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Diversity and role of woody Non-Timber Forest Products in Doba District, Eastern Ethiopia

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Abstract. *Abebaw AF, Damme PV. 2023. Diversity and role of woody Non-Timber Forest Products in Doba District, Eastern Ethiopia. Nusantara Bioscience 15: 38-47.* Non-Timber Forest Products (NTFP) play a pivotal role as local sources of medicine, household paraphernalia, and fodder and offer income opportunities that can mitigate poverty. This study was conducted in Doba District, West Hararghe Zone, Eastern Ethiopia, to analyze the diversity and economic contribution of Non-Timber Forest Products. Both ethnobotanical and vegetation data were cross-sectionally collected from February 2020 up to June 2021. A total of 422 informants selected randomly from forest inhabitants were interviewed using semi-structured questionnaires to explore NTFP utilization and their economic contributions. Vegetation data were collected from 56 sample plots of each 20m x 20m (400m^2) along transects lines. Vegetation data collected were analyzed for the relative density of species, Shannon-Wiener index, species evenness, and relative frequency. From the household survey, 58 plant species categorized in 55 genera and 35 families were identified as NTFP-bearing species. Analysis of the socio-economic data shows that NTFP collection is a day-to-day activity of the local communities. These communities use NTFPs in different types of use categories, namely medicinal plants (32, 55.17%), melliferous species (20, 34.48%), wild food and condiment species (22, 37.93%), farm implements (7, 12.06%), wood and flavoring (6, 10.34%), source of energy (20, 35.71%), and household utensils and construction materials (30, 51.72%). The market survey analysis showed that NTFPs account for about 15.77% of the annual household income. The vegetation survey showed that Ades Forest has a good status with an average density of 1,450 plants ha^{-1}, high Shannon-Wiener index (H =3.299), and species evenness (E = 0.81). Ades Forest harbors a diverse number of NTFP-bearing species used for several categories. The study reveals the real experiences of the local communities in utilizing NTFPs for their livelihood. Forest dependency rates tend to be higher among poor households. However, further study on production potential and market chain analysis should be done together with awareness creation activities to get a sustainable product for the community and conserve the forest resource.

Keywords: Ades Forest, diversity, Non-Timber Forest Products

INTRODUCTION

Non-Timber Forest Products (NTFPs) cover biological resources of plant and animal origin harvested from natural forests, artificial plantations, wooded land, farmlands, and trees outside the forest. Both have been domesticated (Debela 2019). These NTFPs yield diverse sets of products: leaves and twigs that may be used in decorative arrangements; food such as fresh fruits plus juices; wood carved or woven into pieces of art or utilitarian objects; and roots, leaves, and bark processed into herbal remedies or medicines (Solomon and Tajebe 2014). Worldwide, between 3.5 and 5.8 billion people in or around natural forests depend on NTFPs for subsistence income and livelihood security (Shackleton and De Vos 2021), doubling the numbers from previous studies (World Bank 2004; Solomon and Tajebe 2014). About 80% of the populations of developing countries use NTFPs to meet at least some of their health and nutritional needs (Pandey et al. 2016; Talukdar et al. 2021). It is hard to imagine humans and animals living without plants as they often provide a complex array of goods and services. The world benefits from forests (in various stages), deriving resources such as food, medicine, timber, fuel wood, and livestock fodder (Hlaing et al. 2017; Gitz et al. 2021). Moreover, in general, African forests and sub-Saharan African countryside inhabitants considerably depend on NTFPs for their livelihoods (World Bank 2004; Melese 2016; Soe and Yeo-Chang 2019).

The diverse character and scope for exploitation of NTFPs become product and location-specific (Ros-Tonen and Wiersum 2005). This finding has been prompted by the fact that communities living adjacent to forest reserves rely greatly on the NTFPs for their livelihoods. Therefore any effort to conserve such resources should, as a prerequisite, understand how the host communities interact with them (Suleiman et al. 2017). Therefore, scientific documentation and information on diversity use patterns and the economic contribution of species can authenticate the conservation and sustainable use of such plant resources in any given area (Masoodi and Sundriyal 2020).

Ethiopia is a tropical country well-endowed with a diverse floral that includes about 6,000 species of higher plants with 10-12% endemism (IBC 2005; Melese 2016).

Ethiopia's forest and other vegetation resources offer diverse NTFPs that provide substantial inputs for the livelihoods of a very large number of people in the country, with an estimated annual turnover of more than $US 2.3 billion to the national economy (Worku 2015; Melese 2016). Some 8-10% of higher plants recorded in Ethiopia are assumed to be edible, whereas some 10% are used for medicinal purposes for human and livestock diseases (Abebe et al. 2003; Duguma 2020).

Substantial study records (Chilalo and Wiersum 2011; Melaku et al. 2014; Meles et al. 2016; Beyene et al. 2020; Reta et al. 2020) were done in different regions of Ethiopia on the contribution of NTFPs to the local or national economy. However, those studies are confined to only some parts of the country and with patchy patterns. Nevertheless, the vagaries of resident engagement in forest management and their utilization of NTFPs provide knowledge relevant to sustainable forest management practices (Thammanu et al. 2021).

This study addressed the following four principal questions. First, does the local community exercise NTFP harvest at current times? Second, to what extent do these NTFPs contribute to improving the community's livelihoods? Third, what are the major constraints in NTFP utilization? Finally, how diverse is Ades Forest to allow continuing to provide for the current NTFPs utilization needs of the community?

