Ethnoecological investigation of medicinal plants in Andracha District, Southwest Ethiopia

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Research

Abstract

Background: Ethiopian traditional medicine has been a key aspect of the primary healthcare system for a prolonged period. The current study documented medicinal plants and associated knowledge with threats in the Andracha District of Southwest Ethiopia. It explored the link between informants' knowledge and their demographics.

Methods: The study was conducted from November 2020 to April 2022 where 128 respondents (88 regular and 40 healers) participated. Data was collected using semi-structured interviews, focus group discussions, market surveys, and field observations. Authenticated voucher specimens were deposited in the herbarium. Data analysis was through ethnobotanical indices complemented with statistical tests, models, and ordination methods in R software.

Results: A total of 100 medicinal plants in 88 genera with 47 families were identified. Asteraceae and Lamiaceae are the most frequent. Herbs were the most dominant. Leaves followed by roots were the most utilized plant parts. Fresh preparations were the most preferred, with oral administration being the most common, followed by topical use. Firewood, invasive alien species, and charcoal were the most threatening factors. Significant associations among informants' knowledge and their demographics were observed.

Conclusion: Traditional ethnomedicinal plant knowledge documented in Anderacha district significantly adds to the current ethnomedicinal plant knowledge of Ethiopia. *In situ* conservation priorities are needed to minimize the ever-declining number of medicinal plants, endemic species such as *Echinops kebericho, Erythrina brucei, Milletia ferruginea*, as well as associated indigenous knowledge due to threatening factors.

Key words: Biodiversity, Biosphere reserve, Culture, Ethnobotany, Ethnomedicine, Herbalists.

Background

Plants have been essential sources of human medicine for millennia (Bussmann & Sharon 2006; Davis & Choisy 2024). According to (Zemede *et al.* 2024), people's reliance on medicinal plants in developing nations is due to poverty and limited access to modern medical care. Hence, medicinal plants remain a critical element of the human healthcare system in many

parts of the world. About 80% of the world's population depends solely on traditional remedies for healthcare (Assigbaase *et al*. 2023). Ethnobotany is the interaction between people and plants (Cotton 1996). It analyzes the results of indigenous manipulation of plant materials with the cultural context in which plants are used (Balick and Cox 1996). Hence, it is the invaluable insights into the relationships between plants and human cultures (Matin 2010). Particular emphasis regarding traditional knowledge, medicinal practices, and sustainable resource use, are among the key provisions of the science of ethnobotany (Yebouk 2025). The preservation of nature, culture, and biological diversity and the variety of traditional human cultures worldwide is greatly aided by ethnobotany (Asigbaase *et al*. 2023; Derso *et al*. 2024).

Ethnobotanical studies are helpful in recording, evaluating, and disseminating information about the relationship between plant biodiversity and human society, as well as how human activities use and impact plant diversity in nature (Balick and Cox 2020). Ethiopia has a variety of climates and ecological conditions, and its fauna and flora are incredibly diverse (Assefa *et al.* 2020). Several studies reported that 80% to 90% of Ethiopians rely on traditional medicine, primarily medicinal plants, for their primary healthcare needs (Derso *et al.* 2024; Tuasha *et al*. 2023; Zemede *et al.* 2024). Studies showed that 95% of Ethiopia's traditional medicinal preparations come from plants (Tadesse and Teka 2023; Teka *et al.* 2020a; Teka *et al*. 2020b). Ethiopia is renowned for having a wide range of geographical diversity, responsible for having various vegetation and habitat zones (Assefa *et al.* 2020). Ethiopia is also home to several languages, cultures, and beliefs, all of which have influenced the people's traditional knowledge and practices, including medicinal plants (Tamene *et al.* 2023). Ethiopian plants have proven to be highly effective in treating human illnesses. Because of their centrality, the communities' faith in the therapeutic benefits of traditional medicine, and the comparatively low cost of using them, medicinal plants are in high demand in Ethiopia (Tadesse *et al.* 2024). Traditional medical knowledge is passed down orally, and practitioners play a key role in this process (Tadesse *et al*. 2005).

The latest academic flora of Ethiopia and Eritrea documented 6027 taxa of which 647 are endemic (Demissew *et al.* 2021). About 887 of the vascular plants have reportedly medicinal value (EBI 2009). Hence, a synthesis of the proportion of the medicinal plant species and the endemic plant species to the total vascular plants in the Flora of Ethiopia and Eritrea is about 15% and 10.74%, respectively (Abro *et al*. 2024; Tessema *et al.* 2025). Hence, the Ethiopian vegetation is a reservoir of medicinal herbs traditionally used by indigenous communities (Hedberg *et al.* 2009).

Traditional medicines have made substantial contributions to society (Abro *et al.* 2024). They have received little attention in contemporary research and development practice (Derso *et al.* 2024). Ethiopian higher education institutions and health authorities have only recently expressed interest in advancing and developing it. Following the concentration of biological and cultural diversity, the Southwest region of Ethiopia is more abundant in medicinal plants. However, deforestation, environmental deterioration, and population growth cause a serious threat to this wealth of medicinal plant knowledge. A loss of indigenous knowledge resulted from these grave factors, endangering the nation's forest, which provides medicinal plants.

People from Andracha District have a traditional rural lifestyle and a close relationship with plants. Compared to other parts of the country, the area lacks infrastructure, like schools and medical facilities, despite having more forest cover in a multitude of varied and mostly intact traditional cultures. Therefore, recording traditional medicinal plants is crucial for local healthcare, and exploring uncharted territory can help to modernize and strengthen the cultural diversity of the area.

According to traditional healers in the Andracha district, the study area was the most isolated from hospitals and health centers. As a result, patients were at risk of dying from various illnesses, leaving them with no choice but to use traditional medicine. Additionally, because of the area's dense forest cover and the high level of interaction between the local population and the forest or natural vegetation, the inhabitants have been attacked by snake bites, jaundice, and worm bites (locally known as KOSHKOSHO in Shekinono language). These diseases are treated with traditional medicines with the assistance of traditional healers who possess indigenous knowledge, rather than any other modern medicine. Numerous factors, including population-related agricultural expansion, overgrazing, firewood, deforestation, charcoal, construction materials, and cash crop expansions like *Catha edulis* and coffee (*Coffee arabica*), due to private investor investment, hurt medicinal plants in the study area. The study explored whether there is a significant link between informants' knowledge and their demographic characteristics (gender, literacy level, experience of informants, and age groups) in detail.

Even though researchers in Ethiopia have conducted ethnobotanical documentation on various ethnic groups over the past few decades, only a few studies have focused on southwest Ethiopia, revealing methodological, spatial, temporal, and theoretical gaps. In research conducted by kassa *et al.* (2020), for instance, to cover the entire Shake Zone, where the most

remote and inaccessible sub districts remained uncovered. It was due to inaccessibility, time, and financial constraints. Many of the methods used in ethnobotanical studies are time-consuming and moderately costly, making it impractical to apply all in a single period of field work (Martin 2010). Making several trips to the field is expensive. However, the most satisfactory projects from personal viewpoints, community, and colleague perspectives span several seasons and continue for several years. It will also fill the gaps arising from undermining reproducibility (Yebouk 2025).

Documenting and preserving local ethnobotanical knowledge is essential to understand community's knowledge and reliance on plant based traditional medicine (Gitima *et al*. 2025). It is crucial for creating sustainable biodiversity conservation, cultural preservation and identity, minimize threats to traditional knowledge, integrate and validate indigenous knowledge with modern science and ensure access and benefit sharing with recognition. The Andracha District is among the most remote areas in Ethiopia, where detailed ethnobotanical studies and documentation were not fully covered. There are pool of ethnomedicinal knowledge system in the district contributing to range of primary healthcare system.

Thus, conducting a comprehensive ethnobotanical study in Andracha District focusing on the most remote sites is required to record and examine the traditional knowledge and practices of the locals, with an emphasis on medicinal plants for the treatment of human ailments. It will help to preserve and utilize biodiversity. Our knowledge of Ethiopia's remarkable traditional plant-based healthcare system will also be enhanced by comparing the study's findings with the Ethiopian ethnobotanical medicinal plant database, offering insightful information about the regional distribution and use of medicinal plants. The study primarily aimed at documenting medicinal plants, associated indigenous knowledge, and major threats. The statistical analysis involving ethnobotanical indices coupled to ordination methods was used to display the structure of relationships among plants and humans. In detail it aims to; (a) document the medicinal plants and the associated indigenous knowledge utilized by local communities detailing their ethnobotany; (b) Investigate how socioeconomic factors influence the utilization and transmission of ethnobotanical knowledge within these communities; (c) identify and analyze the key threats facing medicinal plants and assess existing conservation strategies; (d) explore the cultural significance of medicinal plants within local communities; (e) formulate policy recommendations based on research findings to guide local government and conservation organizations in developing strategies for the sustainable management of medicinal plant resources in Anderacha District.

Materials and Methods

Study Area

The study was in the southwest Ethiopian Sheka Zone, in the Andracha district. It is located between latitudes 7.39 and 7.81 degrees north and longitudes 35.24 and 35.5 degrees east. The study area is between 1001 meters and 3000 meters above sea level. About 102,000 hectares form its land mass, divided into 17 sub-districts. Gecha is the only city in the woreda. It is located 714 kilometers north of Addis Ababa. The district shares borders with Masha to the north, the Gambela Region to the southwest, the Oromia Region to the northwest, Yeki to the south, and the Kafa Zone to the east (Figure 1). Farming and trading are the people's primary occupations. Shekinono is the primary language spoken in the area, and the Sheka people make up the major inhabitants. About 36,495 people live there in total. Among them, 18,318 are men and 18,177 are women (ESS 2017). Andracha district belongs to the Sheka Biosphere Reserve, which is among the five biosphere reserves founded in Ethiopia.

Climate

According to climate data from the Ethiopian National Meteorological Agency of 21 years, Gecha town experienced monthly lows of 12.6°C, highs of 31.2°C, and averages of 20.6°C annually. The area has a unimodal rainfall pattern. It falls throughout the year. The town received 2074 mm of rain on average each year (Figure 2). According to Kassa *et al*. (2020), extensive rainfall helps create the moist evergreen vegetation of the Afromontane Forest habitat for a wide range of unusual plant species. Highland regions make up 56% of the agroecosystems in the Andracha District, followed by midland (Woynadaga) regions (24%) and lowland (wet qolla) regions (20%).

Reconnaissance survey and selection of study sites

A permission request letter from Mizan Tepi University was received before the start of the reconnaissance survey and used throughout the specified time frame. Verbal informed consent was acquired from every participant in the study. A reconnaissance survey was made in Andracha District between November 2020 and December 2020. Its goal was to produce a preliminary understanding of the agroecological features of the region, the current state of the vegetation, the indigenous knowledge of the local population about the various uses of plants, an evaluation of accessibility, and other relevant

environmental factors. Purposive sampling was used to choose study sub-districts, focusing on finding sub-districts with higher levels of vegetation cover and a known history of using medicinal plants. These sub-districts were to be suitable locations for home gardening projects. Study sites followed previous information from local healthcare professionals, respected elders, community leaders, focus group discussion (FGD) participants, and traditional healers. Consequently, 8 study sub-districts were selected, which is 47% of the Andracha District's total of 17 sub-districts. The chosen study sub-districts: are Modi, Beshifa, Gatba, Duina, Chegacha, Gemadro, Gey, and Shebena.

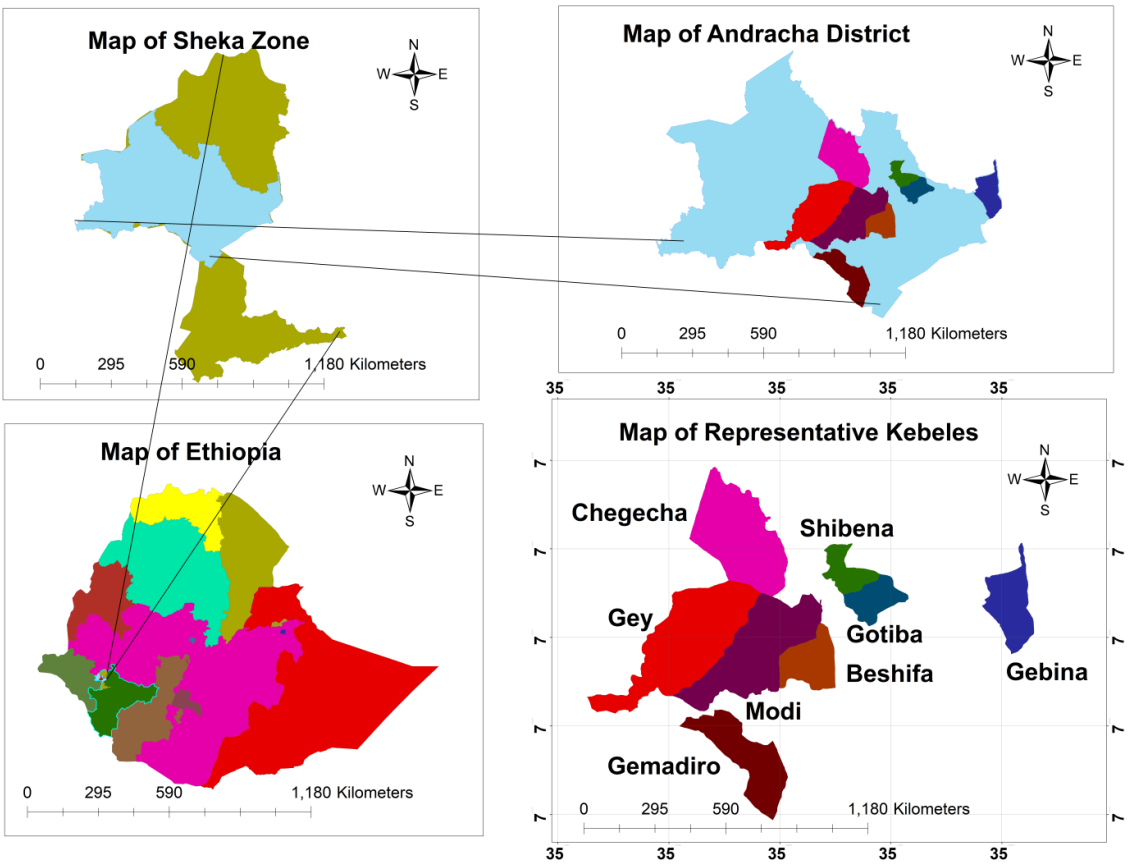

Figure 1. Map of the study area (Arc GIS 10.4.1)

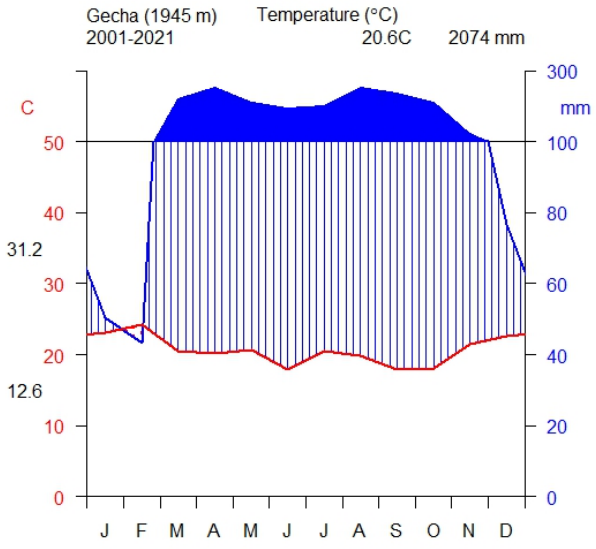

Figure 2. The climate diagram of Gecha town

Informant Selection

In the study, 128 informants aged 18 to 90 participated. Sixteen respondents per sub-district were involved. Following Cotton (1996), 88 general informants were selected by snowball sampling from the local population in the study area, while 40 key informants were selected through purposive sampling by recommendations. Participants in the study were grouped into three groups: young adults (18–35), middle-aged (36–52), and elderly (53–90) (Awoke *et al.* 2024a, b). To examine the transmission of knowledge about medicinal plants between generations, the study focused on people under 30 years of age.

