew the map. All authors read, reviewed and approved the final manuscript. All authors have read and agreed to the published version of the manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this Manuscript

Ethics approval and consent to participate

We followed the ethical guidelines adopted by the International Society of Ethnobiology (2008). All participants were asked for their voluntary participation and had prior informed consent before the interviews were conducted.

Consent for publication

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest. If there is no role, please state "The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results".

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Figures

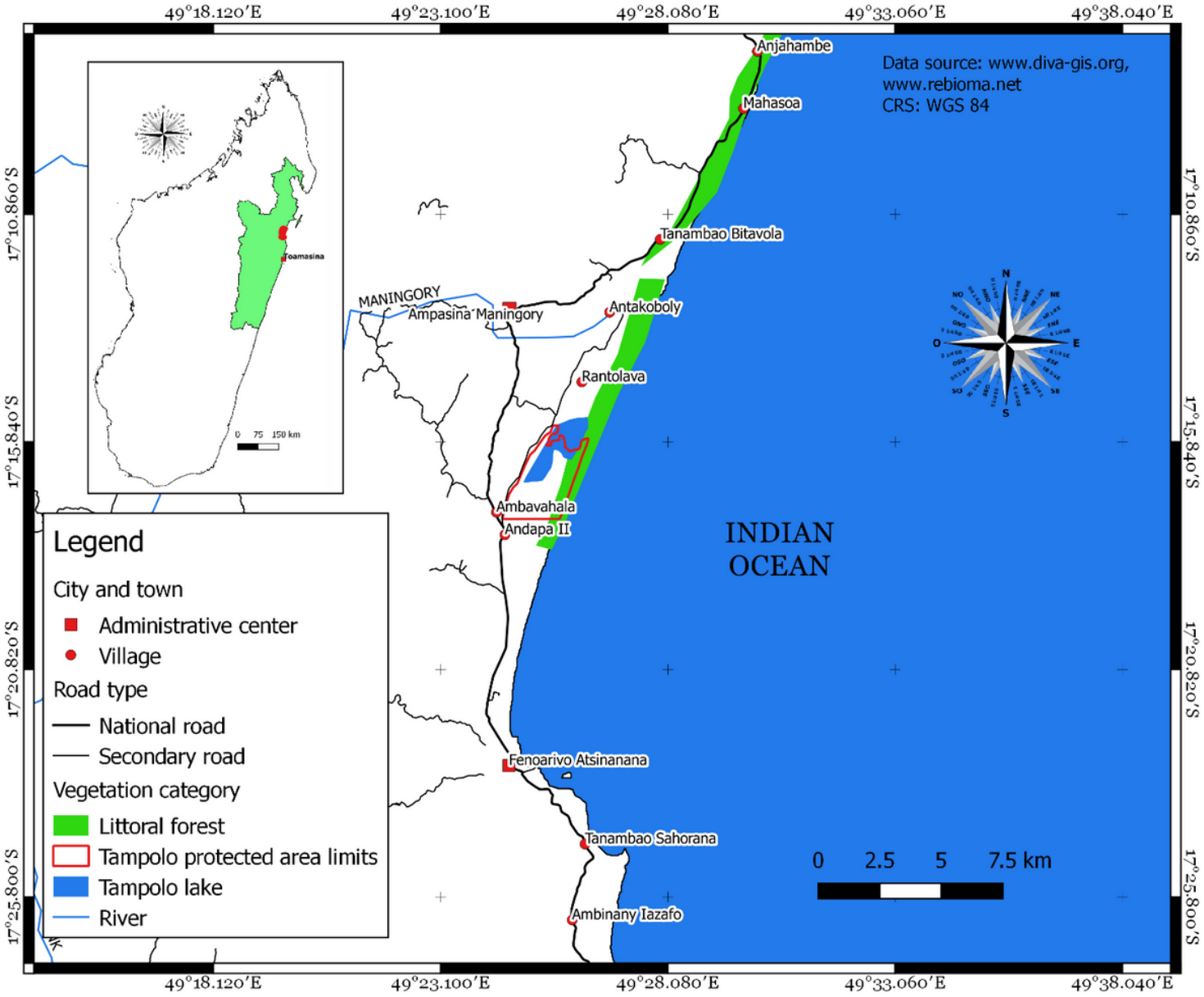

Figure 1

Map of the study area: Location of Tampolo forest and the adjacent communities living around the forest.

