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Diversity and Traditional Use Knowledge of Medicinal Plants among Communities in the South and South-Eastern Zones of the Tigray Region, Ethiopia

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Abstract: In the present study, the diversity of medicinal plants (MPs) and associated traditional knowledge of rural community herbalists to treat human and animals' diseases were assessed in two districts in the Tigray Region, Ethiopia. Study participants were randomly selected for survey and focus group discussions, while key informant traditional healers were identified through snowball/chain-referral sampling. The informant consensus factor (FIC) by ailment category and fidelity level (FL) for some MPs were determined. About 97 MP species were identified. Leaves, roots, and seeds are the parts predominantly used for phytomedication preparation to treat 30 human and 5 animal diseases. Diseases, such as epilepsy, arthritis, otitis media, and fever, are treated with a combination of 2–4 MPs. The FIC value ranged from 0.29–1.00, with most human diseases showing an FIC value of above 0.7. The FL value for the MPs ranged from 53–100%, with plants used to treat more than one disease tending to have lower FL values. Higher values of FIC and FL indicate high levels of traditional knowledge used to identify and administer medicinal preparations. Despite the frequent use of MPs, the four-cell analysis showed that most of them risk extinction due anthropogenic and climate factors. We recommend botanical gardens as a solution to sustainable conservation, study, education and a source for these declining MP species.

Keywords: botanical garden; conservation; ethnobotany; herbal medicine; medicinal plants; snowball sampling; Tigray

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1. Introduction

The Earth's plant genetic resources offer diverse services to humans and the environment. To date, just a small segment of this vast plant diversity—in particular, crops of economic importance—have been extensively studied, while studies on the vast majority of medicinal plants are lacking. Medicinal plants (MPs) play a significant role in healthcare, either as traditional remedies or in the development of modern medicines. The people of Ethiopia have traditionally used MPs to treat various human and animal diseases [1–3] and many rural populations today still depend on traditional medicine. The dependency on traditional medicine could be due to the high cost of modern drugs, the inaccessibility to modern health institutions and cultural acceptability of the system [4–6].

The importance of herbal medicine in Ethiopian healthcare has attracted the attention of ethnobotanists, to better understand the diversity, use, ecology and traditional knowledge associated with herbal/phytomedicine [7]. Medicinal plants are defined as botanicals that provide people and animals with medicine to prevent disease, maintain health or cure ailments [8]. World Health Organization (WHO) expert groups define traditional medicine as the sum of all knowledge and practices, whether explicable or not, used in the diagnosis,

prevention and elimination of physical and mental problems and relying exclusively on practical experience and observation handed down from generation to generation, whether verbally or in writing [9]. Ethiopians describe MPs as useful plants for primary healthcare and those used as remedies for curing diseases and injuries. Different parts of MPs—such as the leaves, stems, roots, bark and twigs, fruits and flowers—are used to treat various diseases. Most MPs are herbs and shrubs, with a significant number of trees also reported as being used [1,2,10]. Medicinal plants are consumed locally as foods, drinks, herbs and spices [3]. Herbal extracts are administered as dermal ointment to treat wounds, abrasions and muscular injuries or to repel insects; via inhalation to treat nasal and chest infections and flu; or they are taken orally [4]. In addition to treating diseases and aliments, MPs are used as a livelihood strategy by traditional healers who convert these natural resources into income using their indigenous knowledge [8,11,12]. The demand for popular herbal medicines is expected to increase in the foreseeable future, even in the presence of modern healthcare facilities [6] and the encouragement by WHO to adopt modern healthcare, especially for chronic diseases [13,14]. These herbal and other plant-derived extracts used as traditional medicines are gathered from the wild—along roadsides, mountains foothills, in valleys, patchy woodlands and in churchyards—with few exceptions, which requires their sustainable management and conservation if they are to be replenished, not only because of their value as a potential source of new drugs, but also due to many traditional medical practitioners' (TMPs) reliance on these natural resources as a source of income.

This important plant/tree diversity, including the number of individual varieties of MPs, is rapidly dwindling. Over decades, certain vegetation types that were used as sources for traditional medicines are drastically declining due to deforestation and uncontrolled overgrazing, climate change, and a lack of systematic conservation, coordinated research, proper harvesting practices and documentation [15]. Safeguarding these important wild plant/tree species from further decline is needed for economic, cultural, aesthetic and environmental reasons. The ethnobotanical studies conducted to document plants with unique importance for medicine and religion, and to understand the associated traditional knowledge, are therefore a pre-requisite in the design of safeguarding measures. In this paper, we present Ethiopia's medicinal plant/tree diversity and the associated traditional knowledge to treat human and animal diseases and aliments. In particular, we provide a broader perspective on the indigenous knowledge of the plant parts used, the acquired method of preparation and administration, and dosage. The paper also suggests possible conservation strategies aimed at ensuring the sustainable production and harvesting of medicinal plant diversity to overcome the impact of anthropogenic and climate change.

2. Materials and Methods

2.1. Geo-Physiological Features of the Study Areas

Our study was conducted in nine villages in the Degua Tembien and Alajie districts of the Tigray Region (Table S1 and Figure 1) in 2018 and includes geophysical and climatic conditions as well as accessibility. The villages lie between 12°53′25″–13°39′01″ E, 39°07′28″–39°32′07″ N and have an altitude range of 2455–2745 m above sea level (m.a.s.l.) (Table S1). The sampled landscape covers hills, plains and valleys, to ensure the representativeness of the study sites.