Ethnobotanical Data collection

To collect field data, we used the selected guidelines for ethnobotanical research (Alexiades and Sheldon 1996) with prior informed consent. Data collection was between January 2021 and April 2022. Plant species were collected with their local names and images. Ethnomedicinal data records followed the procedures outlined in pertinent sources (Cotton 1996; Martin 2010). Semi-structured interview questions were prepared in Shekinano Language to record medicinal plant preparation and application.

By interviewing traditional medicine practitioners and healers who served as key informants and general informants, voucher specimens of medicinal plants were collected from different habitats. Important georeferenced information was recorded using the geographic positioning system (GPS), including plant specimens' habitat, habits, and colloquial plant names. With the aid of the Flora of Ethiopia and Eritrea, voucher specimens were prepared and authenticated (Zemede *et al.* 2024). Comparison with verified plant specimens from Addis Ababa University National Herbarium (ETH) was made to confirm by plant taxonomic specialists. Correct scientific names were referred to databases such as Plants of the World Online, the Royal Botanic Gardens Kew, the African Plant Database, the World Checklist of Selected Plant Families, and JSTOR Global Plants. Ultimately, the voucher specimens were deposited at Mizan Tepi University and Salale University for future use by researchers.

Data Analysis

Microsoft Word 2019 was used to compile, classify, and document the field data, which included scientific and local plant names, families, life forms, parts used, and habitats. Frequency distribution tools like tables, bar graphs, and pie charts were used in the analysis. R software version 4.3.2 was used to compute inferential statistics. Gender differences in Traditional Medicinal Plant Knowledge were checked using an independent t-test. Variations in knowledge across educational levels and healing experiences were examined using a different t-test. Age-group knowledge differences were tested using ANOVA (Awoke *et al.* 2024a) at $p <= 0.05$ level of significant difference (LSD).

To assess the consistency and agreement between two or more codes when applying the same coding scheme to a dataset, the methods of (Höft *et al.* 1999; O'Connor and Joffe 2020) was used. The rated numerical values of sociodemographic and use values variables were used following the Likert Scale (Daniels and Minot 2020; Joshi *et al.* 2015). The average rank of each medicinal plant species by the interviewees for each use value report (Höft *et al*. 1999) was consolidated and transformed to fit for analysis in R Statistical software. Before ANOVA and t-tests, the Shapiro-Wilk test was used to determine normality and homogeneity of variance. Moreover, the anova.cca test for significance of each sociodemographic variables, use value variables and threatening factors was checked before analysis (Woldu 2017). To select the significance of sociodemographic factors and threatening factors; stepwise selection of variables, computing of the variance inflation factor (vif), and analysis of variance in conjunction with cca to filter out the less significant variables was made.

Quantitative Analysis of Ethnobotanical Data

Plant Part Value (PPV): According to the methodology by (Cotton 1996), the plant part value calculation shows the proportion of plant parts such as stems, leaves, roots, fruits, bark, and flowers that are used for medicinal purposes. It is calculated as follows:

$$\mathbf{PPV}(\%) = \frac{\sum \mathbf{RU\ (plant\ part)}}{\sum \mathbf{RU}} \times \mathbf{100}$$

Where $\sum$ RU $_{(\text{plant part})}$ represents the sum of the cited plant parts and $\sum$ RU represents the total number of cited uses for a given plant.

Informant Consensus

The validity of the information recorded was checked by contacting informants at least twice for the same ideas to assess the reliability of the information obtained during the interview (Alexiades and Sheldon 1996; Andrade-Cetto and Heinrich

2011). The original information was rejected because it was unreliable if the informants' opinions conflicted. Each category's informant consensus factor helps to know the informants' agreement regarding the reported treatments for the group of illnesses. The ICF is computed as:

$$\mathbf{ICF} = \frac{\mathbf{Nur} - \mathbf{Nt}}{\mathbf{Nur} - \mathbf{1}}$$

Where Nur is the number of informants use reports for a specific plant-use category and Nt is the total number of taxa or species used for that plant-use category across all informants. The index has a range of 0 to 1, where values close to 1 indicate that informants strongly agree that the same species is used (Heinrich 2000; Heinrich *et al*. 1998).

Fidelity Level (FL)

Using a fidelity level (FL), as suggested by (Asfaw *et al*. 2022), the relative healing potential of medicinal plants in treating human ailments was evaluated. The following formula was used to calculate the fidelity level (FL):

$$\mathbf{FL}(\%) = \frac{\mathbf{IP}}{\mathbf{IU}} \times \mathbf{100}$$

Where**, FL**= fidelity level or relative healing potential, **IP** = the number of informants who independently cited the importance of a species for treating a particular ailment (frequency of citation of a species for a particular aliment), and **IU** = the total number of informants who reported the medicinal plant for a given disease (total number of citations of that species).

Preference ranking

Ten key informants were selected to evaluate the efficacy of five medicinal plants for humans against intestinal parasites. The medicinal plants with the highest value (5) were the most effective in treating the illness, while the least effective ones received the lowest (1) (Martin 2010). Each respondent's scores were summed up to obtain the total score used to determine each species' rank. It made it easier to identify the medicinal plants the community used most successfully to treat illnesses.

Direct matrix ranking

Multipurpose medicinal plants can be ranked using direct matrix ranking (Cotton 1996). Five medicinal plants were selected based on their relative advantage. Key informants assigned values for each attribute, where the highest number indicates the best use and the lowest value indicates the least use (Martin 2010). According to (Zamin *et al*. 2034), identifying novel plant uses through priority ranking is essential to designing conservation approaches.

Results

Sociodemographic characteristics of informants

The surveyed group consisted predominantly of males, accounting for 83.3% (n=99) of the participants, while females comprised 16.7% (n=29). The majority of individuals were general informants, making up 66.7% (n=88), whereas healers constituted a smaller segment at 33.3% (n=40). The age distribution of the participants ranged from 18 to 85 years, with the largest segment, 53.1% (n=64), falling within the 53 to 90-year age bracket, followed by 30.2% (n=41) who were between the ages of 36 and 52. Educational backgrounds varied significantly; approximately 70.8% (n=81) of respondents were illiterate, and a minority, 21.8% (n=29), had completed elementary education. In terms of marital status, a significant majority were married, representing 82.2% (n=88), while 13.5% (n=24) identified as single (supplementary file 1).

Medicinal plant taxonomic diversity

Habitat, the growth form of medicinal plants

About 100 medicinal plant species belonging to 88 genera and 47 families were identified. Asteraceae and Lamiaceae are the most frequent families. From the total of the 100 medicinal plants that were identified, 86% were from the wild, 11% were from home gardens, 4% were from both wild and home gardens, and 4% were from the market. The results show that the locals get more medicinal plants from the wild vegetation than from their home gardens. The results demonstrated that herb species 40%, shrub species 30%, tree species 20%, and climber species 10% were among the medicinal plants used to treat illnesses. The reason for the finding of the large number of herbal medicinal plant species used in Andracha district could be related to the favorable climatic conditions, such as year-round high rainfall and maintaining varieties of plant species.

Parts used, traditional medicines preparation, and forms used of medicinal plants

Informants reported using various parts of medicinal plants as medicines during the study. With 45 species of the total recorded medicinal plant preparations, leaves were the most used plant part. Roots had 15 species; stem 11 species; seeds six species; bark five species; fruit and whole plant four species each; latex, rhizome, root and leaf together two species each; flower, root and fruit together, seed and leaf together, stem and leaf together, tuber all one species each. Leaves were the most reported plant parts used to prepare remedies. The Andracha district inhabitants use four main methods to prepare traditional medicines (supplementary file 2): crushing (44.5%), concoction (27.7%), powdering (23.4%), and decoction (4.4%). The plant parts were reportedly used with common ingredients like honey, coffee, salt, and butter using simple methods and locally produced tools like mortars and pestles.

Routes of administration and dosage measurement for medicinal plants

With different techniques used to maximize the therapeutic benefits of medicinal plants, routes of administration represent yet another aspect of traditional medicine. According to the study, these plants are used differently in regional healthcare practices, from external applications to oral ingestion. The variety of administration methods adds to traditional medicine's adaptability. Hence, oral application 52% and dermal application 36% were the two most common routes of administration in the study area. Traditional healers in the study area estimated and fixed the dosage of the medicine using a variety of units of measurement, including finger length for root and stem bark, pinch for powdered plant parts, numbers for leaves, seeds, fruits, and flowers, and cup for decoction and infusion for plant parts.

Informant Consensus Factor

Dermal, sense organs, digestive, respiratory, circulatory, unclear illness, cultural, animal and vector-related, excretory and reproductive, and musculoskeletal and nervous systems were the ten additional categories into which the ailments were divided (supplementary file 3). The classification follows indigenous peoples' classification of health problems, including the type of disease, the circumstances that cause it, the precise site of the attack, and the symptoms and indicators displayed by those afflicted. The ICF value of 0.91 is the highest for the dermal category, followed by 0.90 and 0.89 for the sense organ and digestive system categories, respectively.

Fidelity level

The fidelity level (FL) of medicinal plants can be used to assess their capacity to heal particular ailments. The current study found medicinal plants with high fidelity values for treating different human health issues. For example, Ficus sur and Cucurbita pepo were very successful in treating malaria and tapeworm, respectively (supplementary file 4).

Preference Ranking

The results showed that the local population's preference for medicinal plants depends on their knowledge of which plants were best for curing their illnesses. Plants like *Phytolacca dodecandra* were used to treat intestinal parasites. On the other hand, *Bidens pilosa* was the most favored plant species for wound treatment (supplementary file 5).

Direct Matrix Ranking

The people in the study area depend on the forests for many purposes, such as building, medicine, charcoal production, fencing, shade, firewood, food, and agricultural tools. Using the direct matrix ranking (DMR) results on five multipurpose MPs used to treat various ailments; it was possible to identify which multipurpose plants are more stressed than other species in the region and the specific factors endangering the medicinal plants. The multipurpose roles of medicinal plants help to identify key threats due to harvesting impacts. Firewood, construction, agricultural tools, furniture, medicinal use, charcoal making, and food were among the most common multipurpose roles of medicinal plants identified (Table 1).

Statistical tests, models, and ordination methods

Statistical tests supplement the multivariate analysis of sociodemographic variables, respondents, and threatening factors about medicinal plants. A multivariate data set can set of sites (respondents) positioned in a space where each variable defines one dimension. The results of agglomerative hierarchical classification using similarity ratio generated 16 groups of respondents (G1-G16) based on their demographics and the 100 medicinal plant species (Figure 3). The cluster groups were further statistically analyzed. There were seven major threatening factors: invasive alien species, material culture, deforestation, modernization, harvesting, firewood, and charcoal. The rated values of these threatening factors showed the degree of relationships among plants and humans in ordination graphs (supplementary file 6, 7).

Table 1. Direct Matrix Ranking score of five TMPs to identify key threats

Use categories	**Plant Species**																								**Total**	**Rank**
	Ekebergia capensis					*Cordia africana* Lam.					*Croton macrostachyus* Del					*Eucalyptus globulus* Labill					*Prunus africana*						
	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5		
Firewood	3	2	3	3	1	4	5	4	5	5	2	1	1	2	3	5	3	2	1	4	1	4	5	4	2	85	**1st**
Const.	1	2	2	2	2	5	4	4	3	3	2	1	1	4	1	4	5	3	5	4	3	3	4	1	5	79	**2nd**
Agri.tool	3	4	2	5	4	4	3	3	4	3	1	5	5	1	5	2	1	1	2	2	5	2	4	3	1	78	**3rd**
Furniture	4	3	3	4	2	5	5	5	5	5	2	1	2	1	1	1	2	1	2	3	3	4	4	3	4	75	**4th**
Medicine	1	2	2	2	2	4	4	3	4	4	3	1	4	3	3	2	3	1	1	1	5	5	5	5	5	76	**5th**
Charcoal	5	1	3	3	5	3	3	4	2	3	1	2	1	1	2	2	4	3	5	1	4	5	3	4	4	74	**6th**
Food	0	0	0	0	0	3	5	1	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	**7th**
SubTotal	17	16	17	19	15	28	29	24	25	26	12	11	14	12	15	13	18	11	16	15	21	23	25	20	22		
Grand Total	**86**					**134**					**69**					**77**					**119**						
Rank	**3rd**					**1st**					**5th**					**4th**					**2nd**						

N.B. R=respondent, **Agri.tool** =Agricultural tool, Const. =Construction

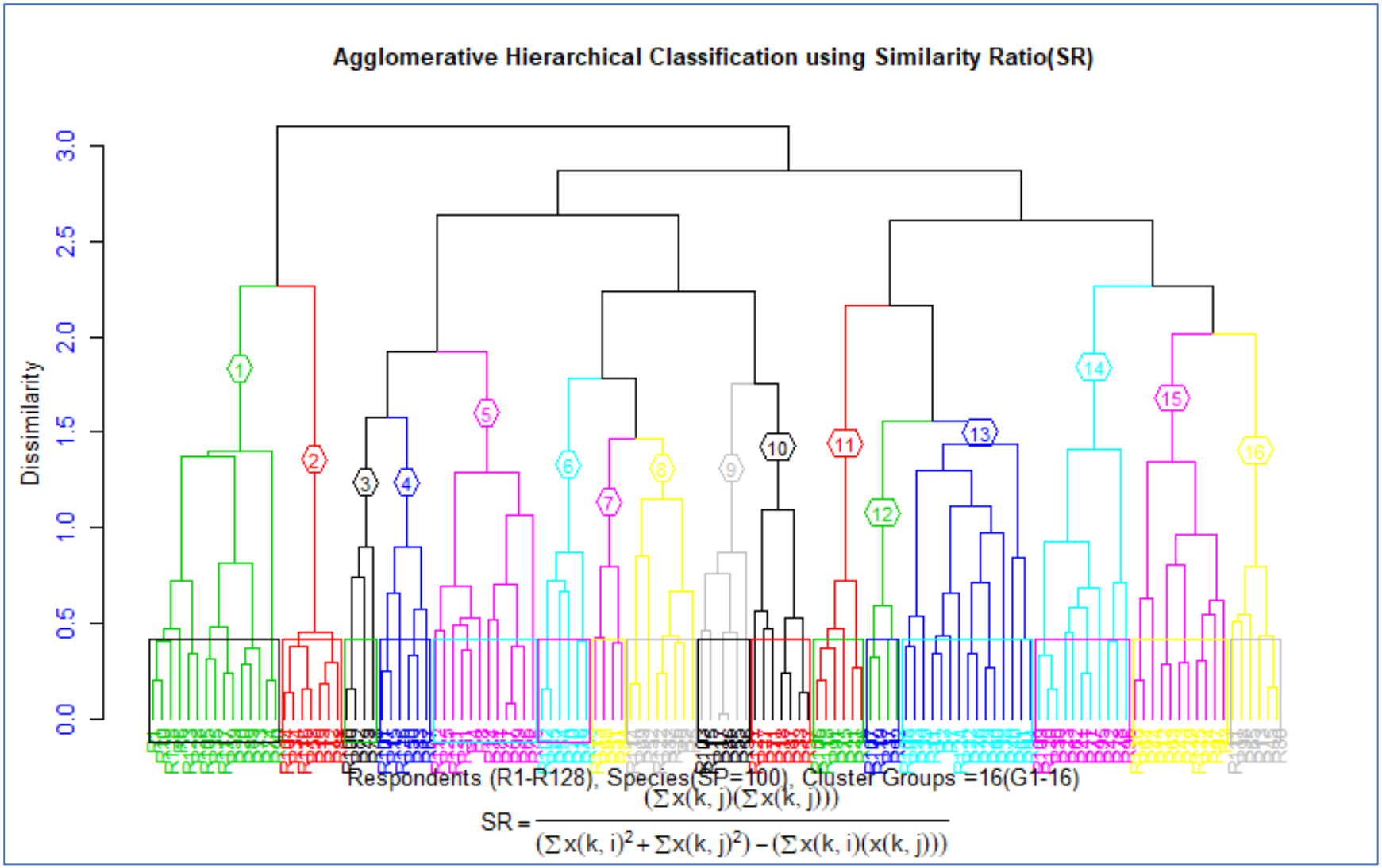

Figure 3. Agglomerative Hierarchical Classification using Similarity Ratio (Species =100 (S1-S100), Respondents =128 (R1-R16), Groups =16 (GI-G16)

Ordination

In the current study, Canonical Correspondence Analysis (CCA), Principal Component Analysis (PCA), and Non-metric multidimensional Scaling (NMDS) were used to visualize the patterns of relationships among plants and humans as well as their environments. The results showing the significance of sociodemographic variables and threatening factors are indicated in Tables 2 and 3 below.