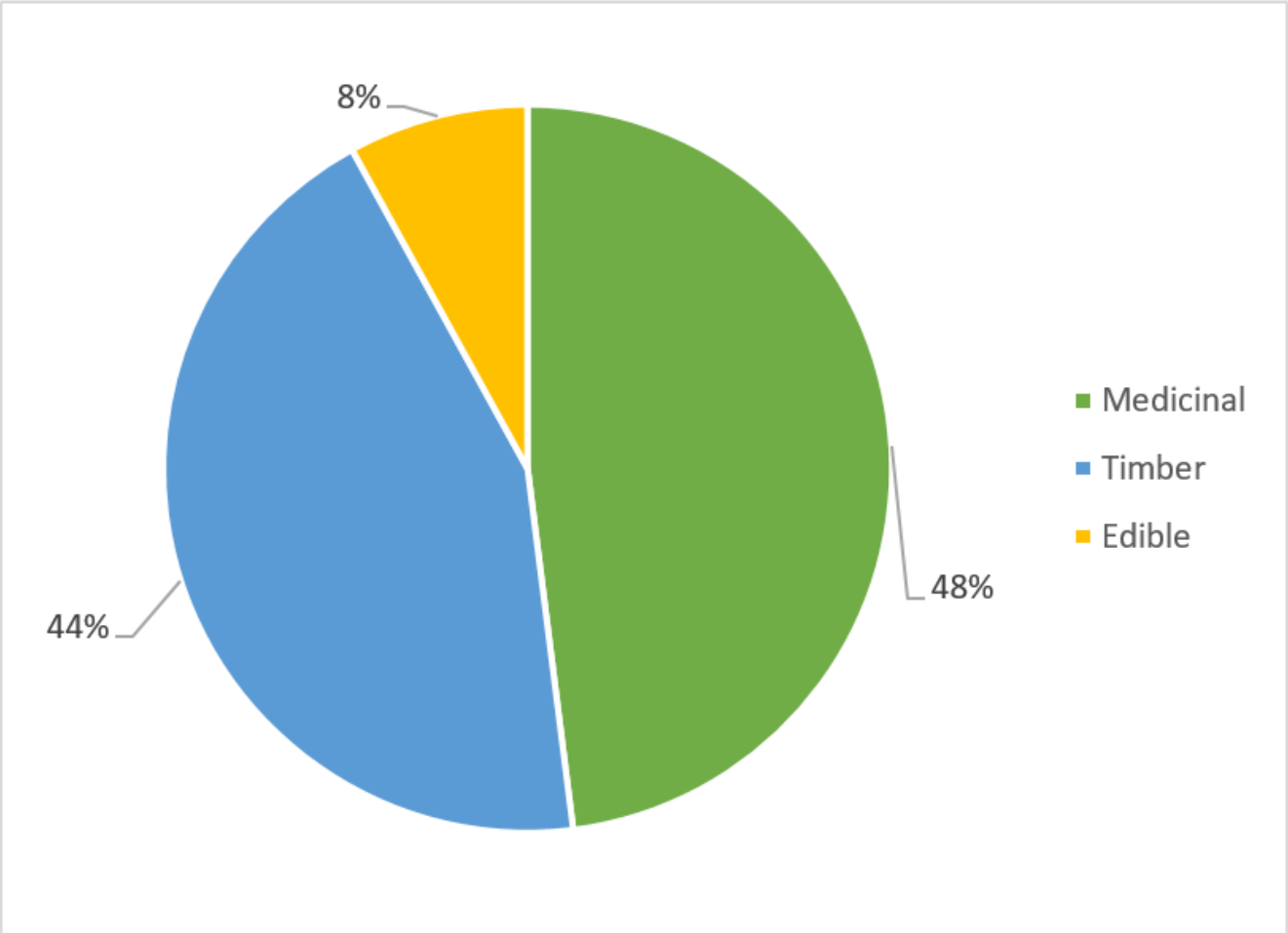

Figure 2

Graphic representation of the utilization of the plants.