2.2. Land Use and Climate of the Study Areas

The study sites are predominantly crop–livestock farming systems and under pressure from high human population density. Land is primarily used for cereal-dominated crop production to the extent that lands unsuitable for crop production are included under this land-use category. The amount of land under natural forests, vegetation, bushes, trees and grasslands has been dramatically declining in both districts, whereas agricultural lands are expanding in response to increasing demands for food production [16]. These changes (in land-use and land-cover systems) have a great impact on the areas' agrobiodiversity and, consequently, on the sustainability of agricultural production and productivity [17]. The

districts are characterized by their bi-modal rainfall pattern, where the short (*Belg*) rains occur from March to April and the long (*Meher*) rains between June and September. The Degua Tembien district is characterized by relatively cool climatic conditions, with a mean annual rainfall of 778 mm and an average annual temperature of 15.1 °C [18,19]. Similarly, the Alajie district is characterized by cool-to-warm climatic conditions, with a mean annual rainfall of 980 mm and a mean annual temperature of 15.7 °C. The remaining months are characterized by a dry summer climate, which exposes the vegetation to long periods of drought. The soil samples were collected using an auger soil sampler and analyzed at the Mekelle University soil physics laboratory, which confirmed that the analyzed soil samples are clay loam.

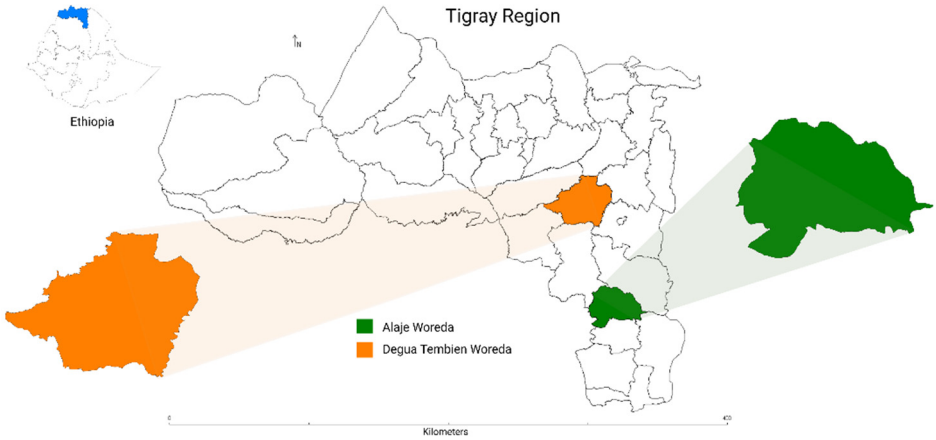

Figure 1. Location map of the study districts in the Tigray Region.

2.3. Study Participant Selection and Data Collection

A total of 135 farmers (47.4% women) participated in this study. A total of 3 villages were studied in the Degua Tembien and 6 in the Alajie districts; 15 farmers were selected from each village (Table S1). Some of the key informant traditional healers, a sub-sample of the participants from each district, were sampled through the snowball/chain-referral sampling method, while the remaining participants were randomly sampled. We conducted transect walks to collect samples of plant diversity, which were brought to one place for characterization, where participant farmers were asked to sort the plant specimens into various categories based on their use. The specimens were classified as cultivated crops, wild edible plants, wild non-edible and medicinal plants. The research team subsequently filtered out the MPs and went back to the same community to further research the MPs for traits presented in Tables 1 and 2. Data were collected through participatory focus group discussions (FGDs), followed by key informant interviews (KIIs) with eight selected traditional healers to acquire information that cannot be disclosed to the wider community. The traditional healers in each district were selected using the exponential non-discriminative snowball sampling or chain-referral method after the survey, whereby each traditional healer referred others to be included in the study. The traditional healers were considered to have good knowledge of medicinal plants due to their dependency on traditional medicine.

Table 1. Identified plants/shrubs/trees used to treat human diseases in Tigray and the associated indigenous knowledge on the plant parts used, administration type and frequency of administration (source: own data).