Table 2. CCA for identifying sociodemographic factors showing maximum correlation with the respondents.

Sociodemographic variables	***VECTORS					
	CCA1	CCA2	r^2	Pr (>r)	Codes	Significance
Age	-0.87660	-0.48121	0.4745	0.001	'***'	Very high
Education	0.91945	-0.39322	0.3001	0.001	'***'	Very high
Marital status	-0.97300	-0.23079	0.2243	0.001	'***'	Very high
Gender	-0.23500	0.97200	0.1713	0.001	'***'	Very high
Informant category	-0.91607	-0.40102	0.8434	0.001	'***'	Very high
Occupation	-0.99270	0.12062	0.1053	0.010	'**'	Higher
Religion	-0.67113	0.74134	0.1154	0.005	'**'	Higher

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1; Permutation: free; Number of permutations: 999

Table 3. CCA for identifying significance threatening factors

Threatening factors	***VECTORS					
	CCA1	CCA2	r^2	Pr(>r)	Codes	Significance
Invasive Alien Species (IAS)	-0.00716	0.99997	0.3812	0.001	'***'	Very high
Deforestation	-0.55326	-0.83301	0.2795	0.001	'***'	Very high
Overharvesting	-0.89965	0.43662	0.1732	0.001	'***'	Very high
Firewood	0.99990	0.01398	0.6666	0.001	'***'	Very high
Charcoal	-0.37792	0.92584	0.3253	0.001	'***'	Very high
Material Culture	0.17652	-0.98430	0.0819	0.013	'*'	High
Modernization	-0.99485	0.10131	0.0098	0.618	' '	None

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1; Permutation: free; Number of permutations: 999

Canonical Correspondence Analysis (CCA)

The results of CCA are based on the set of constraints and their transformations or interactions among the constraints. For the current study, the CCA ordination outputs for sociodemographic variables and threatening factors are indicated in supplementary files 6 and 7 respectively in the figures.

The 3D Scatterplots of Ordination components (3D PCA)

To show the structure of relationships between plants, humans, as well as their environments, the 3D plot of PCA with vertical lines for the 128 Respondents (RI-R128), 100 species (S1-S100), and 16 Groups (GI-G16) is also indicated in Figure 4.

Pairwise Comparison of ordination scatterplots

It is possible to visually assess the similarities in the pairwise comparisons of ordination results generated from the same dataset using different computational methods, such as Nonmetric Multidimensional Scaling (NMDS). However, further analysis is necessary to determine the extent of these similarities. The results of the NMDS for 128 respondents, 100 species, and 16 groups are presented in Supplementary File 8, which illustrates the relationships among plants, humans, and their environments.

Comparison of knowledge differences among informant groups

R software was used to perform a t-test to investigate the difference in TMPK between key and general informants. There was a statistically significant difference in TMPK between these two groups, according to the obtained t-test results ($t = 8.1$, $P < = 0.05$). Compared to general informants ($M = 2.8$, $SD = 1.5$), the key informants showed a significantly higher average TMPK score ($M = 5.2$, $SD = 1.5$). Similarly, there was a statistically significant difference in Traditional Medicinal Plant Knowledge between the two genders, according to the t-test results ($t = 4.9$, $P < = 0.05$). In particular, the mean TMPK score of male informants was significantly higher ($M = 3.7$, $SD = 1.8$) than that of female informants ($M = 2.3$, $SD = 1.2$). In the same manner, the differences in TMPK among informants according to their educational backgrounds showed that the TMPK differences between the two groups were statistically significant, according to the results ($t = 4.3$, $P < = 0.05$). Furthermore,

the mean TMPK score of illiterate informants was significantly higher (M = 3.9, SD = 1.9) than that of literate informants (M = 2.5, SD = 1.6) (supplementary file 9).

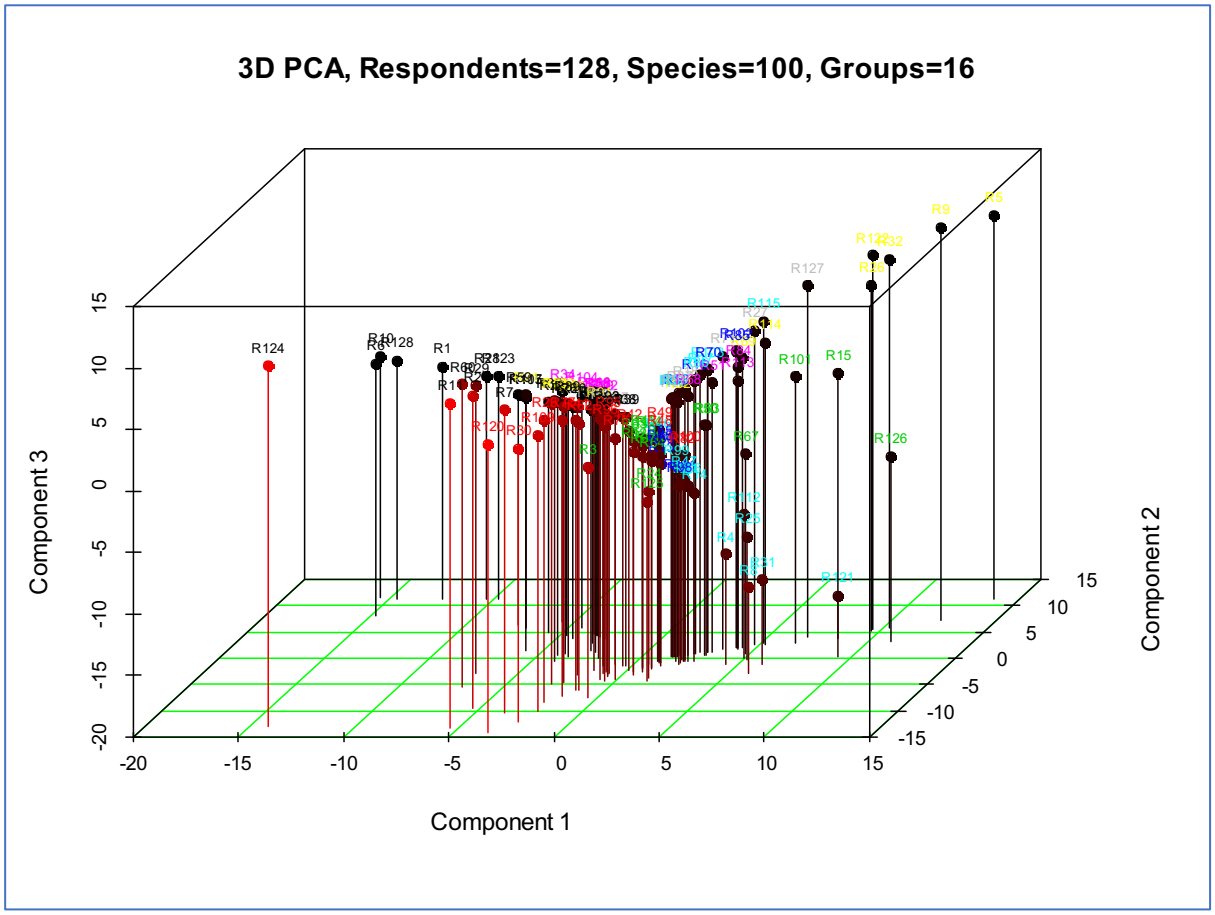

Figure 4. The 3D PCA scatterplots of ordination components

Comparison of knowledge among different age groups

The age group (young, middle, and elder) significantly affected TMPK scores, according to an ANOVA in R ($F=15.53$, $p <= 0.05$). Age-influenced disparities in TMPK, as evidenced by the remarkably higher variance between age groups (SS = 184.5, MS = 92.2) than within-group variance (SS = 396.8, MS = 3.1) (supplementary file 10). The old group had significantly higher mean scores (M = 4.4, SD = 2.1, $p <= 0.05$) than the middle group (M = 3.1, SD = 1.7, $p <= 0.05$) and the young group (M = 1.4, SD = 1.0, $p <= 0.05$), according to additional analysis using Tukey's HSD posthoc tests.

Age groups and MPk are positively correlated, as shown by the correlation coefficient of 0.76 (supplementary file 11). It suggests that as informants get older, their MP knowledge also rises. Moreover, the outputs of the regression analysis showed that, at a significance level of $p <= 0.05$, the $\beta 0$ and $\beta 1$ estimates were -0.86 and 0.09, respectively. Age categories and Medicinal Plant knowledge are positively correlated, according to the $\beta 1$ estimate, which means that for every increase in age category, the projected value of TMPK increases by 0.09 (supplementary file 12).

Threats to and conservation practices for medicinal plants

Deforestation, agricultural expansion, overharvesting, invasive alien species (IAS), and a decline in the use of traditional medicine due to modernization are the main factors threatening medicinal plants (MPs). The impacts of harvesting for multiple uses of these plants have also been significant threats (see Figure 3). Participants in the study expressed concern that medicinal plants are severely affected by the rapid spread of IAS in the Andracha District, particularly by species such as *Parthenium hysterophorus* and *Lantana camara*.

Discussions

Diversity and Distribution of Medicinal Plants

The recorded medicinal plants signify the remarkable diversity available for addressing health concerns. The number of species identified exceeds earlier reports, which noted 98, 63, 71, and 54 species in various studies across Ethiopia (Awoke et al. 2024; Gonfa *et al*. 2020; Tuasha *et al*. 2018; Tessema *et al*. 2024). Furthermore, previous investigations (Mwingira *et al*. 2023; Ma *et al.* 2019; Ma *et al*. 2024) have recorded 42 and 55 medicinal plant species in different regions. Conversely, research conducted by Kassa *et al.* (2020), Bekele *et al.* (2022), and Tamene *et al.* (2023) indicated a much higher count of 266, 145, and 189 species, respectively; however, it's worth noting that these studies encompassed significantly larger geographical areas than the one examined in our study.

According to Awoke *et al.* (2024a, b), the number of medicinal plants found in various study areas may vary based on factors such as the vegetation type, the number of informants, the timing of data collection, and the cultural background of the area. The local population's reliance on traditional medicines is evident from the widespread use of herbal remedies for treating human illnesses. This reliance may be due to the high cost of modern pharmaceuticals, challenges in accessing and utilizing contemporary healthcare services, and the cultural acceptance of herbal remedies. Similar trends have also been observed in other regions of Ethiopia, as documented by Belayneh *et al*. (2012), Tahir *et al*. (2021), and Tahir *et al*. (2023).

The Asteraceae and Lamiaceae families contain 11 species, making them the two dominant plant families in the study area. They are followed by the Cucurbitaceae, Fabaceae, Rubiaceae, Solanaceae, and Euphorbiaceae families, each with five species. These families contribute the most plant species used for medicinal purposes compared to others in the region. This finding aligns with earlier reports from Ethiopia (Agizie *et al.* 2022; Agizie *et al*. 2025; Kindie 2023) and various countries around the world (Aboui *et al*. 2025; Liu *et al.* 2023; Malik *et al*. 2019; Ullah *et al*. 2025). Conversely, the Poaceae, Amaranthaceae, and Apocynaceae families are more commonly reported in Pakistan (Alie et al. 2023). This difference may be due to the greater abundance and distribution of certain plant families in the flora of Ethiopia and Eritrea, as well as the cultural influences of traditional healers (Jaric *et al.* 2024; Kutal *et al*. 2021).

According to this study, people prefer easily accessible plant species, provided they are safe to use. Given this context, the findings underscore the cultural and therapeutic significance of various plant families in traditional medicine. It highlights the importance of further research into their medicinal properties and the need for conservation measures to protect these invaluable botanical resources.

Medicinal plant knowledge among the local people

The people in the study area possess a wealth of traditional healing techniques rooted in their rich cultural heritage. They are recognized as custodians of invaluable medical knowledge passed down through generations. One reason for their extensive knowledge of medicinal plants is their strong connection to the local flora and fauna and their cultural practices. This deep relationship with their natural environment and traditional healing methods underscores the bond between culture and nature. Furthermore, historical customs, environmental factors, and cultural practices are observed. Historical influences, the availability of natural resources and cultural integration may all contribute to their diverse medicinal plant knowledge. Therefore, further research into specific medical practices in the area could enhance our understanding of the various healing traditions present. This research may also help bridge gaps in knowledge and access to healthcare.

Habitat of medicinal plants

The natural habitats of medicinal plants are increasingly threatened by human activities, leading to declining populations as demographic pressures rise. Efforts to grow these plants in home gardens have largely failed, as they tend to flourish in mountainous and shaded areas—conditions that are difficult to replicate at home due to variations in soil and climate. This finding is consistent with previous research in Ethiopia (Anbessa *et al*. 2024a, b; Megersa *et al*. 2023) and similar studies by Liu et al. (2023) elsewhere. To safeguard these vital resources for the future, immediate action is necessary, including the implementation of in situ conservation strategies in biodiversity-rich regions (Heywood and Dulloo, 2005; Muthukrishnan *et al.* 2025).

Growth forms of medicinal plants and their distributions

A remarkable number of medicinal plant species in the study area can be due to favorable climatic conditions, particularly the year-round high rainfall, which supports a plant species. This distribution reflects the greater availability and abundance of herbs in the environment compared to shrubs and trees. Various scholars have noted that herbs are the most commonly

utilized growth forms for treating a range of human ailments (Anbessa *et al*. 2024; Tahir *et al*. 2023), both locally and globally (Alie *et al*. 2023; Amjad *et al.* 2020; Maniyo *et al.* 2024; Navia *et al*. 2022).

This trend is plant conservation, as herbs typically have shorter growth cycles and require less space for cultivation than shrubs and trees. Thus, the consistently high levels of rainfall throughout the year create ideal conditions for the prevalence of herbaceous medicinal plants in the district. These plants account for more than half of the species used, fostering plant species.

In contrast, several studies have reported the use of shrubs and trees both locally and globally (Batool *et al*. 2025; Chekole *et al.* 2023). It could be due to their annual availability, ability to withstand drought in extended dry season locations, and ability to tolerate invasive alien species, making them suitable for widespread use (Bekele *et al*. 2022). Furthermore, this suggests a variation in medicinal plant utilization due to differences in culture, agroecology, topographic features, and ease of access to the species (Tadesse *et al*. 2024). As a result, the diverse range of medicinal plants, including herbaceous species in some areas and shrubs or trees in others, such as drought-prone areas, reflects the rich botanical resources available for medicinal purposes and the importance of preserving traditional knowledge for future generations.

Use of medicinal plant parts

The popularity of utilizing leaves from medicinal plants has surged due to their ease of preparation and the potent compounds they contain. While leaf harvesting is often sustainable, it's important to recognize that excessive collection can harm the plants and hinder their reproductive capabilities. Research conducted by (Chekole *et al*. 2023; Kidane *et al*. 2014) and other international scholars reinforces this concern.

In addition to leaves, roots are commonly used in traditional medicine and generally follow leaves in popularity. Studies show that roots are particularly valued because they are accessible throughout the year, even during dry seasons. However, the increasing demand for these roots in traditional healing practices threatens the plants, particularly agricultural challenges. In local markets of the Andracha district, the root of *Echinops kebericho* commands a high value. Similar findings from various areas in Ethiopia and beyond indicate that overharvesting roots poses a serious risk to the survival of these medicinal species.

Traditional medicine preparation and forms used

Herbalists in the study area crush plant parts with common ingredients like honey, coffee, salt, and butter using simple methods and locally produced tools like mortars and pestles. These additions enhance the remedy's flavor and nutritional value. The Gamo people of Ethiopia have been known to use a similar practice in their traditional medicine, adding items like meat, honey, and butter to improve the nutritional value and taste of the remedies (Zemede *et al*. 2024). Local healers generally consider crushing the most common method of making herbal medicines because it can efficiently and rapidly extract the active ingredients from plant materials. Powdering is the most common method for keeping the active components in dry plants intact. For instance, *Vernonia amygdalina* and *Croton macrostachyus* leaves are smashed, pounded, and combined when making remedies to treat intestinal parasites. Leaves of *Vernonia amygdalina*, *Croton macrostachyus*, and *Maesa lanceolata* ground and combined to treat multiple health problems. Both locally and internationally, these results are consistent with those of (Ayele *et al.* 2024; Dessie and Amsalu 2024; Karki *et al*. 2023; Tahir *et al.* 2023). It is imperative to support conservation initiatives and sustainable harvesting methods.