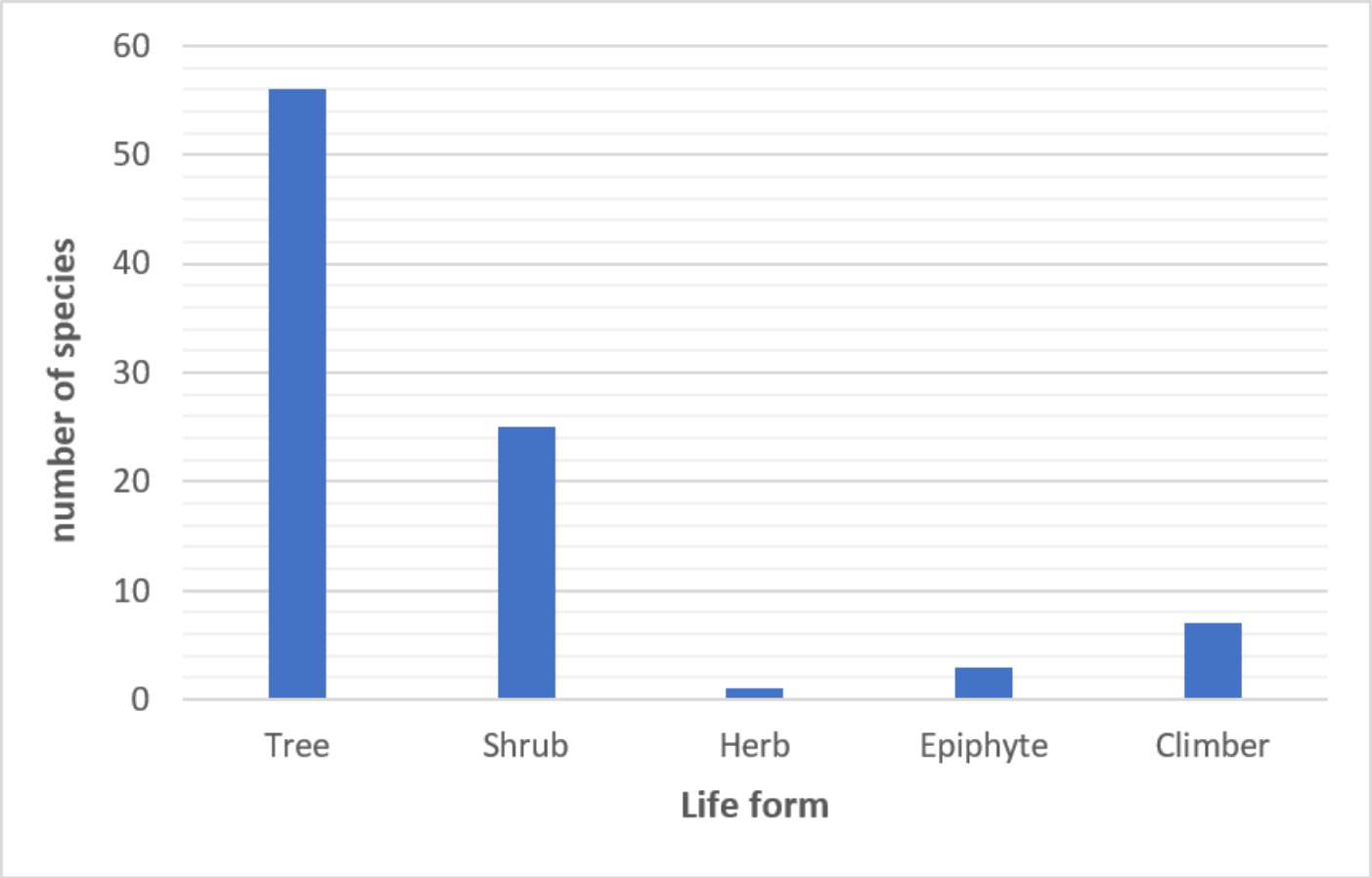

Figure 3

Distribution of species for each lifeform category.