SN	Disease Treated	Number MPs Identified to Treat the Disease	Types of MPs	MP Parts Used to Treat the Disease	Administration	Administration Method and Frequency
1	Wound/swelling	19	Herbs/shrubs/trees	Seeds/stems/fruits/roots	Mostly topical	Ranges from a single dose to multiple applications until completely healed.
2	Abdominal pain	15	Herbs/trees/shrubs	Seeds/leaves/stems/fruits/roots/clades	Mostly oral	Dose and frequency vary, depending on patient age and plant parts used.
3	Eye infection	5	Herbs/trees/shrubs	Leaves/bark/fruits/roots	Ocular or through inhalation	Extracts of the parts applied to the infected eye in powder or liquid form. The dose varies, depending on patient age.
4	Toothache	7	Shrubs/herbs/trees	Leaves/seeds/roots	Oral	Chewing the recommended part and holding it on the affected tooth. Administration is continued until the pain ceases.
5	Hepatitis	6	Trees/herbs/shrubs	Leaves/seeds/roots/fruits	Orally or topically	The extract of the plant part is blended with butter, milk, coffee or human urine and taken orally or applied to the skin. Dosage varies, depending on the administration method applied.
6	Cough	5	Herbs/shrubs	Seeds/leaves/roots	Oral, inhalation or nasal	Boil the plant part and drink or inhale directly into the lungs until the patient is relieved of the cough.
7	Tonsilitis	6	Shrubs/herbs	Leaves/roots/stems/fruits/bark	Topical/oral	For children: crush the parts and apply dermally to the head. Adult: extract the part and take orally until the pain disappears.
8	Bone fracture/dislocation	5	Shrubs/tree	Roots/leaves	Topical	The plant parts are prepared into a paste and placed on broken or dislocated bones, and then bound with appropriate material.
9	Mental illness/epilepsy	3	Herbs	Leaves/roots	Inhalation/oral	Boil leaves and inhale the vapor. Extract of leaves and roots is eaten with injera.
10	Fever **	11	Herbs/trees	Leaves/roots	Oral/inhalation	Boil the leaves and inhale the vapor, or add the leaves to coffee or tea and drink.
11	Malaria	6	Herbs/shrubs/trees	Leaves/seed/bulb/flower	Oral	Extracts of the selected parts are blended with food or drinks and consumed.
12	Heart disease	1	Shrubs	Fruits	Oral	Eat the fruit on an empty stomach.
13	Skin infections	8	Trees/herbs/shrubs	Leaves/seeds/roots	Topical	Parts are crushed and applied to the affected area.
14	Ear infections, such as otitis media	4	Shrubs/herbs	Seeds/fruits	Topical	Extracts of the selected parts are blended with binding agents (such as butter) and applied directly into the affected ear.
15	Hair follicle infection	2	Tree/herb	Leaves/seeds	Topical	Extracts are applied to the affected part.
16	Herpes simplex virus **	6	Herbs/shrubs	Leaves/stems/roots/fruits	Topical	Extracts are applied to the affected area.
17	Arthritis	3	Shrubs	Stems/roots	Inhalation	The parts are boiled and vapor is inhaled.
18	Intestinal parasites ǂ	4	Shrubs/trees	Leaves/roots/seeds	Oral	Eat or drink the extract of the selected parts alone or with other foodstuffs.
19	Hemorrhoid	4	Herbs/shrubs	Stems/leaves	Topical	Apply plant extracts to the affected parts.
20	Headache/migraine	3	Trees/herbs/shrubs	Leaves	Topical/inhalation	Crush leaves, blended with butter and applied to the head; dried parts are put on the fire and the smoke is inhaled.
21	Constipation	2	Herbs	Seeds	Oral	Grind the seeds, mix with water and drink.
22	Evil eye (*buda*) ϯ	1	Shrub	Roots	Inhalation	Mix the root with *Hangoro midri*, boil and inhale the vapor.
23	Gonorrhea ϯ	1	Shrubs	Fluid	Topical	Apply extracted fluid to the affected area.
24	Joint inflammation	2	Herbs/shrubs	Bulbs/seeds	Topical	Blend plant part with unguents/butter and apply to the inflamed area.
25	Tuberculosis	1	Shrub	Leaves		Apply prepared plant remedy to the affected areas.
26	Herpes zoster	2	Herbs	Seeds/leaves	Topical	Boil in water and wash with it; or leaves burned to ash, blended with butter and applied to affected parts.
27	Sunstrike (Michi)	5	Herbs/shrubs	Leaves/stems/seeds	Inhalation	Boil plant parts, sometimes together, and inhale every evening until cured.

Table 1. *Cont.*

SN	Disease Treated	Number MPs Identified to Treat the Disease	Types of MPs	MP Parts Used to Treat the Disease	Administration	Administration Method and Frequency
28	Stabbing chest pain	5	Trees/shrubs	Roots/leaves	Oral	Chew the parts, swallow the juice, but spit out the residue.
29	Insect bites [δ]	2	Shrubs/herbs	Leaves/roots	Fumigation	Burn the roots and leaves and fumigate the house to repel insects.
30	External bleeding	1	Tree	Leaves	Topical	Crush young leaves and tie on to the affected part.

** Parts of two or more plants are combined and used to treat fever. ⸸ Intestinal parasites include tapeworm and hookworm, ┤ information obtained from key informant; [δ] snake and other insect repellents.

Table 2. Medicinal plants identified and the administration method used to treat animal diseases and manage insect infestations, recorded in the study FDGs.

SN	Animal Disease Treated	No. of MPs Identified to Treat the Disease	Types of Plants	Parts Used to Treat the Disease	Administration Method	Preparation and Administration
1	Abdominal pain	3	Trees	Leaves	Oral	Crush the leaves, squeeze and feed the juice to the animal.
2	Eye infection	4	Shrubs/herbs	Leaves/stems/roots	Ocular	Crush the leaves, squeeze them and apply the refined juice into the affected eye.
3	Blood-sucking insects [‡]	9	Shrubs/herbs/trees	Leaves	Topical, oral	Crush the identified part, mix with water and wash the animal's body with it.
4	Rabies	2	Herbs/shrubs	Leaves	Topical	Dry the leaves, crush them, mix with butter and apply the paste to the bite wound by the rabid animal.
5	External wound	5	Herbs/shrubs/trees	Leaves/bark/fruits	Topical	Crush the plant part, mix with water and wash the affected body part.