Doba District, Eastern Ethiopia, is among the districts of West Hararghe Zone where different types of NTFPs and their significance were not extensively studied or well-documented. The district is characterized by low agricultural output and land productivity below what it should be to fulfill the area's minimum food requirements (Gizaw 2021). This study, therefore, aimed at documenting the ethnobotany and diversity of NTFPs in the district. This research has great significance in exploring the socio-economic importance of NTFPs and quantifying them in the study area.

MATERIALS AND METHODS

The study site

The study was conducted at Ades Forest, Doba District West Hararghe Zone of Oromia Regional State, Ethiopia. Doba District is 382 km east of the capital city, Addis Ababa, and 45 km from Chiro, the Zonal capital town. Geographically, the district lies at 9°15′N and 41°00′E with altitudes ranging from 1149 to 2773 m.a.s.l. (Figure 1). Ades Forest is among Ethiopia's national priority forest resources. The forest covers some 618 ha. Some of the dominant species in this forest are *Gymnosporia obscura*, *Podocarpus falcatus*, *Croton macrostachyus*, and *Mytenus* species (Atomsa and Dibbisa 2019).

Data collection

Ethnobotanical and vegetation data were collected from February 2020 to June 2021. Forum Group Discussions (FGD) collected qualitative data from key informants. Quantitative ethnobotanical and vegetation data were collected through semi-structured questionnaires and field surveys following (Teka et al. 2020).

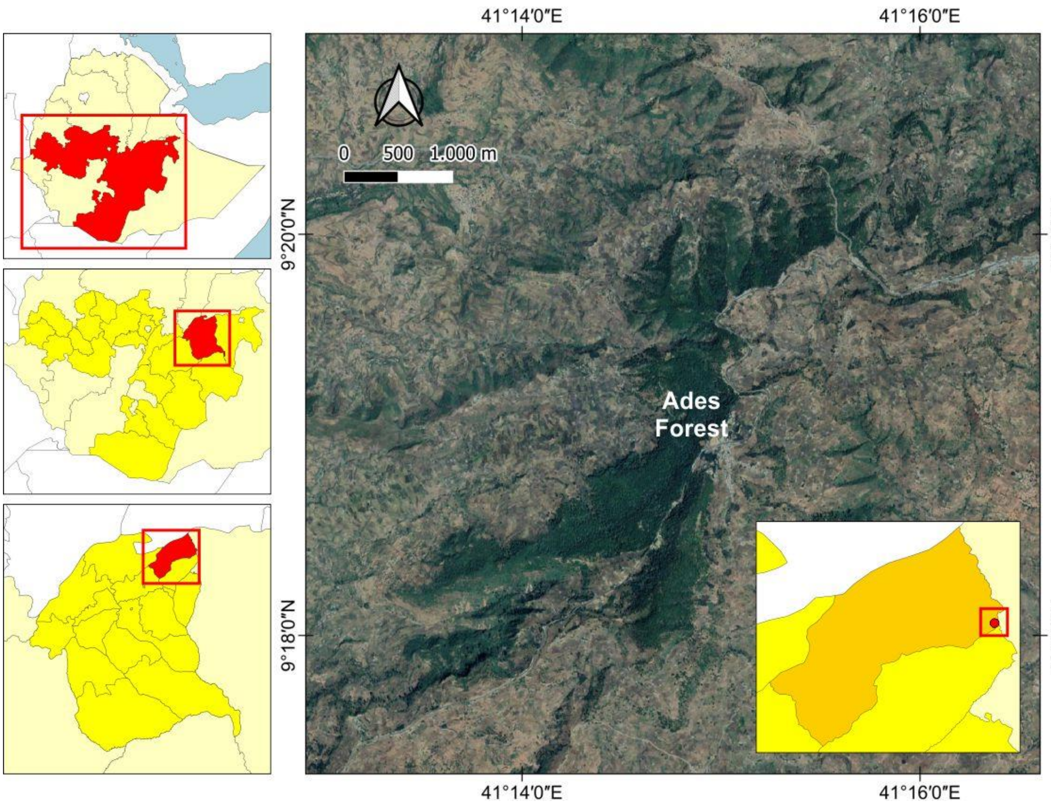

Figure 1. Map of the study area showing Doba District and Ades Forest, Ethiopia

Ethnobotanical data collection and documentation were done through key informant interviews and group discussions to gather information on NTFPs collection methods, use categories, their contribution to household income generation, and the factors that hamper the utilization mentioned above. The total sample size was determined following Cochran (1997) and using a 95% Confidence Level (CL), 0.05 margin of error, 50% proportion, and 10% non-respondent rate proportionally allocated to each of the five selected kebeles (the lowest administrative organization). The sample size was determined as follows.

$$n = \frac{(Z\alpha)2}{2} * P\ (1\text{-}P)/W^2$$

Where: n: sample size; W: Margin of error; P: population proportion, and hence

$$n = \frac{(1.96)2(0.5)(0.5)}{(0.05)^2} = 384$$

Considering a 10% non-respondent rate (38), the final sample size was increased to 422 respondents.

Three Kebeles (The smallest administrative level in Ethiopia), namely Bekelcha Biftu, Ifa Aman, and Ifa Ramata, were selected for the study based on their proximity to the Ades Natural Forest and the local communities' dependency on forest products. Out of the 422 respondents, 36 key informants (i.e., 12 informants from each kebele) having confirmed herbal medicine extraction and local plant identification practices were chosen. The remaining 382 respondents were selected based on the population proportion criterion: Bekelcha Biftu (n = 103), Ifa Aman (n = 125), and Ifa Ramata (n = 154). Systematic sampling was used to select respondents from alphabetically listed households of the three kebeles and compute the skipping interval (K) by dividing the total number of households of each kebele with the total sample size for the kebele (i.e., K = 10). The first respondent of each kebele was determined by a lottery method; the other respondents were selected at every 'K' value from the mother list. A market survey was also done at the local Doba District market in October 2020 for four consecutive weeks for data consistency to assess the commercialization practices for NTFPs in the area.