Some remedies include additives such as bread, milk, water, coffee, food, tea, salt, butter, honey, and sugar. These components are essential in moderating the strength of medications, improving their flavor, and mitigating side effects. Some informants assert that combining specific medicinal plants with food enhances their effectiveness compared to consuming them independently. For example, powdered dried fruits of the *Ficus sur* mixed with honey are used to combat malaria. Similar observations have been documented by Agizie *et al.* (2022, 2025) and Tahir *et al*. (2024).

During the data collection process, informants shared skills related to herbal preparation for treating various ailments. It included the selection of plants used either singularly or in mixtures. Herbalists often combine different species to boost the therapeutic properties of their remedies. The results showed that most remedies (86.4%) were derived from a single plant, while only 13.6% were from a combination of species. This aligns with findings from studies conducted by Derso *et al.* (2024), Tahir *et al*. (2021), and Tahir *et al*. (2023).

Herbalists employ various parts of plants in their remedies based on specific needs. The findings revealed that, among 100 species analyzed, 80% were used fresh, 23% were used in dried form, and 6% were utilized in both conditions. Patients

generally prefer remedies prepared from fresh ingredients, as many herbaceous plants are most commonly used in their fresh state. This preference may stem from the region's unimodal rainfall pattern, which helps maintain the greenery of the plants year-round. The reliance on fresh plant parts is linked to beliefs about their superior effectiveness in treatment. However, this dependence raises concerns about the sustainability of these vital medicinal resources, as noted by Amsalu *et al.* (2018), Megersa *et al.* (2013), and Megersa *et al*. (2023).

Routes of administration

Oral application and dermal application were the two most common routes of administration. It indicates that taking the treatments orally might have several possible side effects. Similar findings worldwide (Ali *et al* 2023; Liu *et al*. 2023) and in Ethiopia (Anbessa *et al*. 2024a; Anbessa *et al*. 2024b) indicate that the oral route is the most common method of administering medicinal plant preparations. The prevalence of internal illness in the study area and the efficiency of oral and dermal methods in quickly interacting with pathogens' physiology and boosting curative potency may be responsible for this preference. It is easier for patients to apply a lower potential for toxicity and absorption. Hence, dermal administration is preferred.

Dosage measurement for medicinal plants

Although healers believe that traditional medicines are effective, the measurements used to determine dosages are not standardized. These dosages vary based on several factors, including age, physical fitness, the stage of the illness, pregnancy, and the presence or absence of other diseases in addition to the condition. This observation aligns with the findings reported by Giday *et al*. (2009a, b), Giday *et al.* (2010), and Teklehaymanot *et al.* (2006).

To lessen the harmful effects of illnesses, they also use a variety of inputs, including milk, coffee, honey, meat, bulla, locally made from Enset ventricosum, and "Tella" (a local beer). The healers often cited the lack of side effects associated with traditional medicines. According to traditional healers, antidotes to counteract any side effects of medicinal preparations like *Phytolacca dodecandra* and *Croton macrostachyus* are used to treat rabies and malaria (Asnake *et al.* 2016). A similar finding was also reported by (Alelign *et al.* 2018). These customs highlight the need for standardization while reflecting the cultural diversity of traditional medicine (Alemu *et al*. 2024). To ensure the safety and effectiveness of healers' treatments, a regulatory framework incorporating distinctive cultural practices and knowledge must be developed (Fekadu *et al*. 2023; Getachew *et al*. 2022; Lulekal *et al.* 2014).

Applications of medicinal plants

The herbalist uses visual observations of the patient's skin and eye color, the areas of the tongue and throat, and body temperature to diagnose. The herbalist also asks the patient about their symptoms. This strategy aligns with the results of various ethnobotanical investigations conducted in other parts of the nation. This finding supports (Beleyneh *et al*. 2012; Beyene *et al.* 2024) conducted in parts of Ethiopia. The techniques used by traditional healers to prepare medicinal plants and administer them to patients. These include drinking, painting, chewing, swallowing, applying to the skin, smelling, smoking, and tying on the afflicted area. The results demonstrate that drinking, chewing, and swallowing were common ways to treat internal illnesses. The medicinal plant is rubbed on the affected areas to treat skin ailments. Moreover, crushing, pounding, decoction, infusion, and oral administration were used to treat conditions like pneumonia and jaundice.

Traditional healing techniques used to treat health conditions, such as the evil eye or headaches, are through nasal scents. To treat intestinal parasites, the stems and roots of *Vangueria madagascariensis* and *Bersama abyssinica* are either consumed as powders or chewed. Local healers agree that different parts of a medicinal plant could treat illnesses. *Croton macrostachyus* and *Phytolacca dodecandra*, for instance, treat intestinal parasites, diarrhea, gonorrhea, and blood clots by drinking, dropping, applying, and chewing leaves, roots, and stem bark. To increase the effectiveness of treatments, herbalists advise patients to take specific precautions, such as skipping meals and liquids and spending the morning without eating. For example, the herbalist prepares a remedy from *Phytolacca dodecandra* L'Herit and *Allium sativum* L. species to treat intestinal parasites and malaria (locally known as WOBO). The patient takes the remedy before breakfast and fasts for a long time, usually four hours, to effectively remove the worms from the intestine. The herbalist also fumigates the patient with smoke from the *Ocimum lamiifolium* species and suggests that the patient goes to bed as soon as possible in sudden illness, or MECHARO as it is known locally.

Informant Consensus Factor (ICF)

Particularly among traditional healers, a low ICF value suggests little cooperation among indigenous people in sharing their TMPK. One possible explanation for this lack of interaction is geographic distance and healers' desire to protect their

knowledge from unauthorized use. Different medicinal plant species are mixed in various settings to treat the same health problems. According to the study, residents shared essential MPK for treating common illnesses. Although some plants were less preferred than others, it did not necessarily mean that they were less effective because only a small number of medicinal plant species were preferred by the chosen respondents, indicating covert activities. The results of (Alemu *et al*. 2024; Enyew *et al*. 2014; Eshete *et al*. 2021; Teklay et *al*. 2023) support these findings.

Fidelity level (FL)

High fidelity level value suggests that after their bioactivities are carefully evaluated and confirmed, plants with high FL values may be prioritized for conservation, management, and sustainable use. Furthermore, a lower FL means informants mentioned a particular MP than those with a higher FL. For instance, *Acmella caulirhiza* had a reduced capacity for healing when used to treat tonsillitis. These results align with those of (Assen *et al*. 2024; Friedman *et al*. 1986; Tadesse and Teka 2023).

Direct Matrix Ranking

Insights into multipurpose plant uses are vital to designing conservation approaches (Aboui *et al.* 2025). According to the current findings, the most preferred multipurpose plant species in the Andracha district were *Prunus africana* and *Ekebergia capensis*, while *Cordia africana* ranked as the most threatened. These medicinal plants are collected for non-medical purposes in addition to their medicinal value. Top-ranked species, such as *Cordia africana*, are expected to be seriously threatened shortly, requiring cooperative conservation efforts to save these multipurpose plant species. The results of (Yimam *et al.* 2022) all showed that *Cordia africana* was a multipurpose medicinal plant in their respective fields of study, which is consistent with this finding. *Croton macrostachyus* was the most versatile plant species as reported by Gonfa *et al.* (2020) and Megersa and Woldetsadik (2022). Species of marketable medicinal plants are mostly preferred for their therapeutic qualities. They are more vulnerable. The informant claims that due to the high market demand for their roots, *Echinops kebericho* is noticeably rare in the Andracha district. The research published by (Alemneh 2021; Girma *et al*. 2022) supports this finding. These results thus imply that the Andracha district's local population is aware of the therapeutic qualities of plants and their significance for their health and welfare. The current study emphasizes the necessity of conservation initiatives to prevent the overexploitation of medicinal plants.

Comparison of knowledge between key and general informants

There was a statistically significant difference in medicinal plant knowledge between regular and key informants. The findings of (Giday *et al*. 2010; Kidane *et al.* 2018; Tahir *et al*. 2023; Teklehaymanot *et al*. 2007) are consistent with this finding. This finding implies that the key informants use traditional knowledge more frequently, most likely due to both cultural influences and their prolonged, intensive engagement with plant resources.

There is a significant association with the disparity in knowledge between key informants and general informants. In medicinal plant knowledge, it first emphasizes how crucial it is to identify and capitalize on an understanding of respondents. The Key informants can be extremely helpful in maintaining traditional medicinal plant knowledge and practices and advancing sustainable harvesting and cultivation techniques. The knowledge gap also highlights the necessity of focused educational and capacity-building programs focusing on general informants' comprehension of medicinal plants. By providing the general public with pertinent information and abilities, we can promote the sustainable use of medicinal plants and develop a greater understanding of conventional healing methods.

Comparison of knowledge between genders

There was a statistically significant difference in MPK between the two genders. This result is consistent with the findings of (Acosta *et al.* 2025; Anas *et al*. 2024; Dip and Vattuone 2024; Georgiadis 2022; Sultan *et al*. 2024). In contrast to this finding, Gnahore *et al.* 2022) discovered that women know more about MPs than men do. Furthermore, according to other researchers, males and females have similar knowledge about MPs (Tahir *et al.* 2021; Kidane *et al*. 2018). These discrepancies could result from historical, social, or cultural variations in MPK proficiency between the sexes. An additional explanation could be that men were more likely to spend time in fields or forests, which are habitats for wild MPs. In addition, other researchers (Chekole *et al.* 2023; Usman *et al*. 2022) have observed that sons, not daughters, inherit medical knowledge. But it's vital to remember that this belief isn't always true. When traveling to far-off places and gathering plant species, many women are just as capable as men. Indeed, historically, women have played remarkable roles in hunting and gathering in many cultures. As a result, it is critical to dispel the myth that only men can contribute to the collection of plant species and to recognize the roles played by both sexes. To create programs and policies that empower female informants and support

gender-inclusive approaches to resource management and traditional medicine, it is imperative that the factors causing this inequality be further investigated (Mondal *et al*. 2025).

Comparison of knowledge between education levels

The variation in medicinal plant knowledge and comprehension of medicinal plants among educational backgrounds may result from the influence of formal learning; the acquisition and dissemination of traditional medicinal knowledge. This result aligns with earlier research carried out across the nation (Gnahore *et al*. 2022; Tahir *et al*. 2021). Additionally, fewer people with advanced degrees may be knowledgeable about medicinal plants due to a lack of exposure to traditional practices in formal educational settings, particularly in higher education institutions. People's awareness of medicinal plants at various academic levels depends on cultural factors, such as the passing down of traditional knowledge within particular communities. Higher-educated individuals may become ignorant of conventional medical practices due to the curriculum's emphasis on Western medicine. Therefore, the study's conclusions have ramifications for public health and education policies, emphasizing the necessity of focused interventions to close the knowledge gap about medicinal plants between people with different educational backgrounds. A more integrated approach between modern and traditional healthcare systems must be encouraged through formal education and healthcare systems.

Comparison of knowledge across age groups

Traditional Medicinal Plant Knowledge (TMPK) has shown significant disparities among different age groups: youth, middle-aged adults, and elderly respondents. Findings indicate that older individuals possess a much greater understanding and appreciation of traditional medicinal knowledge, likely due to its transmission through generations. Supporting this observation, various studies (Liu, 2023; Awoke *et al*. 2024; Bekele *et al*. 2022; Tahir *et al*. 2023) have documented that older adults are often more engaged with the use of medicinal plants than their younger counterparts. This research aligns with our findings, emphasizing the healers regarding local medicinal plants and their traditional applications for health issues.

Conversely, younger generations are becoming increasingly disconnected from these traditional practices, a shift driven by modernization and globalization. It has been observed in local communities that many young people are prioritizing formal education, consequently drifting away from the rich tapestry of ethnomedicinal knowledge. This change raises concerns about the potential decline of local ethnobotanical and indigenous knowledge systems, especially as young individuals migrate looking for job opportunities.

Ordination

Ordination is a collection of multivariate techniques that summarize a multidimensional dataset, transforming vector observations into a new set of observations (Legendre 2012). It helps visualize relationships between species composition patterns and environmental gradients (Borcard & Legendre 2018). Multiple datasets with simultaneous variations were analyzed using CCA, PCA, and NMDS ordination. The Procrustes analysis is useful in comparing two NMDS outputs since it has been indicated that the orientation of the points in the NMDS scatterplot is arbitrary (Woldu 2017).

Canonical Correspondence Analysis (CCA)

The task of CCA is to find the linear combination of variables in each of the two sets having the maximum mutual correlation. It is a constrained ordination since it constrains the value of the underlying ordination to achieve the canonical axes. Rather than displaying all variations in the data, it focuses only on the part that can explain the constraints. Canonical correspondence analysis can be used to assess the social perception of local inhabitants to predict the status of recorded plant populations (Khan *et al.* 2014). The authors emphasized that the assessment of ecological indicators, combined with the indigenous ecological knowledge of the indigenous population, helps in assisting the development of local and regional conservation priorities.

The current study showed a strong association among respondents at various levels and their demographics. Age, education, marital status, gender, and informant categories were more reliable predictors with very high significance. Moreover, occupation and religion were relatively better predictors with higher significance; Invasive alien species, deforestation, overharvesting, firewood, and charcoal making were among the main threatening factors to medicinal plants, with relatively better significance. Use of medicinal plants as material culture was a less threatening factor, with a relatively significant impact. However, modernization is the least threatening factor, with no level of significance. It could be due to modern development projects taking care of environmental impact assessments for conservation priorities of vulnerable species. The study is similar to previous studies that ordination methods best display the structure of relationships among plants and humans (Zamin *et al.* 2024).

The 3D Scatterplots of Ordination components (3D PCA)

The components generated using the various ordination techniques or components from previous analysis may also be submitted directly in 3D scatterplots similar to the 2D scatterplot ordination techniques. The three-dimensional plots have many options to explore the structure of relationships. Following Borcard *et al*. (2018), we used the library (vegan3d) to look for a new perspective on our results. The three-dimensional interactive plots showed the structure of relationships among plants, humans, and their environments. The vertical lines connecting the floor of the cube with the position of the individual respondents provide a better perspective of the three-dimensional scatterplots. It enables viewing the distribution of respondents about the significantly influencing sociodemographic factors of respondents, as well as the threatening factors to medicinal plants as seen in the Canonical Correspondence ordination. The three-dimensional scatterplot may improve the situation if the configuration in the two dimensions appears relatively poor.

Non-metric Multidimensional Scaling (NMDS)

When the primary interest of ordination is not the preservation of distances but presenting the objects in a small number of dimensions, usually two or three non-metric multidimensional (NMDS) becomes the appropriate choice (Woldu 2017). Hence, NMDS uses only the rank order of dissimilarity values. Dissimilar objects are plotted far apart, while similar objects are closer (Borcard *et al*. 2018). It is to preserve the ordering of relationships among objects (plants, humans, and their environment in the current sense). The advantage of non-metric multidimensional scaling is that it is a flexible non-parametric method, providing a way to visualize complex relationships in high-dimensional data to identify patterns and relationships among data points. The more closely the data points to one another, the more similar they are, and vice versa.

Incorporation of numerical analysis and ordination methods into ethnobotanical studies is highly recommended (Kikvidze & Bussmann 2024). In the meantime, significant associations among plants, humans, and their environments are better represented in heterogeneous sociodemographic and major threatening factors to medicinal plants (Ghobbour *et al*. 2024; Gum *et al.* 2024). The robust statistical validation of the threatening variables helps to design conservation priorities (Amjad *et al*. 2020; Anas *et al*. 2024; Dip *et al*. 2024; Gobvu *et al*. 2024).