‡ Includes lice, leeches, and bugs.

2.4. Ethnobotanical Data Collection

The ethnobotanical surveys were carried out using a semi-structured questionnaire and KIIs in the local *Tigrigna* language. Participants' informed consent to document and disseminate their local knowledge was obtained before the administration of the survey through conversations with local enumerators who explained the objectives of the study. After consent was provided in each district, we undertook a transect walk, covering approximately 3 km^2 to collect the medicinal plants analyzed. Several transect walks were carried out in each village, in various directions, to sample the representative plants for the study. Researchers from Mekelle University and development agents from each district who spoke the local language facilitated the transect walks and sample collection processes.

To further study the part or parts of the identified MPs used for medicinal purposes, their method of preparation and administration, 45 farmers were re-sampled from the 135 participant farmers for a second round of FGDs (Table 1, Table 2 and Table S1). Key informant traditional healers in each district were interviewed to obtain their traditional knowledge. The FGDs and key informant interview data on the ailments/illnesses treated by MPs were collected, and we identified 30 (for human) and 5 (for animals) ailments/disease types, respectively (Tables 1 and 2).

2.5. Data Analysis

Descriptive statistics, such as the percentage and frequency, were employed to summarize the ethnobotanical data. The factor of informant consensus (*FIC*) was calculated for categories of human/livestock ailments to identify informants' agreement on the reported cures following the approaches used by other scholars [20,21]. *FIC* was calculated as follows: the number of use citations for aliment categories (n_{ur}) minus the number of species used (n_t) for that aliment, divided by the number of use citations for each aliment, minus one.

$$FIC = \frac{n_{ur} - n_t}{n_{ur} - 1} \quad (1)$$

The fidelity level (*FL*)—the percentage of informants claiming to use a certain plant species for the same major purpose—was calculated for the most frequently reported ailments, as described by Alexiades [22]:

$$FL(\%) = \frac{N_p}{N} \times 100 \quad (2)$$

where N_p is the number of informants that claim the use of a plant species to treat a particular disease and N is the number of informants that use the plants as a medicine to treat any given disease. The average amount of variability in the analyzed variables was presented as the standard deviation (*SD*), calculated for the sampled MPs from the target areas.

The distribution pattern of the MPs was analyzed using four-cell analysis (FCA). The participants were asked to place the collected samples of each medicinal plant species into one of the four quadrants of the FCA, and the total number of species in each quadrant was counted. According to the standard definition of FCA [23], species' allotment into the different quadrants using a participatory methodology indicates both the abundance and distribution pattern, including different levels of conservation concern.

3. Results

3.1. Diversity of MPs Identified in the Study Areas

Despite the study covering only a small portion of the Tigray Region, 97 medicinal plants pertaining to over 90 species were identified by local communities in the *Degua Tembien* and *Alajie* districts (Tables 1, 2 and S2), with a non-uniform distribution across the districts. The MPs identified were classified into three groups: 44 (45.4%) herbs, 34 (35%) shrubs and 22 (19.6%) trees (Tables 1 and S2 and Figure 2). Of all the MPs identified,

herbs were the most abundantly used for the treatment of human and animal diseases within these communities, closely followed by shrubs and, to a much lesser extent, trees.