A systematic sampling technique was used to collect vegetation data in Ades Natural Forest by laying three transect lines following Kent (2012). Sixty-nine sample plots (i.e., 2.76 ha.) of 400 m^2 each laid out along the transect lines at 100 m intervals were used for tree and shrub surveys. A total of 345 subplots of each 1 m^2 were used for evidencing saplings and seedlings. Those subplots are put at the four corners and one at the center of each larger quadrat. All woody plant species in each quadrat were recorded with their growth habits. In addition, older people in the community identified vernacular names (Oromipha language) of plants from the field. Scientific names were identified using Flora of Ethiopia and Eritrea (Volumes 1-8), compared with already identified specimens and using own knowledge, and validated using Plants of the World Online (POWO). Voucher specimens were collected, identified, and stored in Oda Bultum University Herbarium Room. Plant specimen collection permission was attained from Oda Bultum University, Chiro, Etiopia. Our field studies, including plant material collection, comply with the IUCN policy statement on research involving species at risk of extinction, the convention on the trade in endangered species of wild fauna and flora, and other relevant institutional and national guidelines and legislation.

Each plot measured the height and diameters of all woody plant species at breast height (DBH 1.3 meters above the ground) with height $\geq$ 2 m and DBH $\geq$ 2.5 cm. In addition, individuals having a height < 2 m and DBH < 2.5 cm were counted. Key informants (knowledgeable and older people in the area suggested by residents) were used to provide local names of all evidenced plants. Moreover, phytogeographic comparisons of Ades Natural Forest with other similar forests (data from literature) were made using of Shannon-Wiener's diversity (H'), Evenness (E), and richness diversity indices.

Data analysis

Ethnobotanical data were analyzed using descriptive statistics (frequencies and percentages) and presented with tables and figures. Associations among wealth groups against different agricultural activities were assessed using SPSS (Statistical Package for Social Sciences). Species utilized for NTFPs were sub-grouped based on their use category.

Microsoft Excel spreadsheets analyzed Vegetation data using diversity parameters (i.e., relative density, Shannon-Wiener's diversity index, species evenness, and relative frequency). Species density was computed as the number of species collected per area following Gotelli and Colwell (2001). Relative density is the proportion of the density of a given use category to the total density of the study area:

$$\text{Density} = \frac{\text{Total number of individual species}}{\text{Total sampled area}}$$

Species frequency

Species frequency was computed as the proportion of sample units that contain a given species following (Sewale and Mammo 2022).

Shannon-Wiener diversity index

The Shannon-Wiener diversity index was computed as follows:

$$H = -\sum^{s} pi \ln pi$$

Where:
H : Shannon-Wiener's diversity index
$\sum$: The sum of calculations
p : The proportion (n/N) of individuals of one particular species (n) divided by the total number of individuals found (N)
ln : Natural logarithm
s : Number of species

RESULTS AND DISCUSSION

Results

Analysis of the ethnobotanical survey revealed 58 woody plant species categorized in 55 genera and 35 families as NTFP-bearing species. The use of such a diverse number of plant species for NTFP use was also evident from similar studies (Fetene et al. 2010; Solomon and Tajebe 2014; Reshad et al. 2017) in the country. The analysis of the ethnobotanical data shows that NTFP collection is a daily activity of the local community in the study area. Local communities have multiple use categories for NTFP, which is in line with results from other studies in the country (Mullatu 2010; Chilalo and Wiersum 2011; Melaku et al. 2014; Reshad et al. 2017; Debela 2019). The ethnobotanical survey found seven use categories, Medicinal plants, wild food plants, melliferous plants, energy, farm implements, wood for smoking (and burning) and flavoring plants, household utensils, and construction. Studies by van Andel (2006) and Fetene et al. (2010) supported the NTFP types identified in this study. Concerning the type of use category, our study showed significant similarity with the studies of (Fetene et al. 2010; Solomon and Tajebe 2014; Reshad et al. 2017), which should imply the cultural exchange and intimacy between the communities.

The different use categories, medicinal plants with 32 species (55.17%), household utensils with 30 species (51.72%), and wild food plants with 22 species (37.93%), were ranked the top three use categories. Those top three use categories harnessing the largest number of plant species (Figure 2). Whereas plant species used for farm implements and hygiene, smoke wood, and flavoring plants were represented by 7 (11.86%) species each.

Ethnobotanical survey

Our study highlights the significant variation observed for the multi-purpose use of NTFPs in the seven use categories (Table 1). Twenty-four plant species are used for over 40% of the use categories. By the same token, *P. falcatus*, and *Olea europaea* subsp. *cuspidata* occur in five out of seven (71.42%) use categories. Whereas *Ficus sur*, *Mytenus obscura*, *Myrica salicifolia*, *Prunus africana*, and *Zehneria scabra* occur in four out of seven (57.14%) use categories. Using plant species for several use categories may threaten species diversity due to over-exploitation, as is also evident from another study (Corlett 2016), especially for threatened plant species like *P. falcatus* in our country.