Color coding groups

Multivariate analysis of the dataset for sociodemographic and threatening factors can be enhanced through, clustering algorithms, ordination techniques, models as well as statistical tests. One approach is through cluster analysis using dendrograms (Tessema *et al.* 2025). Figure 3 indicated Agglomerative Hierarchical Classification using Similarity Ratio. It creates a tree-like structure depicting a different number of clusters (k). It facilitates flexible analysis and interpretation of the colored clusters. The hierarchical classification is useful to decide partitioning by grouping respondents following their sociodemographic characteristics. In the dendrogram, the x-axis lists all respondents, while the y-axis represents the similarity at which the clusters are combined. The color codes indicate that they are instrumental in different ordination methods (Figures 3, 4). They provide deeper insights into patterns and relationships within datasets where homogeneous subgroups are put together (Höft *et al.* 1999). As an exploratory technique, cluster analysis seeks to minimize variability within groups while maximizing it between them. When applied to respondents, this method organizes individuals based on the similarity or dissimilarity of their ethnobotanical knowledge, creating clusters of those with similar expertise while distinguishing those with differing knowledge into separate groups (Tessema *et al*. 2024).

Correlation and regression models

Complementing indices with robust statistical tests and multivariate models uncovers significant relationships and patterns among plants and humans (Kikvidze & Bussmann 2024; Yebouk 2025). Hence, the current study showed that age groups and medicinal plant knowledge are positively related. It suggests that as informants get older, their level of MPK also rises. This current finding is consistent with that of (Awoke *et al* 2024; Bekele *et al*. 2022). Moreover, regression analysis showed that, at a significance level of $p<=0.05$, the $\beta 0$ and $\beta 1$ estimates were -0.86 and 0.09, respectively. Age categories and medicinal plant knowledge are positively correlated, which means that for every increase in age category, the projected value of MPK increases. These findings therefore, have significant ramifications for the transmission and preservation of TMPK, emphasizing the necessity of supporting and giving priority to older generations as information repositories.

Threats and conservation practices of medicinal plants

Human-induced threats to medicinal plants and the impact of invasive alien species need immediate attention. The IAS are dangerous because they can quickly proliferate and take over, changing the ecosystem when introduced. Their ability to outcompete native species upsets the natural equilibrium and puts the native plants at risk of extinction (Karki *et al*. 2023; Kloos 2023). Such threats are among the causes of herbaceous MPs' decline. Additionally, *Prosopis juliflora* has been

recognized by other researchers as another IAS that could endanger MPs (Shiferaw *et al.* 2018). According to the research, multipurpose MPs are particularly vulnerable because they face different dangers (Tawseef *et al.* 2021). Previous research (Alemu *et al.* 2024) is consistent with this finding. *Lantana camara* and *Parthinium hystrophorus* are among the threatening IAS in Andracha District. Although studies to identify the treats of invasive alien plants species in Ethiopia is restricted, the country has recognized the urgent need to tackle the problem (https://ebi.gov.et/biodiversity/conservation/invasive-species). Merawi *et al.* 2023 reported that sharing practical findings coupled to local knowledge and participatory response can scale up management interventions to the impact of *Lantana camara*. Moreover, "Removing Barriers to invasive Plant Management" project is among the management interventions in Ghana, Uganda and Zambia (https://ebi.gov.et) which could be lessons learnt for Ethiopia.

However, the current findings imply that the local population in the study area has not been actively engaged in community-based conservation initiatives. This claim aligns with the findings of (Abro *et al.* 2024; Derso *et al.* 2024; Dessie and Amsalu 2024; Gatersleben and Andrews 2023). Raising awareness of the importance of MPs and the difficulties they face is therefore imperative (Zamin *et al*. 2024). Outreach programs, media outlets, and educational initiatives can all help achieve this. The study's conclusions are consistent with other reports (Alemu *et al.* 2024; Lulekal *et al*. 2013; Tahir *et al*. 2024).

Marsandi *et al.* 2025 noted that integrating ethnobotany and indigenous knowledge into school curricula furnish students with practical skills to tackle global challenges. From the local point of view, in Andracha District, the local people have pool of indigenous knowledge-based biodiversity conservation and management practices such as the GUDO and KOBO system of forest management which encourage conservation of native plant species *in-situe*. For practical implementation, recognition of local clan leaders (the GEPITATOs and the SHEKITATOS) and community incentives are needed. Such practices need encouragement and policy insights by the Ethiopian Government.

Cross-cultural analysis and implications

Ethnobotanical cross-cultural analysis is an approach to comparing and contrasting plant use knowledge and practices among and within people of diverse socio-demographic variables (Gitima *et al.* 2025; Haq 2023; Teka *et al*. 2020). Variations in medicinal plant knowledge and usage among a range of ethnic groups are owing to sociocultural barriers (Sulaiman 2025). However, cultural interactions through a common body of information about ethnomedicinal plants resulted in similarities in knowledge transmission (Anbessa *et al.* 2024; Tamene *et al*. 2023). Hence, ethnicity, cultural patches coupled to the flux of knowledge among inhabitants resulted in isolated ethnobotanical knowledge systems (Kujawska *et al*. 2017; Quave and Pieroni 2015; Saynes-Vasquez *et al.* 2016).

Rigorous ethnobotanical research better emphasize investigation of driving factors influencing medicinal plant use and selection (Yebouk 2025b). Insights into the role of cultural roles in guiding plant-human-environmental interactions can be obtained through quantitative ethnobotanical tools (Quave and Pieroni 2015). Therefore, for better cross-cultural analysis in ethnobotany, descriptive weak study aims must be complemented with statistical tests, modes, and ordination methods (Kikvidze and Bussmann 2024; Yebouk 2025a; Yebouk 2025b). Ethnobotanical field work is affected by a number of factors (Kassa *et al.* 2020; Sop *et al.* 2012), so that ethnobotanical researchers must design appropriate approaches relevant to local traditions.

In the current study, the influence of sociocultural backgrounds of the society on medicinal plant knowledge, use, as well as conservation and management strategies is reflected. One hand, respect for traditional rules given by the clan leaders (locally known as the GEPITATOs and SHEKITATOs) governing the society which is unique to the area are contributing to conservation and preservation of medicinal plants and associated indigenous knowledge. On the other hand, increasing investment activities in coffee and tea plantations driven by high market dynamics is threatening the wild habitats that are reservoirs of medicinal plants and forest coffee as well as the traditional rules governing the unique ecosystem of the biosphere. Moreover, sociocultural and religious taboos restrict ethnobotanical data retrieval from the local people by researchers as required. For instance, less number of female informants, traditional religious leaders were interviewed as compared to male informants and other community groups during the study. Traditional healers prefer the youngest of their children to accompany them while collecting and preparing medicinal plants. They never want to disclose it to anyone even to those the member of their family. Consequently, repeated field visits over a range of years were made to validate the consistency of ethnobotanical information retrieved filling the gaps. Traditional medicinal knowledge is transmitted through the word of mouth. That why is documentation is very important.

Even though it is not enough, the participants were compensated for the wild resources and associated indigenous knowledge they maintained for generations. Despite the imperative challenges due to investment activities in the area, both governmental and non-governmental organizations are engaging in collaboration with the Ethiopian Biodiversity Institute (EBI). The EBI has the mandate to protect the access and benefit-sharing through the Convention on Biological Diversity (CBD) Articles and Protocols (https://ebi.gov.et).

Cross-cultural analysis in ethnobotany has a range of implications. It helps understanding knowledge diversity and medicinal plant use diversity. It contributes to local, regional, national as well as global health well-being through identifying cultural importance by creating consensus for rural development and health. It encourages threat analysis to both the medicinal plants and associated traditional knowledge thereby formulate policies and strategies for possible conservation priorities through documentation and preservation of resources. It paves ways to integrating local traditions to modern science by assessing the impact of external influences developing new tools for assessment through robust ethnobotanical methodologies across diverse cultures and social groups.

Conclusions and Recommendations

The traditional knowledge of medicinal plants in the study area has been documented for future research and significantly adds to the current understanding of medicinal plants. It also highlights how helpful traditional medicine is to the primary healthcare system. Identification of potential therapeutic species could be used for further research and contribute to enhancing community-based healthcare systems. Hence, documenting this crucial knowledge will help with future drug discovery, the maintenance of traditional medical practices, and the preservation of endangered species. Additionally, investigating unexplored areas contributes to the enrichment of the flora and the traditional uses of medicinal plants, which helps to compile the region's herbal medicine. Together with their historical uses, the wide variety of medicinal plants offers a starting point for future research, preservation, and possible incorporation into the contemporary healthcare system. Identifying key therapeutic category species and researching pharmacological and biological activities enables achieving key healthcare systems. It could encourage more scientific research and improve the health system locally and nationally.

The current study emphasizes how traditional knowledge applies to biological resource conservation. In the Andracha District, the current study identified approximately 100 species of medicinal plants that the local communities use to treat human illnesses. There is documentation of traditional knowledge about how to use, prepare, and apply remedies for these medicinal plants. Future research into new medical resources may benefit from using the data as a starting point. Herbs, shrubs, trees, and climbers were plant habits collected from the wild, home garden, and markets. Leaves, roots, and seeds were parts used as medicines. In traditional medicine, men were more engaged than women because of cultural beliefs.

Compared to educated and young people, a large percentage of the population was illiterate, farmers, and knowledgeable about ethnobotany. It shows that formal education is limited and may be related to their exposure and experience. For species with more use reports, pharmacological testing, chemical compound isolation, and characterization are priorities. Local governments and conservation organizations needed to concentrate on documenting the people's ethnobotanical knowledge and conserving traditional medicinal plants. The rapidly declining number of medicinal plants should be avoided by prioritizing conservation and encouraging conservation techniques such as *in situ* and *ex-situ* approaches, which support traditional healers. To motivate the local population to manage and sustainably use medicinal plant resources, there is also a need for greater public awareness.

Traditional practices and cultural taboos restrict female participation. Females are too shy to talk to the third person except their husbands or their family members. Unwillingness of females to respond to the third person is due to the belief that they must respect commands from their couples and traditional rules governing their community. There are community-led interventions to address the low participation of females. Researchers can interview females in the presence of their couples or family members but not alone. In some cases, the clan leaders; the GUPITATOs and the SHEKITATOs can help as they are the community leaders. However, female participation is still low because they are too shy to speak in front of researchers for interview.

Declarations

List of abbreviations: AAU: Addis Abba University**;** ANOVA: Analysis of variance**;** CCA- Canonical Correspondence Analysis**;** ESS: Ethiopian statistical service**;** FL: Fidelity level**;** IAS: Invasive alien species**;** ICF: Informant consensus factor; IK: Indigenous knowledge; LSD= Level of Significance Difference defined at $p < = 0.05$ (p less or equal to 0.05); NMDS- Non-metric multidimensional Scaling; PCA- Principal Component Analysis (PCA); PPV: Plant parts value; TMPK: Traditional medicinal plant knowledge; TMPs: Traditional medicinal plants; 3D-Three Dimensional Scatter Plots

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Appendices

Appendix1. List of medicinal plants for treating human ailments

Family /VN/	Scientific Name	LN	Ha	S	PU	CPU	RoA	DT	Preparation and application
Acanthaceae **VN-BH001**	*Justicia schimperiana* (Hochst.ex A. Nees)	**Shesharo** (Kf)	SH	W	LF	FS	Dermal	swelling	Fresh leaf heated on fire, then salt added and tied on the swollen part
				HG	LF	FS	Oral	Abortion	Fresh leaf crashed and drank for 3 days by small cup
Amaranthaceae **VN-BH002**	*Achyranthes aspera* L.	**Bilegadi** (Shk)	H	W	LF	DR FS	Oral	Diabetes	Dry/fresh leaves crushed, pounded and filtered then infusion drunk in the middle of night
Amaryllidaceae **VN-BH003**	*Allium sativum* L.	**Duqisho** (Shk)	H	MK	RT	FS	Dermal	Rabies	Fresh roots/stem chewed and sprayed on the bite place or put on the wound part
Apiaceae **VN-BH004**	*Coriandrum sativum* L.	**Dimbilal** (Am)	H	MK	SD	DR	Oral	Common cold	The process involves grinding the roasted seeds, blending them with water, and consuming the resulting solution orally usually as soup or other food supplement.
VN-BH005	*Foeniculum vulgare* Miller	**Shukeajjo** (Shk)	SH	W	ST	FS	Dermal	Fungus	Stem part latex added on infected nail.
					WH	FS	Oral	Stomachache	Whole plant is finely pounded mixed with spices and condiments in water and honey. A coffee cup of the concoction is drunk until the pain relievers.
Araliaceae	*Polyscias fulva* (Hiern) Harms	**Karasho** (Shk)	T	W	LF	FS	Oral	Toothache	The leaf of this plant heated and pressed teeth
VN-BH006					LF	FS	Oral	Gingivitis	Fresh young leaf is chewed with salt and kept in mouth.
Asparagaceae **VN-BH007**	*Asparagus africanus* Lam.	**Yet'c'ufo** (Shk)	H	W	ST LF	FS DR	Dermal	Herpes zoster	Stem crashed and painted on infected body for 3 days. Fresh or dry leaf is finely grinded and sprayed on body.
VN-BH008	*Dracaena steudneri* Engler	**Youdo** (Shk)	SH	W	ST	FS	Oral	Jaundice	Stem internal part pounded, and the liquid mixed with bread of *Eragrosts teff* and drunk for three days with small cup.
Asphodelaceae **VN-BH009**	*Aloe kefaensis M.G.*Gilbert & Sebsebe	**Gineatto** (Shk)	H	W	LT	FS	Dermal	Ring worm	Taken the latex part and put on the infected area, also taken the latex part and painted on the infected part continuously for 3or 4 days

				W	LT	FS	Dermal	Wound	Taken the latex part and put on the wound, also taken the latex part and painted on the infected part continuously for 3or 4 days
Asteraceae **VN-BH010**	*Acmella caulirhiza* Delile	**Shishimo** (Shk)	H	W	FL	FS	Oral	Tonsillitis	Chewing the fresh fruit parts and swallowing orally with small amount, Chewing and painting around infected parts. Fruit used to clean any garbage from the eye
VN-BH011	*Artemisia absinthium* L.	**Boqaro** (Shk)	H	M K	LF	FS	Dermal	Headache	Fresh leaves crashed and taken trough nasal
VN-BH012	*Artemisia afra* Jacq. ex Willd.	**Natillo** (Shk)	H	W	LF	DR	Nasal	headache	Leaf crashed and smell. Also consumed as spice and condiment as part of food and beverage ingredients.
VN-BH013	*Bidens biternata* (Lour.) Merr. & Sherff.	**Kello** (Shk)	SH	W	LF	FS	Ear	Ear diseases	Leaf crashed, pressed and added liquids through ear for three days with small amount
VN-BH014	*Crassocephalum crepidioides* (Benth.) S. Moore	**Mandillo** (Shk)	H	W	ST	FS	Oral	Pancreatic diseases	Stems crashed and added on k'oc'c'o which is local food.
VN-BH015	*Echinops kebericho* Mesfin	**Qapharo** (Shk)	SH	M K	RT	DR FS	Dermal	Snake poison	Root crashed and spray around the body for 2 or 3 days.
VN-BH016	*Laggera alata* (D.Don) Sch.Bip. ex Oliv.	**Huphiso** (Shk)	SH	W	LF	FS	Dermal	Headache	Leaves heated and put on the facial parts. Leaves together with *Ocimum lamiifolium* and *Eucalyptus globulus* boiled together and fumigated to the patient.
VN-BH017	*Laggera crispata* (Vahl) Happer & J.R.I.Wood	**Huphiso** (Shk)	SH	W	LF	FS	Dermal	Headache	Leaves heated and put on the facial parts. Leaves together with *Ocimum lamiifolium* and *Eucalyptus globulus* boiled together and fumigated to the patient.
VN-BH018	*Vernonia amygdalinaDelile*	**Grawo** (Shk)	T	W H G	LF	FS	Oral	Endo-parasites	Fresh leaves usually the young sprouting parts are finely pounded, soaked in water, filtered, mixed with honey and a coffee cup or more drunk every morning.
VN-BH019	*Vernonia hymenolepis* A.Rich.	**Dengrato** (Shk)	SH	W	LF	FS	Oral	Rabies	Fresh shoot part crashed and mixed with *Measa lanceolata* and ate with cheese
VN-BH020	*Vernonia wollastoni* S.Moore	**Fot'eqombe** (Shk)	Cl	W	ST	FS	Optical	Eye diseases	Young stem cut and liquid exudate is used as eye drop for 3-4 days until the pain relievers.