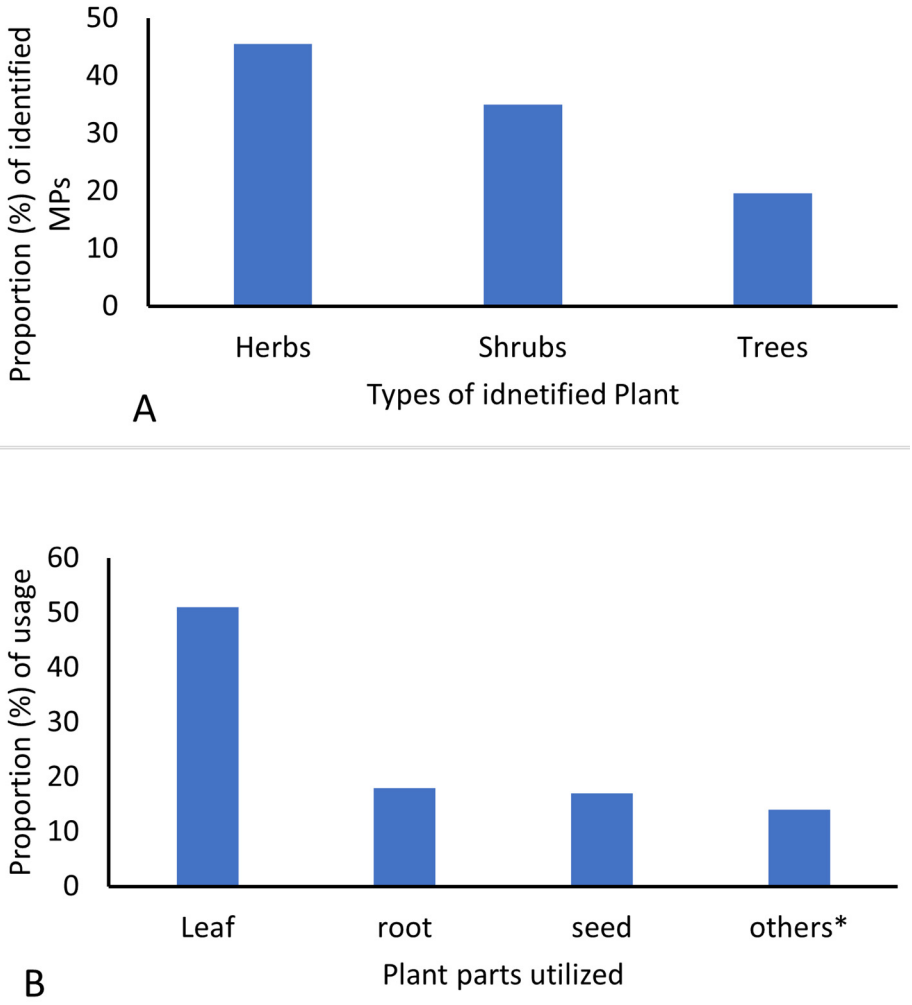

Figure 2. (**A**) Forms of identified MPs. (**B**) Plant parts and the proportion used in the preparation of herbal remedies. Others* include barks, bulbs, clade, flowers, fluid and stem.

According to the FGD participants, fresh plant specimens are most-commonly used by traditional healers in herbal medicine preparation. Plant parts include leaves, roots, seeds, latex (fluids), stems, bulbs, bark, clades, and flowers (Figure 2A). Most of the herbal remedies were prepared from leaves (51%) and, to a lesser extent, the roots (18%) and seeds (17%), compared to other parts, such as the stem, bark, milk, clades, flowers, and latex (Figure 2B).

3.2. Diseases Treated Using Herbal Medicine

The local communities of the Degua Tembien and Alajie districts use MPs to treat about 30 human and 5 animal diseases, and to repel insects (Tables 1 and 2). The number of MPs identified to treat a single disease ranged from 19 (wound/swelling) to 1 (external bleeding) for humans, and 9 (for blood sucking insects) to 2 (rabies) for animals. The types of human diseases reported to be treated by these various medicines include wounds/swelling, abdominal pain, eye infection, toothache, hepatitis, cough, tonsilitis, bone fractures, mental illness/epilepsy, fever, skin infections, ear infections, hair follicle infection, herpes simplex virus, intestinal parasites, hemorrhoids, and herpes zoster (Table 2). Similarly, locally sourced MPs are used to treat animal diseases, such as rabies, wounds, abdominal pain, and eye infections, and to rid them of infestation from blood-sucking insects (Table 2).

The largest diversity of medicinal plants (19) is used to treat wounds/swellings, which is presumably associated with injuries linked to the rural communities' means of living. The probability of obtaining a topical abrasion or injury while operating on farms, collecting and gathering foods, medicinal plants and/or firewood, and the common practice among rural communities of traveling barefoot from place to place, might justify why so many of the herbal plants identified are used to treat wounds and swellings.

3.3. Local Knowledge of Traditional Medicine

In Ethiopia, rural communities' lifestyle, coupled with poor accessibility to and affordability of modern medicine, drives the demand for natural remedies to treat both human and animal diseases. Our study confirmed that both communities in Degua Tembien and Alajie are endowed with traditional knowledge about MPs, the parts to be used to treat diseases, as well as methods of herbal medicine preparation, administration, and application frequency (Tables 1, 2 and S2). The FIC values calculated ranged from 0.29 to 1.00, with most of the diseases having an FIC value greater than 0.7 (Table 3).

Table 3. FIC values of the therapeutical uses of medicinal plants.

SN	Therapeutical Use	Number of Medicinal Plants Used (N_t)	Use Citation (N_{ur})	FIC Value
1	Wound/swelling	19	153	0.88
2	Abdominal pain	15	50	0.71
3	Eye infection	5	46	0.91
4	Toothache	7	34	0.82
5	Hepatitis	6	23	0.77
6	Cough	5	20	0.79
7	Tonsilitis	6	52	0.90
8	Bone fractures/dislocation	5	35	0.88
9	Mental illness/epilepsy	3	8	0.71
10	Fever	11	29	0.64
11	Malaria	6	31	0.83
12	Heart disease	1	4	1.00
13	Skin infections	8	26	0.72
14	Ear infections, such A otitis media	4	30	0.90
15	Hair follicle infection	2	4	0.67
16	Herpes simplex virus	6	8	0.29
17	Arthritis	3	25	0.92
18	Intestinal parasites	4	52	0.94
19	Hemorrhoids	4	12	0.73
20	Headache/migraine	3	42	0.95
21	Constipation	2	12	0.91
22	Evil eye (buda)	3	16	0.87
23	Gonorrhea	2	23	0.95
24	Joint inflammation	2	13	0.92
25	Tuberculosis	1	12	1.00
26	Herpes zoster	2	8	0.86
27	Sunstrike (Michi)	5	51	0.92
28	Stabbing chest pain	2	14	0.92
29	Insect bite	2	27	0.96
30	External bleeding	3	33	0.94
	SD	*4.01*	*27.64*	*0.14*

SD = standard deviation.