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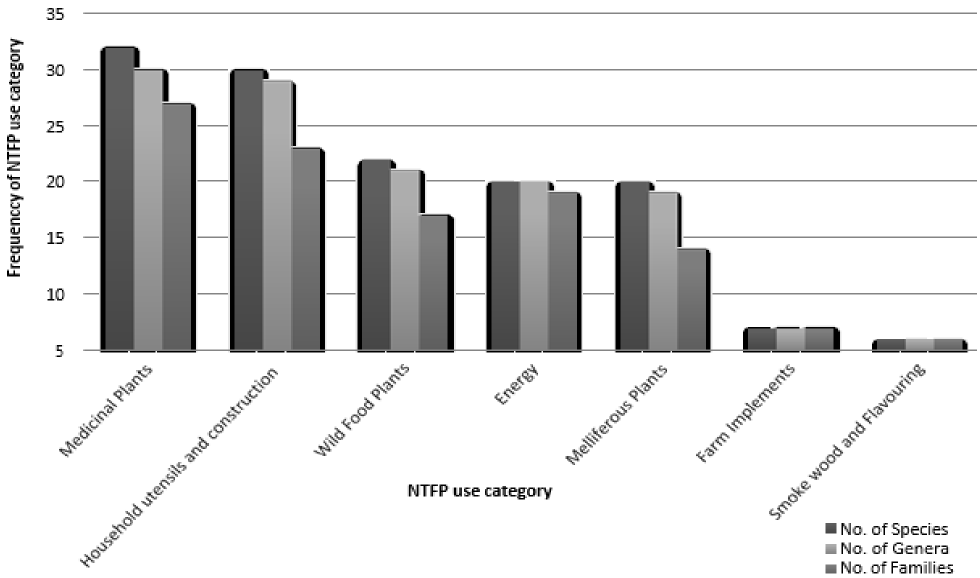

Figure 2. Proportions of NTFP categories in the study area

Table 1. NTFP-bearing species per different use categories

Species name	Family name	Vernacular name	Life-form	MP	MF	WFP	FI	SW	E	HUC
Agave sisalana Perrine	Agavaceae	*Alghee*	Shrub	-	-	-	-	-	-	+
Astropanax abyssinicus (Hochst. ex A.Rich.) Seem.	Araliaceae	*Gatama*	Tree	+	+	-	-	-	-	+
Bersama abyssinica Fresen.	Malianthaceae	*Lolcisa*	Shrub	+	-	-	-	-	-	-
Cadaba farinosa Forsk	Capparaceae	*Qalqalcha*	Shrub		-	-	-	-	+	-
Calpurnia aurea (Ait.) Benth.	Fabaceae	*Ceekaa*	Shrub	+	-	-	-	-	+	-
Canthium lactescens Hiern	Rubiaceae	*Galoo*	Shrub	-	-	+	-	-	-	-
Capparis cartilaginea Decne.	Capparaceae	*Goraa*	Shrub	+	+	+	-	-	-	-
Carissa spinarum L.	Apocynaceae	*Agamsa*	Shrub	+	-	+		+	+	-
Celtis africana Burm.f.	Cannabaceae	*Maxaqoma*	Tree	-	-	-	-	-	+	-
Cissampelos mucronata A.Rich	Menispermaceae	*Baltoke*	Climber	+	-	+	-	-	-	+
Croton macrostachyus Del.	Euphorbiaceae	*Bakanisaa*	Tree	+	+	-	-	-	-	+
Cucumis ficifolius A. Rich.	Solanaceae	*Haregogee*	Climber	+	-	+	-	-	-	-
Cupressus lusitanica Mill.	Cupressaceae	*Gatira faranjii*	Tree	-	-	-	-	-	+	+
Dombeya torrida (J. F. Gmel.) P. Bamps	Malvaceae	*Daannisa*	Tree	-	+	+	-	-	-	+
Ekebergia capensis Sparrm.	Meliaceae	*Sombo*	Tree	-	+	-	-	+	+	+
Embelia schimperi Vatke	Primulaceae	*Haanquu*	Shrub	+	+	+	-	-	-	+
Englerina woodfordioides Gilbert	Loranthaceae	*Digaluu*	Shrub	-	+	-	-	-	-	-
Eucalyptus globulus Labill.	Myrtaceae	*Citaa fura*	Tree	+	-	-	-	-	+	+
Ficus sur Forssk.	Moraceae	*Harbuu*	Tree	+	+	+	-	-	-	+
Gardenia ternifolia Schumach. & Thonn.	Rubiaceae	*Gambeela*	Tree	-	-	-	-	-	-	+
Grewia bicolor Juss.	Malvaceae	*Harooreessa*	Tree	-	-	+	+	-	-	+
Gymnanthemum amygdalinum (Delile) Sch.Bip.	Asteraceae	*Eebicha*	Shrub	+	+	-		+	-	-
Gymnanthemum auriculiferum (Hiern) Isawumi	Asteraceae	*Reejjii*	Tree	+	-	-	-	-	-	-
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	*Heexo*	Tree	+	-	+	-	-	-	+
Helichrysum schimperi (Sch.Bip.ex A.Rich.) Moeser	Asteraceae	*Baalchii*	Shrub	-	+	-	-	-	-	-
Helinus mystacinus (Ait.) E. Mey.ex Steud.	Rhamnaceae	*Hidda xarii*	Climber	+	-	-	-	-	-	+
Jasminum floribundum L.sub sp. *Floribundum* (R.Br. ex. Freesen.)	Oleaceae	*Biluu*	Shrub	+	-	-	-	-	-	-
Juniperus procera Hochst. ex Endl.	Cupressaceae	*Gatira abesha*	Tree	+	-	-	-	-	-	+
Maesa lanceolata Forssk.	Primulaceae	*Abbayi*	Tree	-	+	-	-	-	+	+
Mytenus obscura (A.Rich.) Cuf.	Celestraceae	*Kombolcha*	Tree	-	+	+	-	-	+	+
Mytenus undata (Thumb.) blackelock	Celestraceae	*Wanta fulas*	Tree	-	-	-	+	-	-	-
Myrica salicifolia Hochst ex A. Rich.	Myricaceae	*Macheensoo*	Shrub	+	-	+	-	-	+	+
Myrsine Africana L.	Primulaceae	*Qachaamu*	Shrub	-	+	+	-	-	-	+
Myrsine melanophloeos (L.) R. Br.	Primulaceae	*Tuu1a*	Tree	-	+	+	-	-	-	+
Ocimum gratissimum subsp. *Gratissimum*	Lamiaceae	*Hanchabi*	Shrub	+	-	-	-	-	-	-
Ocimum lamiifolium Hochst. ex Benth.	Lamiaceae	*Daamma kaasee*	Shrub	+	-	-	-	-	-	+
Olea europaea L. subsp. *cuspidata* (Wall. Ex G. Don) cif.	Oleaceae	*Ejersa*	Tree	+	-	-	+	+	+	+
Olinia rochetiana A. Juss.	Oliniaceae	*Noolee*	Tree	-	+	-	-	-	-	+
Opuntia ficus-tndioa (L.) Miller	Cactaceae	*Tini*	Shrub	+	-	+	-	-	-	-
Osyris lanceolata Hochst. & Steud.	Santalaceae	*Waatoo*	Tree	-	-	+	-	-	-	+
Pentanema confertiflorum (A.Rich.)	Asteraceae	*Haxawwii*	Shrub		+	-	-	-	-	-
Periploca linearifolia Quart.Dill. & A.Rich.	Apocynaceae	*Hidda aannannoo*	Liana	+	-	-	-	+	-	-
Phyllanthus ovalifolius Forssk.	Euphorbiaceae	*Jilolafaa*	Tree	-	-	-	-	-	+	-
Phytolacca dodecandra L.'Hėrit.	Phytolaccaceae	*Handodee*	Climber	+	-	-	-	+		+
Podocarpus falcatus (Thunb.) R.B.ex Mirb.	Podocarpaceae	*Birbirsa*	Tree	+	-	+	+	-	+	+
Premna schimperi Engl.	Lamiaceae	*Urgeessaa*	Tree	+	-	-	-	-	-	-
Protea gaguedi J. F. Gmel.	Proteaceae	*Daanisa/ gaarrii*	Shrub	+	-	-	-	-	+	-
Prunus africana (Hook.f.) Kalkm	Rosaceae	*Muka guracha*	Tree	-	+	-	+	-	+	+
Rhamnus prinoides L.Herit	Rhamnaceae	*Garabagush*	Shrub	+	-	-	-	-	-	+
Rosa abyssinica Lindely	Rosaceae	*Qajima/goraa*	Shrub	+	+	-	-	-	-	-
Rubus steudneri Schweing.	Rosaceae	*Enjorii*	Shrub	-	-	+	-	-	-	-
Rytigynia neglecta (Hiern) Robyns	Rubiaceae	*Mete-guree*	Shrub	-	-	+	+	-	+	-
Sageretia thea (Osbeck) M. C.Johnston	Rhamnaceae	*Asgori*	Shrub	-	-	-	-	-	+	+
Scolopia theifolia Gilg.	Flacourtiaceae	*Qilisa*	Tree	+	-	-	-	-	+	-
Searsia glutinosa (Hochst. ex A.Rich.) Moffett	Anacardiaceae	*Xaaxeessaa*	Tree	-	-	-	+	-	-	+
Vangueria madagascariensis Gmel	Rubiaceae	*Abba bunee*	Shrub	-	+	+	-	-	+	-
Verbascum sinaiticum Benth.	Scrophulariaceae	*Gurra harree*	Shrub	+	-	-	-	-	-	-
Zehneria scabra (L.f.) Sond.	Cucurbitaceae	*Shimbirqoolii*	Climber	+	+	+	-	-	+	-