Balsaminaceae **VN-BH021**	*Impatiens ethiopica* Grey-Wilson	**Tepacho** (Shk)	H	W	ST	FS	Dermal	Schistosomiasis	Stem crashed and painted with its latex for 3 days.
VN-BH022	*Impatiens rothii* Hook.f.	**Oc'ino** (Shk)	Cl	W	RT	FS	Oral	Blood pressure	Root part cooked and ate for three days. Soup is prepared from the cooked rhizome and consumed.
Boraginaceae **VN-BH023**	*Cordia africana* Lam.	**Di'o** (Shk)	T	W	BR	FS	Oral	Toothache Endoparasites	Fresh stem bark chewed. Fruits are eaten raw. Fresh fruits are eaten raw to expel intestinal parasites.
				HG	BR	FS	Oral	Acute/Malaise	Fresh stem bark crushed drunk. Fruits eaten raw.
VN-BH024	*Cynoglossum coeruleum* Hochst.ex.A.DC.	**Michiato** (Shk)	H	W	LF	FS	Dermal	Body swelling	Fresh roots chewed and sprayed on swollen part. Fresh leaf smashed, squeezed, sniffed into nostrils.
Campanulaceae **VN-BH025**	*Lobelia giberroa* Hemsl.	**Gaderano** (Shk)	SH	W	ST RT	FS FS DR	Dermal Oral	Shingles/t'okko Hepatitis	Stem crashed and put on infected part of a body. Root is finely pounded, mixed with honey, boiled added to soup then orally taken with a cup of tea.
Caryophyllaceae **VN-BH026**	*Stellaria media* (L.) Vill.	**Dabehec'awe** (Shk)	H	W	LF	FR	Dermal	Spider poison	Leaf and stem crashed and paint on body, put on the wound
VN-BH027	*Stellaria sennii* Chiov.	**Shekiato** (Shk)	H	W	RT	FS	Oral	Jaundice	Root crashed, pressed and drunk with cup for three days and taking fresh milk to minimize the power of drug
Celastraceae **VN-BH028**	*Catha edulis* (Vahl) Endl.	**C'aato** (Shk)	SH	W, HG	RT	DR FS	Oral	Amoeba	Dry/fresh roots crushed, boiled, filtered, cooled and drunk until recovery.
VN-BH029	*Gymnosporia obscura* (A.Rich.) Loes.	**At'at'o** (Shk)	SH	W	LF	FS	Dermal	Insect bite (koshkosho)	Fresh shoot parts of the leaf crashed, heated put on the infected part
Commelinaceae **VN-BH030**	*Cyanotis vaga*(Lour.) Schult. & chult.f.	**Nalat'o** (Shk)	Cl	W	LF	FS	Dermal	Headache	Leaf crashed and inserted/sniffed in to nose.
Crassulaceae **VN-BH031**	*Kalanchoe petitiana* A. Rich.	**Motto** (Shk)	H	WHG	LF	FS	Dermal	Leg swelling	Fresh Leaves heated with fire, and then salt added and tied on the swollen part.
Cucurbitaceae	*Coccinia abyssinica* (Lam.) Cogn.	**Ajjo** (Shk)	H	W	TB	DR	Oral	Stomachache	Root tuber is eaten continuously to relieve the pain.
VN-BH032					TB TB	FS DR FS	Oral Oral	Endoparasites Gastritis	Fresh tuber is cooked and eaten. Root tuber parts eaten continuously for a few days

VN-BH033	*Cucumis maderaspatanus* L.	**Gaato** (Shk)	Cl	W	RT	FS	Oral	Toothache	Root boiled and gargle with its decoction and infusion. Fresh root is chewed with salt and kept between teeth.
VN-BH034	*Cucurbita pepo* L.	**Buqee** (Or)	H	W	SD	DR	Oral	Tapeworm	Dry seeds are cocked and eaten in the morning. Entire fruit is cooked and eaten as food supplement.
				H G	SD	DR	Oral	Ascariasis	Dry seeds are cocked and eaten in the morning.
VN-BH035	*Momordica foetida* Schumach.	**Omballo** (Shk)	H	W	W H	FS	Oral	Glandular swelling	Whole part crushed and pounded, then filtered and drunk
VN-BH036	*Peponium vogelii* (Hook.f.) Engl.	**Tojjo** (Shk)	Cl	W	FR	FS	Oral	Gastritis	Fruit part peeled and eaten raw or fried as snack. Entire fruit is cooked and prepared as soup for consumption.
Cupressaceae **VN-BH037**	*Juniperus procera* Hochst. ex Endle.	**T'ido** (Shk)	T	H G	SD	DR	Oral Nasal	Respiratory	Dry seeds are pounded and powdered then mixed with tea, and drunk. It also sniffed through nostrils.
Cyatheaceae **VN-BH038**	*Alsophila manniana* (Hook.) R.M.Tryon	**Sheshino** (Shk)	SH	W	LF	FS	Oral	Abortion	Fresh leaves crashed and drunk with small coffee cup for three days
Euphorbiaceae **VN-BH039**	*Croton macrostachyus Hochst. ex Delile*	**Shomo** (Shk)	T	W	LF	FS DR	Dermal	Multiple uses	Dry or fresh leaves pounded, powdered and put on wound. Latex from petiole is used to treat hemorrhage, tetanus, and intestinal parasites and fungal infections.
					BR	FS	Oral	Amoeba, STI	Fresh stem bark is crushed, finely pounded, mixed with water, filtered then drunk after breakfast in the morning until recovery from Amoeba, Gonorrhea and pneumonia.
VN-BH040	*Euphorbia ampliphylla Pox.*	**Qakaro** (Shk)	SH	W	LT	FS	Oral	Endo-parasite	Latex mixed with butter taken orally with food. Latex is baked together with *Eragrosts teff* and eaten.
					RT	FS	Dermal	swelling	Root is crushed and tied on swollen part of a body.
VN-BH041	*Euphorbia dumalis* S.Carter	**Abdombo** (Shk)	SH	W	ST	FS	Dermal	Body swelling	Stem cut and latex paint on the swollen body parts of a body. Stem pounded and tied on the affected part.
VN-BH042	*Ricinus communis* L.	**Eho** (Shk)	SH	H G	RT	FS	Oral	Pneumonia	Fresh root crushed and pounded then, decoction of the ingredient is drunk every night and morning until recovery. Honey and butter are used as ingredients.
					RT	FS DR	Dermal	Body swelling	Fresh or dry roots chewed and sprayed on the affected part of the body.

Fabaceae **VN-BH043**	*Erythrina abyssinica* Lam.	**Bero** (Shk)	T	W	LF	FS	Optical	Eye diseases	Fresh shoot parts crashed and added a drop of liquid in the eye
VN-BH044	*Erythrina brucei* Schweinf.	**Kocho** (Shk)	T	W	R	FS	Oral	Tumors /Body warts/	Root of *Erythrina brucei* together with fruits of *Lepidotrichilia volkensi* are boiled together with salt and eaten. Then the swollen body /tumor/ oozes releasing lesions. Finally, the wound will dry gradually until it disappears.
VN-BH045	*Melilotus suaveolens* Ledeb.	**Manio** (Shk)	SH	W	LF	FS	Oral	Common cold	Fresh leaf part crashed, pressed and drunk ½ of cup for 3-4 days specially to child
VN-BH046	*Millettia ferruginea* (Hochst.) Hochst. ex Baker	**Yago** (Shk)	T	W	BR	FS	Dermal	Ecto-parasites	Fresh stem bark is crushed and pounded with water and given orally ad painting on the body.
					BR	DR	Oral	Toothache	Bark burn and catch teeth with it.
VN-BH047	*Vicia faba* L.	**Baqero** (Shk)	H	W	SD	DR	Oral	Bone fracture	Seeds coked and drunk the decoction as soup. Seeds are roasted and eaten as food.
Francoaceae **VN-BH048**	*Bersama abyssinica* Fresen.	**Boqo** (Shk)	T	W	LF	DR	Dermal	Skin infection	Dry leaves burned and mixed with butter, then pasted in open sun light
Lamiaceae **VN-BH049**	*Achyrospermum parviflorum* S.Moore	**Atbatto** (Shk)	H	W	LF	FS	Dermal	Wound	Fresh leaf's part crushed and then painted on the wound
VN-BH050	*Ajuga integrifolia* Buch.-Ham.ex D.Don	**Wujikasho** (Shk)	H	W	LF	FS	Oral	Stomach hemorrhage	Fresh leaves crushed and drunk with small finger measurement at morning
VN-BH051	*Clerodendrum myricoides* (Hochst.) R.Br. ex. Vatke	**Agio** (Shk)	SH	W	RT	DR FS	Oral	Pneumonia	Dry or fresh roots are crushed, finely pounded, boiled in salt water, cooled and decoction of the boiled mixture is added to hone or butter and drunk every morning until recovery. Fresh stem bark is also smelled through nostrils.
					RT	FS	Dermal	Body swelling	Fresh root is chewed, mixed with salt and tied on the affected part of the body.
					LF	FS	Optical	Eye problems	Fresh leaves are pounded and the powder is sprayed into the eye.
					R	FS	Oral	Rabies	Fresh root together with root of Asparagus species are finely pounded mixed with water and a coffee cup of dosage is orally taken. Milk is used as antidote.

VN-BH052	*Clinopodium simense* (Benth.) Kuntze	**Neddo** (Shk)	H	W	LF	FS	Dermal	Fibril illness	Leaves crashed and females washed their body for five days after birth
VN-BH053	*Coleus abyssinicus* (Fresen.) A.J.Paton	**Yeiro** (Shk)	SH	W	LF	FS	Oral	Stomachache	Fresh leaf crashed, pressed and liquids mixed with cheese and ate.
VN-BH054	*Coleus igniarius* Schweinf.	**Yet'o** (Shk)	SH	W	LF	FS DR	Dermal	Skin infection	Fresh or dry leaves are pounded and mixed with butter and used as ointment or body lotion on the affected skin.
VN-BH055	*Coleus maculosus subsp.edulis* (Vatke) A.J.Paton	**Shawedoqe** (Shk)	H	W	RT LF	FS	Oral	Toothache	Root heated and put on teeth. Fresh leaf crashed, pressed and liquids mixed with cheese and ate.
VN-BH056	*Isodon schimperi* (Vatke) J.K. Morton	**Yabagawi** (Shk)	H	W	LF	FS	Nasal	Fibril illness	Leaf crashed and taken through nasal and painted around the eye
VN-BH057	*Leucas tomentosa* Gürke.	**Timbaguo** (Shk)	H	W	LF	FS	Oral	Intestinal parasite	Fresh leaves mixed with *Ocimum urticifolium* chewed and swallowed in the morning
VN-BH058	*Ocimum lamiifolium* Hochst. ex Benth.	**Damo** (Shk)	SH	W H G	LF	FS	Nasal	Fibril illness	Leaf crashed insert in to nose and taking through nasal
VN-BH059	*Ocimum urticifolium* Roth	**Damo** (Shk)	H	W H G	LF	FS	Oral	Fibril illness	Fresh leaves rubbed by hand and droplets are drunk and leaves painted on the body and sniffed
					LF	FS	Oral	Headache	Fresh leaves rubbed by hand and droplets are drunk and leaves painted on the body and sniffed
Malvaceae **VN-BH060**	*Dombeya torrida* (J.F.Gmel.) Bamps	**Boaro** (Shk)	T	W	LF	FS	Dermal	Snake bite	Fresh leaves crashed and mix with *Setaria megaphylla* leaves and paint on the body
VN-BH061	*Malva verticillata* L.	**Yewusato** (Shk)	H	W	RT	DR	Oral	Abortion	Root crash/pounded and mixed with soap berry and drunk ½ of the cup for three days
Meliaceae **VN-BH062**	*Ekebergia capensis* Sparrm.	**Ororo** (Shk)	T	W	SD	DR	Oral	Endo-parasites	Dry seeds are chewed and swallowed directly to expel intestinal parasites.
Menispermaceae **VN-BH063**	*Stephania abyssinica* (Quart.-Dill. & A.Rich.) Walp.	**Fiko** (Shk)	Cl	W	RT	FS	Oral	Sudden illness	Fresh roots chewed and the juice swallowed
					LF	FS	Dermal	Skin cancer	Fresh leaves rubbed by hand and droplets rubbed on the skin
					W H	FS	Oral	Jaundice	Fresh and whole parts crushed, pounded, then infusion and decoction drunk on the evening

					ST	FS	Oral	Cough	Fresh stem chewed and extracts swallowed
Moraceae **VN-BH064**	*Ficus sur* Forssk.	**Et'o** (Shk)	T	W	FR	DR	Oral	Malaria	Dry fruits pounded, powdered and then mixed with honey and taken orally twice
					FR	DR	Dermal	wound	Dry fruits pounded, powdered and then pasted on wound
					FR	DR	Dermal	Acute bleeding	Dry fruits pounded, powdered and then pasted on wound
					BR	FS	Oral	Vomiting	Fresh stem barks crushed, pounded, boiled, and cooled, then drunk twice as tea
Moringaceae **VN-BH065**	*Moringa stenopetala* (Baker f.) Cufod.	**Moringa** (Am)	T	W, H G	LF	FS	Oral	Diabetes	Fresh leafs cocked as food and eaten
Musaceae **VN-BH066**	*Ensete ventricosum* (Welw.) Cheesman	**Qawo** (Shk)	H	W	ST	DR FS	Oral	Bilharzia	Latex (bulla/Etino in Amharic/local name) painted on infected body part after the scratched of inset
Myrtaceae **VN-BH067**	*Eucalyptus globulus* Labill.	**Nech bahrzaf** (Am)	T	W	LF	FS	Nasal	headache	Fresh leaves rubbed by hand and sniffed. Fresh leaf is boiled and fumigated to the patient.
				H G	LF	FS	Nasal	Common cold	Fresh leaves rubbed by hand and sniffed
Oleaceae **VN-BH068**	*Olea europaea subsp. Cuspidata* (Wall.ex G. Don) Cif.	**Yeho** (Shk)	T	W H G	LF	DR FS	Oral	Toothache	Dry/fresh branches used as tooth brush and chewed.
					LF	FS	Oral	Intestinal parasites	Fresh leaves boiled and the infusion drunk in the morning
Phytolaccaceae **VN-BH069**	*Phytolacca dodecandra L'Hér.*	**Yingo** (Shk)	Cl	W	RT	DR FS	Oral	Bilharzia	Dry or fresh root is chewed and swallowed with honey.
					BR	DR	Oral	Endo-parasites	Stem bark is put in sun light to dry. Then chewed with salt and directly swallowed.
					RT	DR	Oral	Pneumonia	Dry root is pounded and the powder is mixed with water and drunk after breakfast every morning.
					RT	DR	Oral	Contraception	Dry root is pounded, the powder is mixed with water and drunk after breakfast to stop pregnancy.
Piperaceae **VN-BH070**	*Peperomia retusa* (L.f.) A.Dietr.	**Gargio** (Shk)	Cl	W	ST	FS	Oral	Stomachache	Stem chewed and swallowed its liquid orally
					ST	FS	Oral	Intestinal	Stem chewed and swallowed its liquid orally