We report higher FIC values for many of the diseases, which might indicate the higher incidence of these diseases within the community. However, diseases treated by herbal medicines, but only known to traditional healers, had lower FIC values. Diseases, such as wounds/swelling, eye infection, tonsilitis, ear infection, constipation, gonorrhea, and joint inflammation, have a relatively higher FIC value, which might indicate the higher incidence of these diseases in the two districts. Disease types that are treated by traditional healers

and those that are rare have lower FIC values. These include mental illness/epilepsy (0.71), fever (0.64), hair follicle infection (0.67), and herpes simplex virus (0.29). On the other hand, disease types treated by a single or combination MPs tend to have a higher FIC.

The FL values for all MPs ranged between 53 and 100% (Table 4). Similarly, MPs that are frequently used by the local community have higher FL values than those that are less popular; but MPs only known to traditional healers to treat single diseases usually have an FL value of 100% (Table 4). For instance, *Brassica nigra* L. and *Ruta chalepensis* L.—plants grown by most households as home-garden vegetables for food, and that are also used to treat coughs, malaria, and fever, among other ailments—have an FL value of 100%, while MPs known to few traditional healers, such as *Rumex nervosus*, *Merendra bengalensis* and *Artemisia abyssinica*, have <70% FL values (Table 4). Similarly, MPs used to treat diseases, such as the herpes simplex virus, evil eye, gonorrhea, stabbing chest pain, and external bleeding, are known to few community members and hence have a lower FL.

Table 4. Fidelity level (FL) values of some local commonly used medicinal plants (MPs).

Sn	MPs	Therapeutical Use	N_p	N	*FL* Value (%)
1	*Allium sativum* L.	Toothache, malaria, coughs	51	53	96
2	*Aloe megalacantha* Bark	Abdominal pain, ameba, gonorrhea, dislocated bone	32	48	67
3	*Artemisia abyssinica* Sch.	Mental illness/epilepsy, Agnin	8	12	67
4	*Brassica nigra* L.	Coughs, malaria	53	53	100
5	*Calputina avena* (Ait)	Hepatitis	30	50	60
6	*Dodonia augustifolia* L. f	Bone fractures, hair follicle infection, wounds	24	40	60
7	*Eucalyptus globulus* Labili	Migraine, fever, Michi (sunstrike)	50	53	94
8	*Melia azandrachata* L.	Abdominal pain	45	50	90
9	*Merendra bengalensis*	Epilepsy	6	8	75
10	*Ricinus communis*	Wounds	48	53	91
11	*Rosa abyssinica*	Arthritis	10	14	71
12	*Rumex nervosus*	Herpes simplex virus	8	15	53
13	*Ruta chalepensis* L.	Fever, coughs	53	53	100
14	*Solanum bastifolium*	Otitis media	9	12	75
15	*Verbena officinalis*	Tonsillitis, abdominal pain	37	51	73
	SD (*sample*)		18.73	18.98	15.74

SD = standard deviation.

3.4. Herbal Medicine Preparation, Form, and Dosage

Different plant parts are used to prepare herbal medicines (Figure 2) through drying, chopping, maceration, boiling, direct compression of the fresh leaves against ailing parts, and squeezing the liquid contents. Detailed methods of the preparation, administration and doses are presented in Table 1, Table 2, and Table S2. The key informant traditional healers may combine two or more MPs to treat certain diseases, such as epilepsy, fever, arthritis, otitis media, herpes simplex virus, and bone fractures (Table S2).

The most common administration methods for the herbal medicines are summarized in Figure 3, which are oral (43%), topical (38%), inhalation (13%), nasal (4%) and ocular (2%). The dose and frequency of the administration are also determined by the number or size of the leaves, stems, roots, seeds, or fruits prepared. Most of the herbal medicines are administered once daily for a few days (ranging from a day to seven days). There are cases in which the medicines are administered for months, until the ailment is cured. The informants indicated that, when herbal medicines are administered for the first time, the initial doses are small and are gradually increased and adjusted as a result of observing the patient's condition and symptoms. When new herbal medicines are tried for the first time, milk or whey is prepared and set aside, ready to be given to the patient, in case signs of toxicity are observed. We also learned from the participants in *Degua Tembien* that whey is administered to women after childbirth to ensure rapid uterus recovery and to improve their libido.

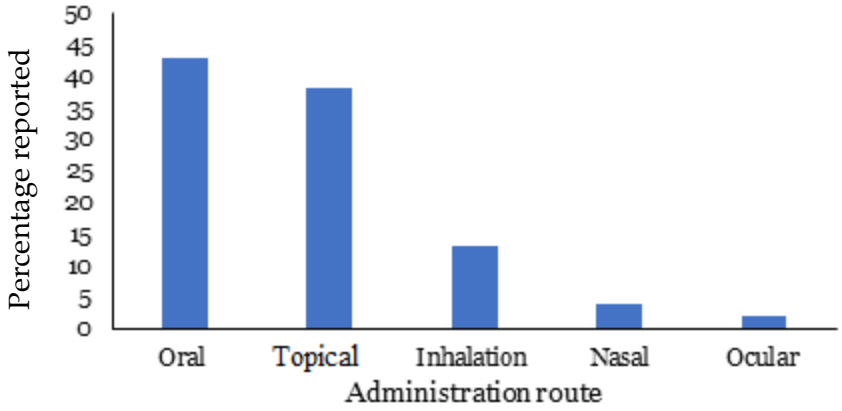

Figure 3. Most common methods for the administration of herbal medicines.