Note: MP: Medicinal Plants, MF; Melliferous Plants, WFP: Wood Food Plats, FI: Farm implements, SW: Smoke Wood and Flavoring, E: Energy, HUC: Househpld Utensils and Construction

Medicinal plant species

Of the total 58 NTFPs recorded in the study area, 32 species (55.17%) distributed under 30 genera (54.54%), and 25 families (71.42%) were identified as medicinal plants used for one or several diseases. Medicinal plant species identified in our study showed about 28-35% overlap with previous studies (Reshad et al. 2017; Fassil and Gashaw 2019; Assefa et al. 2021). The high proportion of plant species used for traditional medicine can be attributed to the greater preference of the local community for traditional medication as their primary healthcare system (Pathy et al. 2020).

Three species represented Lamiaceae. Asteraceae, Apocynaceae, Oleaceae, Rhamnaceae, and Rosaceae were represented by two species, while the rest families represented one species each. The medical importance of the 32 species in the medicinal plant use category, the types of treatments, and preparation and administration methods are presented in Table 2.

Woody medicinal plants fall under four plant habits, i.e., shrubs, trees, climbers, and lianas. Of the 32 medicinal plant species identified, the majorities are shrubs (15, 46.88%) and trees (11, 34.38%), while the remaining are climbers (5, 15.62%) and lianas (1, 3.12%). Seven plant parts are used in treatments (Table 2); these are leaves (50%), roots (18.75), seeds (18.75), fruits (9.38%), bark (9.38%), shoot (9.38%), and stems (9.38%). This preference for using leaves, roots, and seeds in traditional medicine preparations was also seen in other studies (Duguma 2020; Gonfa et al. 2020; Kassa et al. 2020).

Using plant parts such as leaves and seeds for medical purposes can be mutual with forest conservation schemes. In contrast, harvesting roots, stems, barks, and shoot parts needs reconsideration or proper control as they result in resource exhaustion and sometimes even species extinction (Chen et al. 2016; Van Wyk and Prinsloo 2018).