Poaceae **VN-BH071**	*Arundinaria alpina* K. Schum.	**Ho'o** (Shk)	SH	W	RT LF	FS	Dermal	Body swelling	Fresh root chewed and sprayed on swollen part. Leaves of young shoots cooked and eaten as food.
VN-BH072	*Narenga porphyrocoma* (Hance) Bor	**Agado** (Shk)	SH	W	ST	FS	Oral	Gastritis	Stem sweet part crashed and swallowed through oral
VN-BH073	*Setaria megaphylla* (Steud.) T. Durand & Schinz	**Fotto** (Shk)	H	W	RT	DR FS	Dermal	Snake poison	Root crashed or chewed and spray on the body
Polygonaceae **VN-BH074**	*Rumex nepalensis* Spreng.	**Shorato** (Shk)	H	W	LF	FS	Ear	Ear infection	Fresh leaves heated on fire then fluids from the leaf is dropped in to the ear and putted in side
					RT	DR FS	Dermal	Body swelling	Dry/fresh root chewed and put on the swollen part
Primulaceae **VN-BH075**	*Embelia schimperi* Vatke	**Dup'P'o** (Shk)	SH	W	SD LF	FS	Oral	Intestinal pain	Seeds in freh fruits are pounded and drunk with honey. Leaves crashed and liquid part drank for 3or 4 days.
VN-BH076	*Maesa lanceolata* Forssk.	**C'eggo** (Shk)	SH	W	LF	FS	Oral	Rabies	Fresh shoot part crashed and mixed with *Vernonia hymenolepsis* and ate with cheese
Pteridaceae **VN-BH077**	*Cheilanthes bergiana* Schltdl.	**Sheso** (Shk)	H	W	RT	FS	Dermal	Snake bite	Root crashed/pounded and painting or rubbing around the body for 2-3 days
Ranunculaceae **VN-BH078**	*Ranunculus multifidus* Pursh	**Fogio** (Shk)	H	W	LF	FS	Oral	Pneumonia	Fresh leaves are pounded then infusion and decoction of the pounded leaf is mixed with salt and honey and drunk every morning until recovery.
					LF	FS	Nasal	Headache	Fresh leaves are rubbed by between hand palms, smashed into fine and dropped into the nostrils.
Resedaceae **VN-BH079**	*Caylusea abyssinica* (Fresen.) Fisch. & C.A.Mey.	**Arac'o** (Shk)	H	W	LF	FS	Dermal	Ringworm	Fresh leaves crushed and painting around the infected body parts until the fungus discharge from the skin
Rhamnaceae **VN-BH080**	*Rhamnus prinoides* L'Herit.	**Geesho** (Shk)	SH	W H G	LF	FS	Dermal	Skin infection	Fresh leaves rubbed on the infected skin
Rosaceae **VN-BH081**	*Prunus africana* (Hook.f.) Kalkman	**Omo** (Shk)	T	W	BK	DR	Dermal	Wound	Dry stem bark is crushed, finely grinded and the powder is directly applied to the body wound.
VN-BH082	*Rubus apetalus* Poir.	**Garo** (Shk)	Cl	W	LF SD	FS	Dermal	Body swelling	Fresh leaves are chewed, sprayed on the swollen body. Seeds in fresh fruit are eaten raw.
					LF	DR FS	Dermal	Wound	Fresh/dry leaves are pounded then either sprayed or tied on the wound

Rubiaceae **VN-BH083**	*Coffea arabica* L.	**Buna** (Am)	SH	W	WH	DR	Nasal	Malaria	Whole parts are burned and smoking
				HG	SD	DR	Oral	Gastritis	Seeds are cocked and chewed and swallowed
					SD	DR	Nasal	Headache	Dry cocked seeds are pounded and given nasal
VN-BH084	*Galium simense* Fresen.	**Shatto** (Shk)	H	W	RT	FS	Dermal	Wound	Internal root part scratched and put on wound for 2or 3 days
					LT	FS	Oral	Pneumonia	Latex from the stem collected in certain container and drunk orally for 3 days with in small cup
VN-BH085	*Mitragyna rubrostipulata* K.Schum.) Havil.	**Oppo** (Shk)	T	W	BR	FS RD	Oral	Jaundice	Bark crashed/pounded and drunk ½ of cup for 3 days
VN-BH086	*Pavetta gardeniifolia* Hochst. ex A.Rich.	**Qorbandaro** (Shk)	T	W	LF	FS	Optical	Eye disease	Leaves cut four times and thrown in fronts of the patient at the side sick eye
VN-BH087	*Vangueria madagascariensis* J.F.Gmel	**Gujjimato** (Shk)	T	W	BR	DR	Oral	Ascariasis	Bark crashed, mixed with wheat Powder, boiled and drunk one glass for 2 days
Rutaceae **VN-BH088**	*Citrus x sinensis* (L.) osbeck	**Burtukan** (Am)	SH	WHG	FT	FS	Oral	Gastritis	Fresh fruits juice is drunk
VN-BH089	*Clausena anisata* (Willd.) Hook.f. ex Benth.	**Irmoc'o** (Shk)	SH	W	ST	DR FS	Oral	Toothache	Stem clean any bacteria from tooth trough brushing daily
VN-BH090	*Ruta chalepensis* L.	**C'dramo** (Shk)	H	HG	WH	FS	Oral	Amoeba	Fresh plant is chewed and directly swallowed every morning.
					LF	DR	Oral	Vomiting	Dry leaves are cocked in tea and drunk during the time of pain or sense of vomit.
					LF	FS	Oral	Pneumonia	Fresh leaves are pounded, powdered, mixed with oil then drunk every morning for three days.
					LF	FS	Oral	Stomachache	Fresh leaves are chewed with salt and swallowed.
					WP	FS DR	Anal	Abdominal cramp	The whole plant is boiled in water, warmed and used as a washing agent of the abdomen.
Sapindaceae **VN-BH091**	*Allophylus abyssinicus* (Hochst.) Radlk.	**She'o** (Shk)	T	W	WH	FS	Dermal	Skin diseases	Taken the root, leaf and bark parts and crashed together and rubbing for 4 days respectively
Solanaceae **VN-BH092**	*Datura stramonium* L.	**Nafnifo** (Shk)	H	W	LF	FS	Dermal	Head shingles	Fresh leaves pounded and pasted on the head
					SD	FS	Oral	Toothache	Fresh or dry seeds are heated on fire with butter and smoked to teeth.

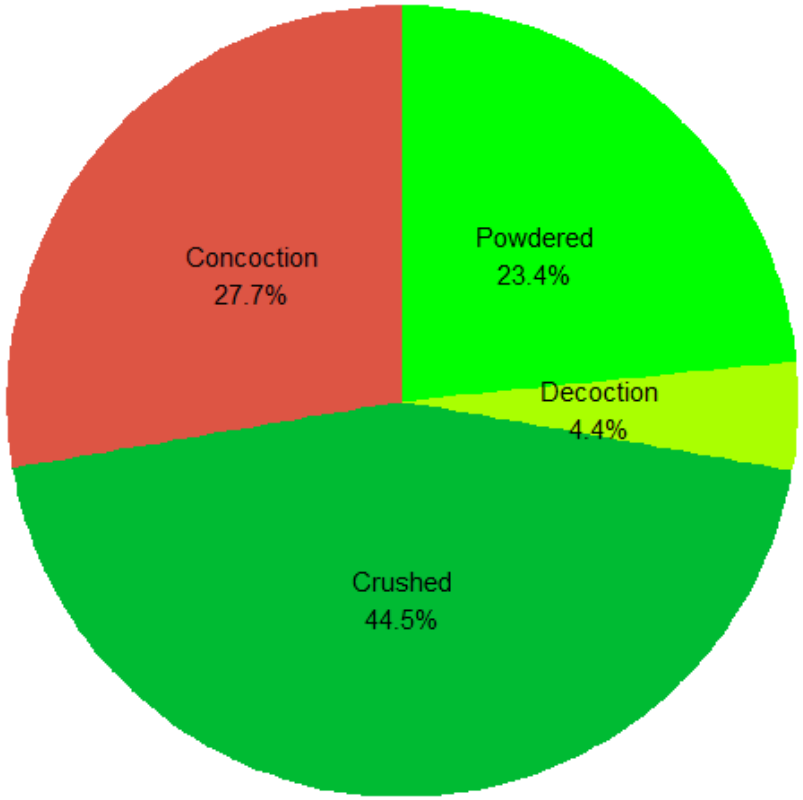
VN-BH093	*Nicotiana tabacum* L.	**Timbaho** (Am)	H	H G	LF	DR	Oral	Headache	Dry leaves are finely pounded and the powder is smelled through the nostrils.
VN-BH094	*Physalis peruviana* Mill.	**Wat'qai** (Shk)	H	W	FR	FS	Dermal	Glandular	Fruit heated and catch the swollen glands with it. Fruits eaten raw as food supplement.
					FR				
VN-BH095	*Solanum incanum* L.	**Duri** (Shk)	SH	W	RT FR	FS	Oral	Endo-parasite	Fresh root chewed and swallowed. Fresh fruits orally taken as tablets.
					LF	FS	Nasal	Nasal bleeding	Fresh leafs are rubbed and inserted in to nose
					FR	FS	Dermal	Snake bite	Fresh fruits or leaves are rubbed on the part with the snake bites
VN-BH096	*Solanum villosum* Mill.	**Acho** (Shk)	H	W	LF	FS	Oral	Gastritis	Fresh leaves cooked and eaten as food during every meal. Fruits also eaten raw with salt or sugar.
Urticaceae **VN-BH097**	*Urera hypselodendron* (Hocst. Ex A.Rich.) Wedd.	**Imano** (Shk)	Cl	W	LF	FS	Dermal	Ear problems	Leaf is crushed, pressed, squeezed and the liquid part is used as ear drop.
Verbenaceae **VN-BH098**	*Lippia adoensis var koseret* Sebsebe	**Shobo** (Shk)	SH	W	LF	FS	Oral	Blood pressure	Fresh shoot leaf by using art mixed with milk and drank by using cup
					LF	FS	Oral	Endo-parasite	Fresh shoot leaf by using art mixed with milk and drank by using cup
Zingiberaceae **VN-BH099**	*Curcuma domestica* Valeton.	**Ird** (Am)			R H	FS DR	Oral	Stomach problems	Rhzome is finely pounded and used as spice and condiment togetherwith other spices as food supplement.
VN-BH100	*Zingiber officinale* Roscoe	**Yenjibalo** (Shk)	H	H G	RZ	DR FS	Oral	Common cold	Rhizome is chewed or pounded, cocked, boiled in tea and drunk.

Key: VN =Voucher Number**, LN=** Local Name, **Habit (Ha)** (**T**=Tree, **SH**=Shrub, **H**=Herb, **Cl**=Climber), **S=** Source(**W=** wild, **HG=** Homegarden**, MK=** market), **PU**=Parts Used (**LF**=Leaf, **RT**=Root, **BR**=Bark, **FR**=Fruit, **SD**=Seed, **ST**=Stem, **LT**=Latex, **BU**=Bulb, **FL**=Flower, **WH**=Whole part, **RZ**=Rhizome, **TB**=Tuber). **RoA**=Route of Administration. **DT**= Diseases Treated, **CPU**=Condition of Plants used (**FS**=Fresh, **DR**=Dry), **Local Name**: **Or**=Afan Oromo, **Am**=Amharic, **Shk**=Shekinnono, **Kf**=Kaffnano.

Supplementary files

Supplementary file 1.. Socio demographic characteristics of respondents

Socio-demographic characteristics	Category		N	%	Total
Gender	Male		99	77.3	128
	Female		29	22.6	
Informant category (Healing experience)	General informants		88	68.8	128
	Key informants		40	31.2	
Age groups	18-35	Male	16	12.5	
		Female	7	5.4	128
	36-52	Male	31	24.2	
		Female	10	7.8	
	53-90	Male	52	40.6	
		Female	12	9.4	
Marital status	Married		88	68.7	
	Single		24	18.8	128
	Divorced		16	12.5	
Education level	Illiterate		81	63.3	
	Literate	Elementary	29	22.6	
		High school	12	9.4	128
		Diploma and above	6	4.7	
Occupation	Farmer		59	46.1	
	House wife		14	11	
	Student		41	32	128
	Merchant		14	11	



Supplementary file 2.Preparation Method of Medicinal Plants

Supplementary file 3.Table. Informant Consensus Factor Values of Medicinal Plants

Diseases category	Nt	Nur	Nur-Nt	Nur-1	ICF	%	Rank
Dermal	16	155	139	154	0.91	91	1st
Sense organs	5	41	36	40	0.90	90	2nd
Digestive system	15	131	116	130	0.89	89	3rd
Respiratory systems	12	87	75	86	0.87	87	4th
Sudden illness	8	57	49	56	0.87	87	4th
Cultural related	9	55	46	54	0.85	85	5th
Circulatory systems	7	41	34	40	0.85	85	5th
Animal and vector cause	13	61	48	60	0.80	80	6th
Excretory and Reproductive system	3	9	6	8	0.75	75	7th
Musculoskeletal & nervous system	2	5	3	4	0.75	75	7th

ICF= Informant consensus Factor, **Nur** = number of use reports by informants, **Nt** =number of plant taxa or species used. One informant cited more than one ailment

Supplementary file 4. Table. Fidelity levels of most cited Medicinal Plants

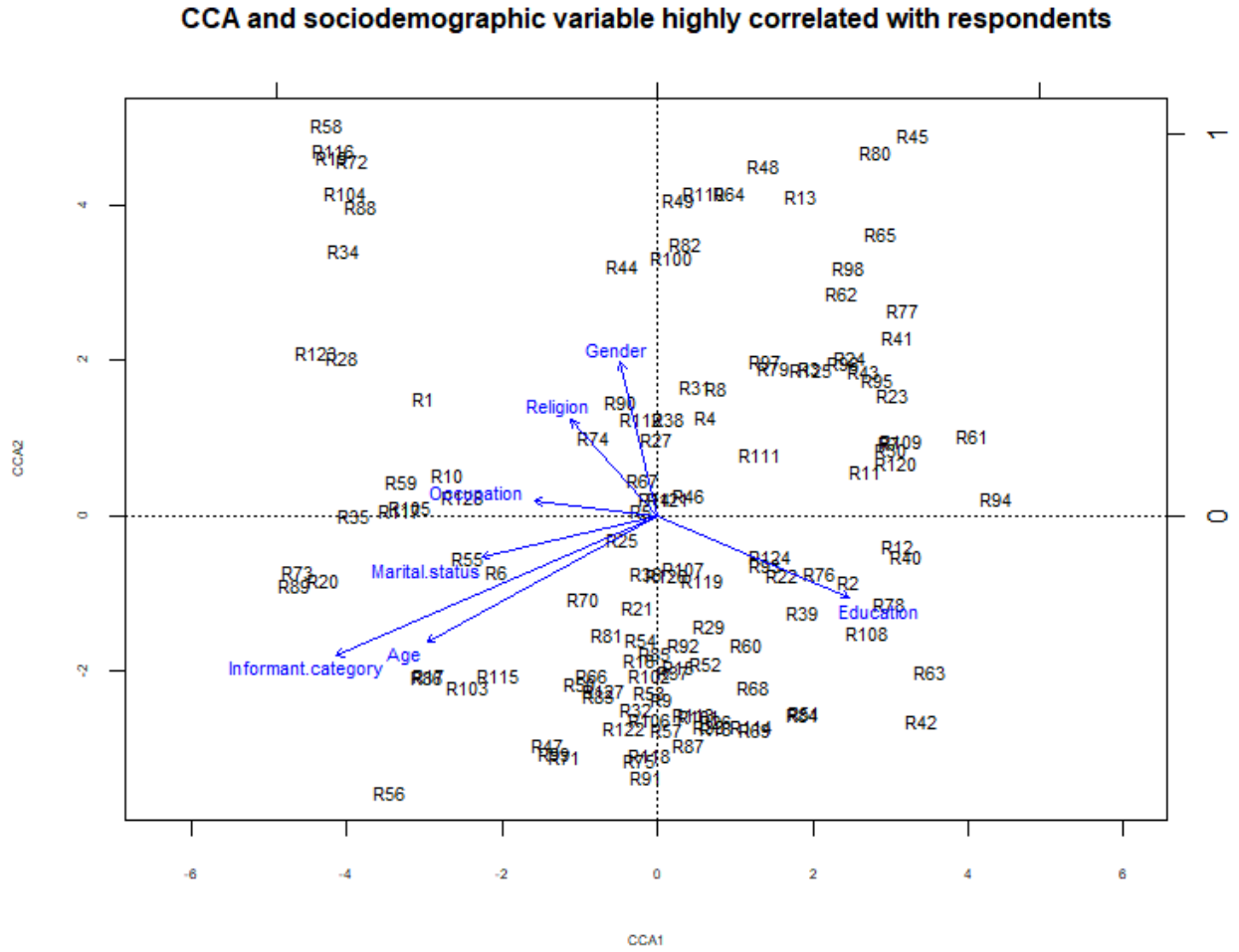
Scientific name	Human Diseases	IP	IU	FL	%	R
Cucurbita pepo L.	Tape worm	12	12	1	100	1st
Ficus sur Forssk.	Malaria	16	16	1	100	1st
Phytolacca dodecandra L'Herit.	Rabies	19	27	0.70	70	2nd
Kalanchoe petitiana A. Rich	Leg swelling	8	12	0.66	66	3rd
Solanum incanum L.	Nasal bleeding	21	37	0.6	60	4th
Momordica foetida Schumach.	Wound	12	21	0.57	57	5th
Millettia ferruginea (Hochst.) Bak.	Toothache	19	33	0.57	57	5th
Coccinia abyssinica (Lam.) Cogn.	Gastric	21	40	0.56	56	6th
Stephania abyssinica Dillon and A.Rich.	Jaundice	29	54	0.53	53	7th
Acmella caulirhiza Del.	Tonsillitis	14	35	0.4	40	8th

R= Rank. **FL**= Fidelity Level, **Ip** = number of informants who independently cited the importance of a species for treating a particular disease, **Iu** = total number of informants who reported the plant for any given disease.