3.5. Abundance of the Identified Medicinal Plants

The MPs sampled during the transect walk and those brought by participant farmers were analyzed for their abundance using FCA (Figure 4). Most of the sampled MPs can be classified as rare. MPs, such as *Rhamnus prinoides* (*gesho*), *Ruta chalepensis* L. (*Tena Adam*) and *Brassica nigra* L. (*Senafich*), are cultivated as backyard crops on small areas of land by many farmers, and are hence not under threat of extinction. The participants indicated that samples of the studied MPs were mostly collected from gorges, valleys, mountains, under hedgerows, roadsides, patchy woodlands, church compounds, and homestead backyards, implying that MPs grow mainly in inaccessible places, other than on cultivated land. These resources are under the threat of extinction due to anthropogenic and natural factors. The participant farmers claimed that the associated indigenous knowledge is also threatened because of reduced interest from the younger generations to learn about the MPs and their use for medicinal purposes. The anthropogenic factors threatening the survival of MPs include the expansion of agricultural lands, and the overgrazing and overharvesting of the plants by traditional healers. Drought has been mentioned as the major climatic factor reducing MP diversity in both areas. Some key informants indicated that many medicinal plants they had once collected in their area have been lost, forcing them to travel long distances—even to other districts, such as Axum—in search of these specific plants.

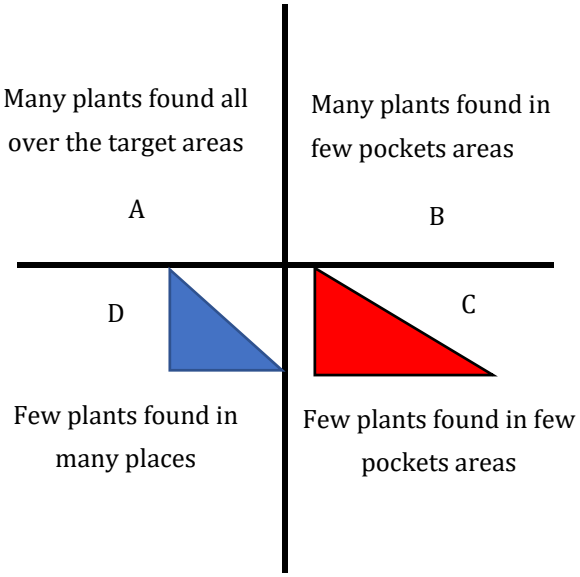

Figure 4. Four-cell analysis showing the status of MPs in the study areas. None of the sampled MPs are in quadrant ((**A**)—many plants found all over the sampled areas) and quadrant ((**B**)—many plants in few pocket areas). However, most of the MPs identified by the current study were categorized in

quadrant ((**C**)—few plants growing in few pocket areas), the red triangle. This imply that these MPs are under the threat of extinction. The blue triangle in quadrant ((**D**)—few plants dispersedly covering wider areas) shows few MPs growing in few pocket areas.

4. Discussion

This study identified 97 MPs in the *Degua Tembien* and *Alajie* communities of Ethiopia. This implies that there is a wealth of biological resources available for community health care in areas where physical accessibility and economic affordability of modern medicine is lacking, thus continuing the demand for natural medicines. Most of the MPs identified are herbs followed by shrubs, and the most harvested parts used in the preparation of traditional herbal medicines include the leaves, roots, seeds, stems, and fruits. These preparations can be administered in various forms and in different doses and frequencies to cure approximately 30 human and 5 animal diseases, in addition to controlling pest and insect infestations (Table 2).

This data aligns with those collected by many other scholars on the dominance of herbs and shrubs as selected MPs by traditional healers, who mainly harvest the leaves, roots, and seeds [24–26]. The practice of using traditional medicine, identifying the plants, their specific parts, and the tendency to use similar groups of plants, mainly herbs and shrubs, throughout Ethiopia suggests that the transfer of this traditional knowledge may have originated or have been spread through common venues, such as churches, which have had a profound and extensive impact in the country. In particular, the knowledge of traditional medicine in the Ethiopian Orthodox church dates back to the 15th century AD, even though the *Metsehafe Fews* (book of remedy) text of first traditional remedies was published around the mid-17th century in the *Ge'ez* language [7,27].

Herbal medicines are administered in various forms (Figure 3), with oral and topical administration being the most extensive. Again, the literature cites other studies conducted in various parts of Ethiopia and elsewhere in the world [11,12,27], where the same methods of administration were also reported. Even though not well captured in the literature, some herbal medicines are also administrated through the ear. Herbal remedy preparations are usually taken with water, milk, coffee, honey and bread, or injera at varying doses, depending on the age of the patient and the type of the disease. Lower doses are usually administered to children, lactating and pregnant mothers, and seriously ill persons.