A total of 24 diseases were evidenced to be treated by the medicinal plant species in the study area (Table 2). Ascariasis and Tenidiasis were treated with 3 (9.38%) medicinal plants each, whereas blood clotting, dermatitis, intestinal parasites, toothaches, and wounds were treated with 2 (6.25%) medicinal plant species each. The remaining 17 diseases only had a single (3.13%) species.

Melliferous species

Of the 58 species recorded in this study, 20 (34.48%) species in 19 (33.93%) genera and 14 (37.83%) families were identified as Melliferous plants (Table 1). Some families, like Primulaceae (4 species), Asteraceae (3 species), and Rosaceae (2 species), are represented by more than one species, whereas the remaining families are represented by a single species each (Table 1). More than 80% of identified Melliferous species were also cited in the Honey Bee Flora of Ethiopia book written by Fichtl and Adi (1994), which signposts the good knowledge of the local community on this category species. Such awareness of local communities on the importance of melliferous species greatly impacts sustainable conservation and quality-honey production (Coh-Martínez et al. 2019).

Wild food and condiment plant species

Of the 58 NTFP-bearing plants recorded in the study area, 21 (36.21%) species in 20 (36.36%) genera and 15 (42.85%) families were identified as wild foods for both humans and livestock (Table 1). Among the 20 wild food-bearing families, Primulaceae and Rubiaceae are represented by three (20%) species each, followed by Rosaceae with two (13.33%) species with the remaining 14 families represented by one species (6.67%) each. Of these wild food plants, *Carissa spinarum*, *Cucumis ficifolius*, *P. falcatus*, and *Cissampelos mucronata* are evidenced in their medicinal and dietary values by Lulekal et al. (2011), Fassil and Gashaw (2019), and Maroyi (2020).

Farm implements

We recorded 7 (12.72%) plant species in 7 (12.5%) genera and 7 (20%) families to produce farm implements (Table 1). These species were evidenced to have good wood hardness, strength, and elasticity properties. For example, *Grewia bicolor* and *O. europaea* have good wood hardness, strength, and specific weight, which make them well-placed for traditional plowing implements and hence ideal candidates for agricultural farming equipment (Govorčin et al. 2010; Ruffo et al. 2002).

Wood for burning and flavoring plants

Out of the 58 NTFP-bearing species, 6 (10.91%) species in 6 (10.71%) genera and 6 (17.14%) families were used as wood for burning (and smoking) and flavoring (Table 1). When preparing food and beverages, either they need to improve the taste that might have deteriorated due to the containers they use (such as removing the bitter taste of Cucurbitacins from storage jars of *Lagenaria siceraria*) or adding good flavors through fumigation and washing. The characteristic smoke flavor of plants is attributed to phenolic compounds found in them (Shahidi and Ambigaipalan 2015). Previous studies signpost the presence of Oleuropein in *O. europaea* (Nediani et al. 2019) and Cardiac glycosides in *C. spinarum* (Wangteeraprasert et al. 2012).

Plant species used for combustion

Twenty (34.48%) species in 19 (34.54%) genera and 19 (54.28) families recorded in this study are used as wood fuel (Table 1). Only Rubiaceae contribute two (10.52%) species, while the remaining 18 families only contribute one species each. Our study reveals that the local community prefers selected plant species for fuel wood purposes which is in line with the studies of Reshad et al. (2017) and Dadile et al. (2020). About 35% of recorded plant species to be used for fuel wood overlapped with another similar study in the country (Fetene et al. 2010).

Household utensils and construction materials

Thirty (51.72%) species in 29 (52.72%) genera and 23 (65.71%) families were identified as household paraphernalia (Table 1). From the 23 families identified, Primulaceae, Rhamnaceae, Cupressaceae, and Rosaceae families are represented by 4 (17.39%), 3 (13.04%), 2 (8.70%), and 2 (8.70) species, respectively. The remaining 19 families were represented by only one species each. Of the 30 plant species identified, 11 (36.67%) were also cited by previous studies (Fetene et al. 2010; Reshad et al. 2017).

Table 2. List of medicinal plants with their modes of preparation, diseases treated, way of administration, and plant parts used