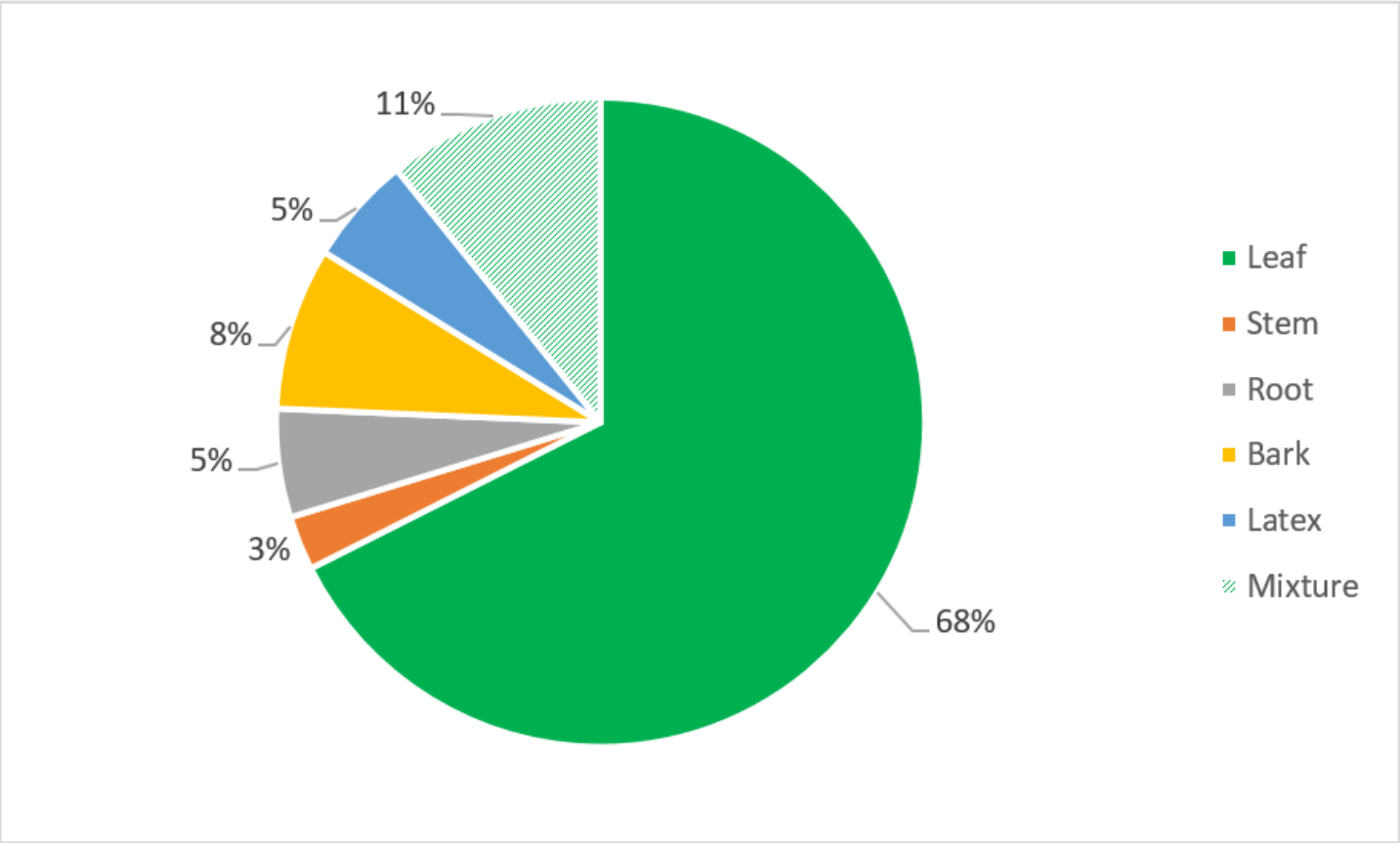

Figure 4

Graphic representation of the part of the plant used for the treatment.