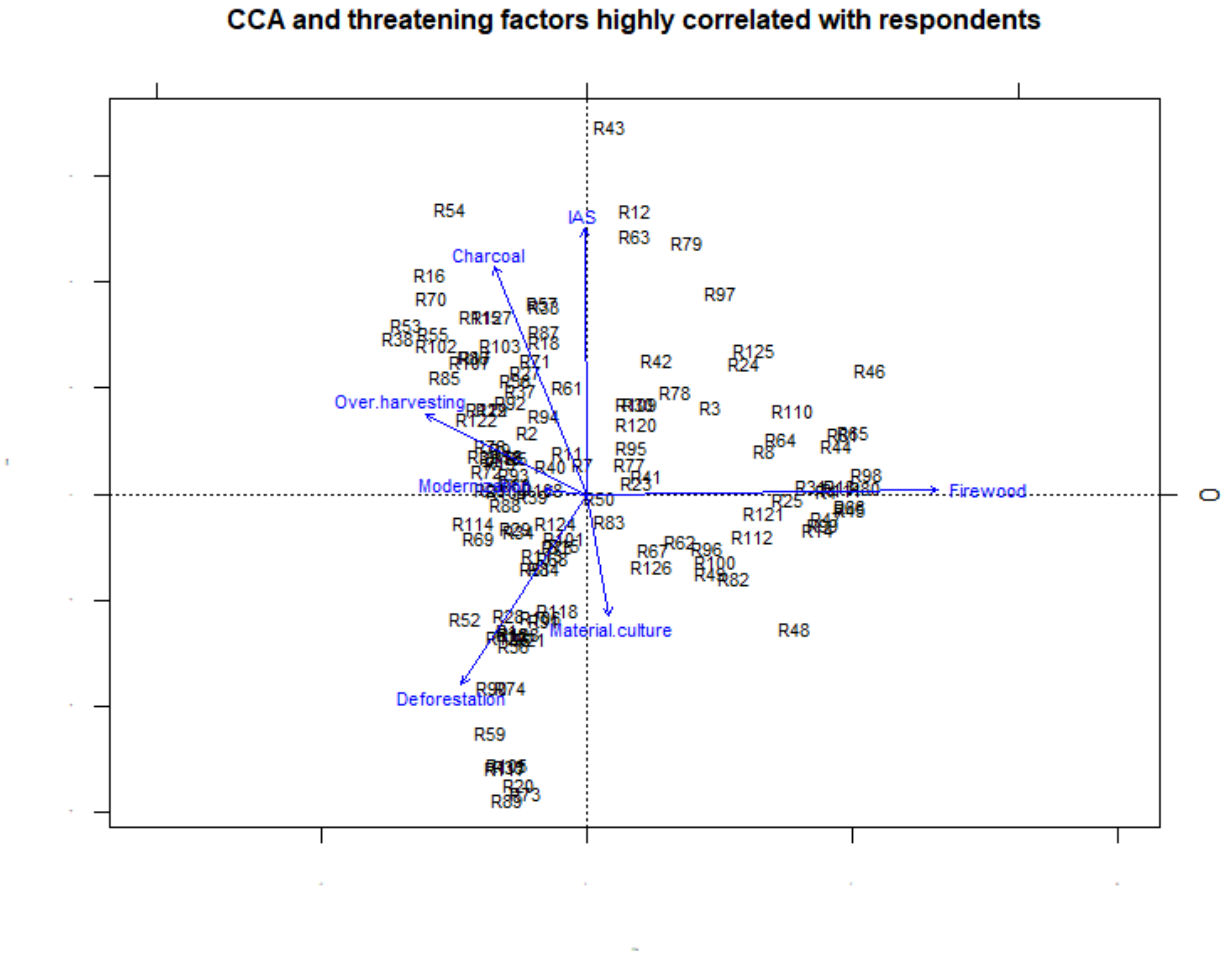
Supplementary file 5:.Table. Preference ranking of TMPs reported for treating human Intestinal parasites

Medicinal plants	Respondents(R_1-R_{10})											
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	Total	Rank

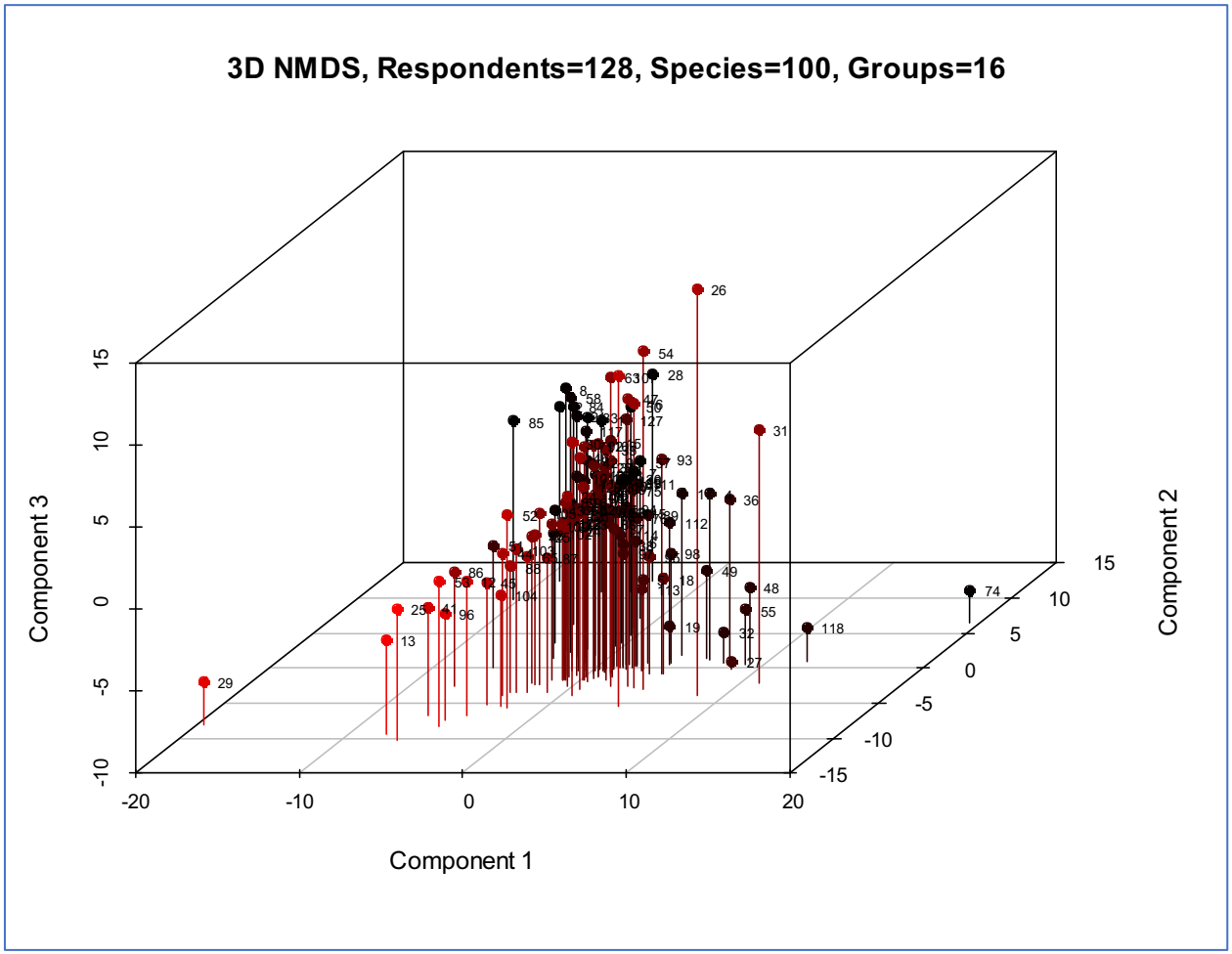
Phytolacca dodecandra L'Herit.	5	4	5	3	5	4	5	4	5	4	44	1st
Vernonia amygdalina Del.	4	3	4	4	3	5	4	5	4	5	41	2nd
Solanum incanum L.	3	5	3	1	4	3	3	2	3	2	29	3rd
Embelia schimperi Vatke	1	1	2	2	2	1	2	3	2	3	19	4th
Croton macrostachyus Del.	2	2	1	5	1	2	1	1	1	1	17	5th



Supplementary file 6. The CCA for sociodemographic factors correlated with respondents.



Supplementary file 7. The CCA for threatening factors to medicinal plants



Supplementary file 8. The 3D NMDS scatterplot

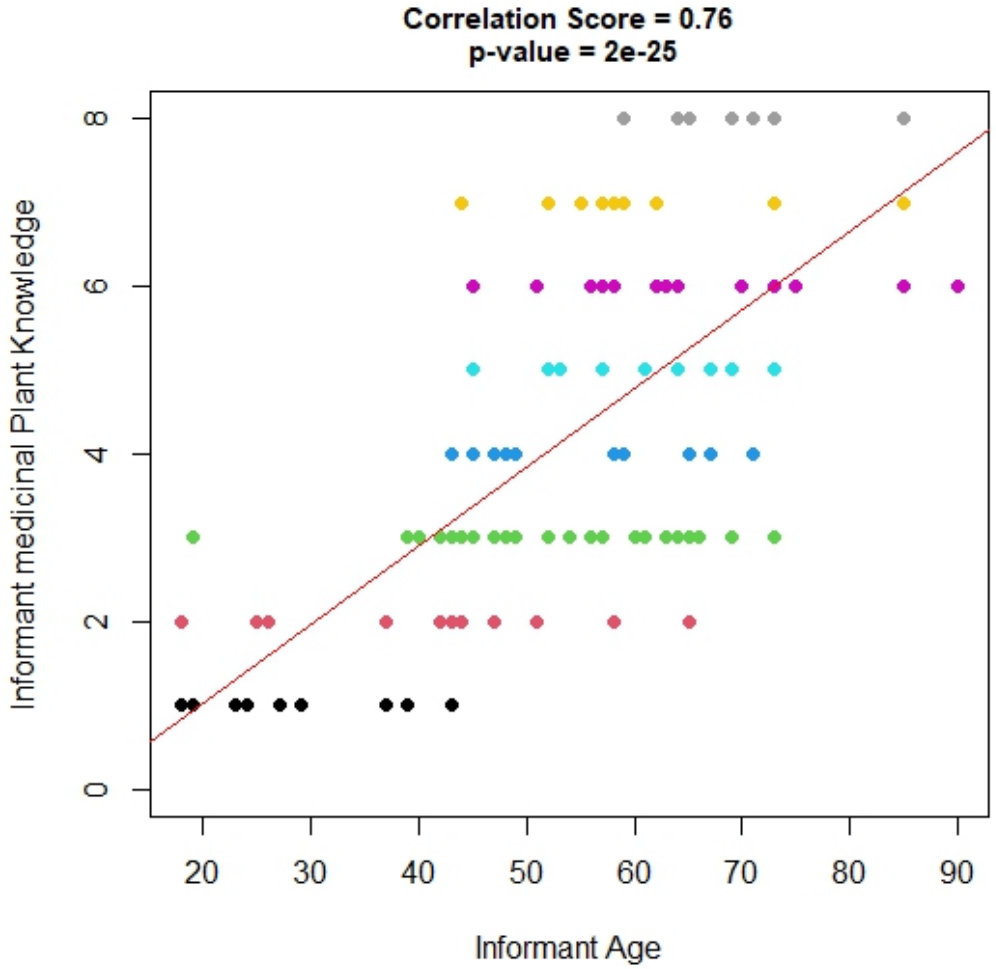
Supplementary file 9. Table. Medicinal Plants Knowledge among Informant Groups (t-test)

Characters	**Informant groups**	***N***	***Mean ± SD***	***t –value***	***p – value***
Gender	Male	99	3.7±1.8	4.9	*P<=0.05*
	Female	29	2.3±1.2		
Literacy level	Illiterate	81	3.9±1.9	4.3	*P<=0.05*
	Literate	47	2.5±1.6		
Experience of Informant	Key informant	40	5.2±1.5	8.1	*P<=0.05*
	General informant	88	2.8±1.5		

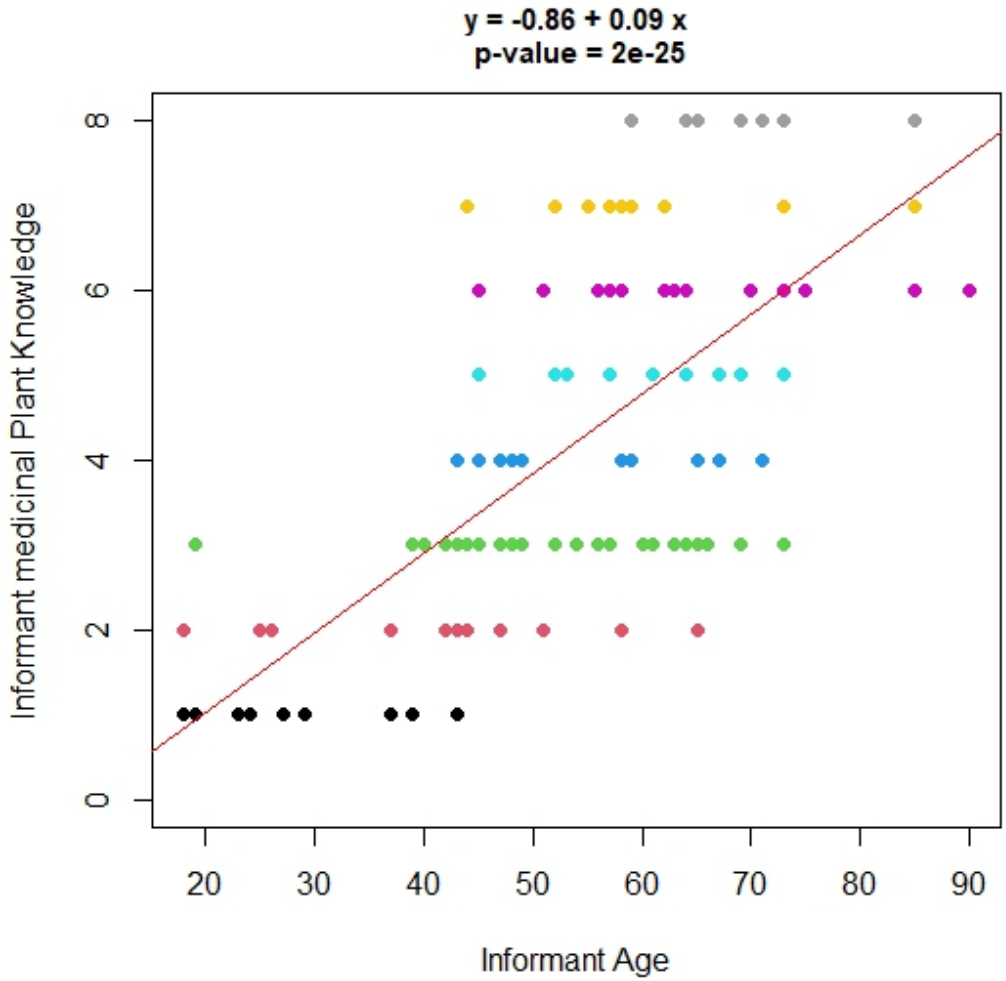
Supplementary file 10. Table. Age Categories with Informant Knowledge (One way ANOVA)

Source of Variation	**Df**	**SS**	**MS=SS/df**	**F Ratio**	***P-value***
Between Groups	k – 1 3-1=2	184.5	92.2	29.5	*P<=0.05*
Residual (within)	n-k 128-3=125	396.8	3.1		
Total	n – 1 128-1=127	581.3	95.3		

Note: **K**=number of levels, **n**=number of observations, **df=**degree of freedom, **SS**= Sum of Squares, **MS**= Mean of Square, Significant codes: 0.05



Supplementary file 11. Correlation Model of Informant Age Category



Supplementary file 12. Regression Model of Informant Age Category