Species name	Family name	Vernacular name	Life-form	Diseases treated	Plant parts	Modes of preparation and administration
Astropanax abyssinicus (Hochst. ex A.Rich.) Seem.	Araliaceae	*Gatama*	Tree	Ectoparasite	Leaf	Pounding the leaf and rubbing over the affected body part with ectoparasite
Bersama abyssinica Fresen.	Malianthaceae	*Lolcisa*	Shrub	Wound	Leaf	The leaf is pounded and tied on the affected body part
Calpurnia aurea (Ait.) Benth.	Fabaceae	*Ceekaa/cekata*	Shrub	Intestinal parasites	Seed	Pounding the seeds and drink them with water
Capparis cartilaginea Decne.	Capparaceae	*Goraa (ankusa)*	Shrub	Ascariasis	Sees	Chewing the seed and swallowing it
Carissa spinarum L.	Apocynaceae	*Agamsa*	Shrub	Blood clotting	Bark	Pounding the bark and tie on the affected body part
Cissampelos mucronata A.Rich	Menispermaceae	*Baltoke*	Climber	Stomach ache	Root	Chewing the root or pounding it and drink with water
Croton macrostachyus Del.	Euphorbiaceae	*Bakanisaa*	Tree	Ringworm	Shoot	Cut the shoot tip and rub over the affected body part (Skin)
Cucumis ficifolius A. Rich.	Solanaceae	*Haregogee*	Climber	Stomach ache, rabies	Root leaf	Chewing the root and taking the juice Pounding the leaves and allowing the dogs to drink it with milk
Embelia schimperi Vatke	Primulaceae	*Haanquu (enkoko)*	Shrub	Tapeworm	Seed	Pounding the dried seed and drink it with water
Eucalyptus globulus Labill.	Myrtaceae	*Citaa fura*	Tree	Common cold	Leaf	Boiling the leaf in water and fumigating it
Ficus sur Forssk.	Moraceae	*Harbuu*	Tree	Toothache	Fruit	Fire the fruit and chew with the teeth
Gymnanthemum amygdalinum (Delile) Sch.Bip.	Asteraceae	*Eebicha*	Shrub	Tonsillitis, diarrhea	Leaf leaf	Pounding the leaf and taking the leaf extract Pounding the leaf and drinking the extracts
Gymnanthemum auriculiferum (Hiern) Isawumi	Asteraceae	*Reejjii*	Tree	Wound	Leaf	The leaf is pounded and tied on the affected body part
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	*Heexo*	Tree	Tapeworm	Seed	Pounding the seed and drinking with water
Helinus mystacinus (Ait.) E. Mey.ex Steud.	Rhamnaceae	*Hidda xarii*	Climber	Rheumatism	Root	Pounding the root and wash the body with it for seven days
Jasminum floribundum L.sub sp. *Floribundum* (R.Br. ex. Freesen.)	Oleaceae	*Biluu*	Shrub	Tufa	Leaf	Pounding Leaves of *Jasminum floribundum*, *Premna schimperi*, *Searsia glutinosa Ehretia cymosa*, *G. bicolor*, and roots of *C. spinarum* and wrap over affected body parts
Juniperus procera Hochst. ex Endl.	Cupressaceae	*Gatira abesha*	Tree	Evil spirit	Leaf	Pounding the leaf of *Juniperus procera* with *P. falcatus* leaf and wash the body with the extracts
Myrica salicifolia Hochst ex A. Rich.	Myricaceae	*Macheensoo*	Shrub	Dermatitis	Leaf	Pounding the dried leaves, mix them with water and put them on the affected skin part
Ocimum gratissimum subsp. *Gratissimum*	Lamiaceae	*Hanchabi*	Shrub	Mich	Leaf	Rubbing the leaf on the skin part
Ocimum lamiifolium Hochst. ex Benth.	Lamiaceae	*Daamma kaasee*	Shrub	Mich	Leaf	Squeezing the leaf and cream over the body
Olea europaea L. subsp. *cuspidata* (Wall. Ex G. Don) cif.	Oleaceae	*Ejersa*	Tree	Headache	Stem	Burning of the stem with fire and taking the oil through the nasal cavity
Opuntia ficus-tndioa (L.) Miller	Cactaceae	*Tini*	Shrub	Anemia	Fruit	Chewing and eating the fruit
Periploca linearifolia Quart.Dill. & A.Rich.	Apocynaceae	*Hidda aannannoo*	Liana	Eye disease	Root	Pounding the dried root and fumigating it
Phytolacca dodecandra L.'Hėrit.	Phytolaccaceae	*Handodee*	Climber	Bleeding	Leaf	Squeezing the leaf and putting on the affected nasal part
Podocarpus falcatus (Thunb.) R.B.ex Mirb.	Podocarpaceae	*Birbirsa*	Tree	Heart disease	Seed	Boiling the Seed oil of *P. falcatus* with *Allium sativum* and *Ocimum gratissimum* and mix the juice with coffee and drink it
Premna schimperi Engl.	Lamiaceae	*Urgeessaa*	Tree	Toothache	Leaf	Chewing the leaf with affected teeth
Protea gaguedi J. F. Gmel.	Proteaceae	*Daanisa/ gaarrii*	Shrub	Tapeworm	Seed	Pounding the roasted seed and take it with water
Rhamnus prinoides L.Herit	Rhamnaceae	*Garabagush*	Shrub	Dermatitis	Fruit	Rubbing the ripened fruit over the affected body part
Rosa abyssinica Lindely	Rosaceae	*Qajima/goraa*	Shrub	Ascariasis	Root	Pounding the root and drinking with water
Scolopia theifolia Gilg.	Flacourtiaceae	*Qilisa*	Tree	Ascariasis	Leaf	Pounding the leaf with coffee arabica leaf and drink it with goat milk
Verbascum sinaiticum	Scrophulariaceae	*Gurra harree*	Shrub	Cancer	Root	Pounding the root with coffee and drinking it
Zehneria scabra (L.f.) Sond.	Cucurbitaceae	*Shimbirqoolii*	Climber	Intestinal parasite	Leaf	Pounding the leaf part and drink it with water

Socio-economic contribution of NTFPs

To assess the economic contribution of NTFPs to the local community, we performed several market surveys in the nearby Doba Market. Data was collected by walking through the market and registering the type of NTFPs encountered. We found that the local community living in and around Ades Forest has various income sources from different agricultural activities. Those income sources include crop production, animal production, fruits and vegetables, *Catha edulis*, and NTFPs. The mean annual income generation per household was 24,805.16 ETHB (Ethiopian Birr hereafter). Out of this, the mean annual contribution of income share from NTFPs across all wealth categories was about Birr 3,912.5 per household (Figure 3). On aggregate, NTFPs' income share accounts for about 15.77% of the annual household income. This finding evidences the vital contribution of NTFPs to the livelihood community. However, NTFPs' economic share differs among wealth groups: the rich, medium and poor wealth categories got about 6.16%, 14.78%, and 30.82% economic share, respectively. From the wealth categories, the poor depend more on NTFP utilization than other agricultural activities or wealth groups (Figure 3.) This finding is also supported by studies of Suleiman et al. (2017) from Nigeria and Gonfa et al. (2020) from Ethiopia. The household survey found that fuel wood, household paraphernalia, wild edible plants, honey, smoke wood, and flavoring plants, farm implements were the six most important traded NTFPs for income generation by the community living in and around Ades Forest.