About 30 types of humans and 5 animal diseases and pest infestations are treated with herbal medicines, which are prepared from a diversity of plant species in the two communities (Tables 1 and 2). For instance, 19 and 15 plant species were known by the communities to treat wound and abdominal pains, respectively. On the other hand, single plant species are known to treat some disease types, such as the evil eye, gonorrhea, tuberculosis, heart disease, and external bleeding (Table 1). Some plants are also used to treat diseases, such as the herpes simplex virus, herpes zoster (*Almaz belechira*), and epilepsy, for which modern medicines are not widely available in the rural areas of Ethiopia. This data reflects similar findings reported by studies conducted in other parts of Ethiopia [4,16,20,28]. In some cases, MPs are prepared in combinations. For instance, a combination of *Ocimum lamifolium* and *Ruta chalepensis* parts are prepared to treat fever. Similarly, three plant species (*Olea europea* + *Eucalyptus globulus* + *Schinus mole*) are combined in preparations that also treat fever, which presumably indicate the wealth of traditional knowledge of MPs. The human herpes simplex virus is treated with extracts prepared from a combination of four medicinal plant species (*Rumex nervosus* + *Lepidium sativum* + *Citrus aurantifolia* + *Plumbago zeylanica*). The combined use of two or more medicinal plant species to treat human and animal diseases was also reported in different parts of Ethiopia [20,29]. These combination medicines are prepared from MPs that contain a range of pharmacologically active compounds that could make it difficult to know which plant or specific part contributed the ingredients that produce the therapeutic effect [30]. Overall, the FIC value ranged from 0.29 (for human simplex virus) to 1.00 (for heart disease) (Table 3). Diseases treated with single MP preparations tend to have higher FIC values. The magnitude of the FIC and FL is likely to vary between localities and studies.

For instance, Mengistu et al. [21] reported a higher FIC value for abdominal pain than that reported in our study. On the other hand, Teklehaymnot and Giday [20] reported a lower FIC value for "evil eye" than our study, but comparable FL values for common MPs. The knowledge about MPs' FIC and FL values is helpful in distinguishing MP species known to the wider community and those only known to a few traditional healers. This knowledge is important in the design of further MP studies, and conservation and production strategies.

The 98 MPs identified, pertaining to more than 90 species, from which are derived a broad diversity of herbal medicines, the diverse dosage of prescription, and forms of administration indicate that the two communities have a wealth of traditional knowledge in regard to traditional medicine. This is presumably because MPs make up the main source of health remedies and natural medicines used to treat the majority of people in rural Ethiopia. Traditional healers provide these cures at a much lower cost to rural communities than modern medicine [31,32]. However, traditional healers' indigenous knowledge cannot be fully captured and documented in ethnobotanical studies, as the procedures of herbal medicine preparation and administration remain a guarded secret. This is partly because herbal medicine is the foundation of their livelihood and is therefore considered as a business strategy; secondly, many traditional healers believe the more their knowledge is shared, the less effective and powerful their medicines become [11,12,27]. They would not disclose certain aspects of their practice, even to researchers for scientific purposes. The importance of MPs as a source of income for traditional healers and cheap medicine for the community justifies the need for their conservation through sustainable utilization. However, the fact that they are not cultivated or that they grow in remote locations or are being over-harvested may not make this possible, unless collected and grown in botanical gardens.

The scarcity of the species samples collected during the transect walk sounds the alarm for the dwindling species abundance in both study areas (Figure 4). This scarcity could be largely associated with the destruction of natural habitats from the expansion of farmlands, under pressure from continued population growth and the need for crop cultivation. Such human-driven factors were reported as major causes of the loss of many thousands of hectares of forest, harboring medicinal plants, every year over several years in Ethiopia [10,33,34].

To protect these valuable plant species and preserve the associated indigenous knowledge of herbal medicine, organized conservation and cultivation centers need to be established. The establishment of botanical gardens for medicinal plants could be suggested for both the studied sites for multiple purposes. Botanical gardens would play a key role in the conservation, production, and utilization of the already threatened MP species. In addition to conservation, they would create opportunities for research activities related to their ecology, taxonomy, breeding, biotechnology and pharmacology, and could serve as education centers for students and the public. We posit that the establishment of botanical gardens would:

1. Increase the interest of the young generations in the use of herbal medicine for health maintenance and treatment.
2. Promote herbal medicine as a livelihood strategy for many individuals.
3. Continue to provide traditional healers with access to traditional MPs within their vicinity, so that they are not forced to travel long distances to gather them.

Furthermore, the sustainable production, use, and conservation of these plants would be ensured. The botanical gardens will be of increasing importance to conserve existing biodiversity by reducing the effects of anthropogenic and climate change on these important biological resources.

5. Conclusions

The diversity of MPs in *Degua Tembien* and Alajie is high, compared to the diversity presented in other studies in other parts of Tigray. The communities treat a broad range of common and important human and animal diseases with these natural resources. The indigenous knowledge of processing and administering herbal medicines is quite rich.

Despite these facts, MPs are mostly located along roadsides, in valleys, at the foothills of mountains, in patchy woodlands and in churchyards, mostly because of the expansion of agricultural land, deforestation and climate change. Furthermore, the unplanned and unsustainable practices of traditional healers, for example, uprooting MPs for harvesting root parts, could mainly be attributed to the decrease in or loss of these plants. Therefore, interventions that closely engage and inform herbal medicine harvesters are important to halt and reverse the negative impact they impose on these natural resources. One such intervention strategy could be the establishment of botanical gardens at both study sites. These would support the conservation of these valuable genetic resources, serve as an open space for research, act as education hubs to promote a wider appreciation for their use among younger generations, and enable traditional healers to access sustainably harvested MPs in a single place.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d14040306/s1, Table S1: Geophysical location and cropping system of the study locations within each district, and Table S2: Medicinal plants used to treat diseases (both human and animal) in the Degua Tembien and Alajie districts, Tigray.

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