Diversity of non-timber plant species in Ades Forest

Species density

The nearest accessible forest resource in the Doba District is Ades Forest, which community members depend on for NTFP collection. A total of 3,770 woody NTFP-bearing plant specimens with an average of 1,450 plants ha^{-1} were evidenced in the forest. This study reveals that *P. falcatus*, *Englerina woodfordioides*, and *Sageretia thea* were the top-three densely populated NTFP-bearing plant species with average densities of 683, 232, and 207 plants per hectare.

Species frequency

Species frequency is defined by Kent (2012) as the probability or chance of finding a species in a given sample area or quadrat. As of occurrence, species were grouped into five percentage frequency classes 0-20, 21-40, 41-60, 61-80, and 81-100, following Kent (2012). The frequency class distribution showed an inverted 'J' shape. The greatest number of species occurring at the lowest frequency class in species composition (Figure 4). The *P. falcatus*, *G. obscura*, and *C. macrostachyus* were the three most frequently occurring plant species found in 67.69%, 49.23%, and 41.54% of sampled quadrats.

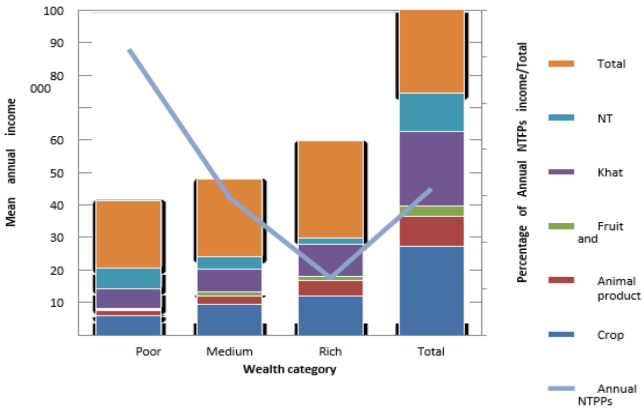

Figure 3. Mean annual income contribution of agricultural activities in wealth categories

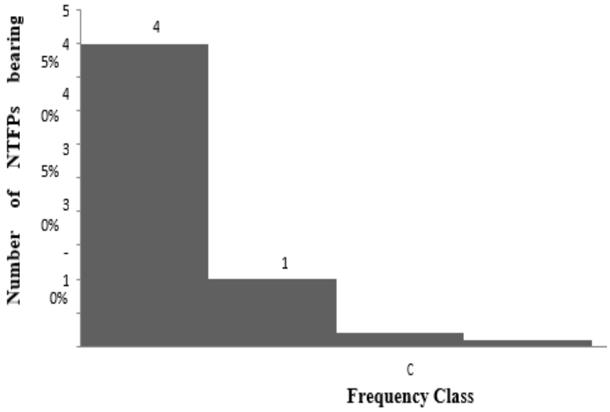

Figure 4. Distribution of NTFPs over frequency classes

Species diversity and evenness

Analysis of species diversity and evenness results shows that Ades Forest has many NTFP-bearing plant species. The Shannon-Wiener's diversity index and evenness of the forest were H' = 3.299 and E' = 0.81, respectively. The high value of Shannon-Wiener's diversity index indicates there were somewhat better representations of NTFP-bearing plant species in Ades Forest.

The phytogeographic comparison of our study site with similar dry Afromontane forests Menagesha Suba, Jello – Muktarand Gelawoldie community forests were made (Table 3). The forest has similar species richness to the Menagesha Suba and Gelawde community forests but is lower than the Jello-Muktar Forest (Table 3). Shannon-Wiener and evenness diversity indices show that the Ades Forest has relatively higher species heterogeneity with a more even plant distribution than Menagesha Suba and Jello-Muktar Forests (Fetene et al. 2010; Reshad et al. 2017). Such high species diversity was possibly ascribed to a preference for environmental/ecological gradients with which the biotic community interacts. Contrarily, the higher diversity and evenness recorded in the Gelawoldie forest reflect better forest management in that community (Mucheye 2020).

Table 3. Phytogeographic comparison of Ades Forest, Ethiopia, with other dry Afromontane forests

Forest	Richness	Shannon-Wiener diversity index (H')	Evenness (E')	Source
Ades Forest	58	3.299	0.81	*Current study*
Gelawoldie community forest	59	3.8	0.9	Mucheye (2020)
Jello –Muktar Forest	97	1.95	0.79	Reshad et al. (2017)
Menagesha Suba Forest	59	1.773	0.816	Fetene et al. (2010)

Our study revealed that the Doba District community endowed a diverse number of NTFP-bearing species for one use or other. From the vegetation and ethnobotanical surveys, 58 NTFP-bearing species were identified and confirmed for their presence in the Ades Forest. The local community has wide experience with the different plant species in diverse use categories. These NTFP-bearing species can be classified into seven NTFP use categories. Many NTFP-bearing plants are used for medicinal plants, Melliferous species, wild food and condiments, farm implements, wood for burning and flavoring plants, energy, household paraphernalia, and construction materials confined in the study area. We also showed that NTFP collection and marketing in the study area have a significant economic contribution to livelihoods.

Ades Forest has a high density and diversity of NTFP-bearing species. However, rather than following a strict protectionist approach in the management of the forest, involving local communities in the management by allowing them to benefit from the forest sustainably may result in lower pressure on these resources. The vegetation survey indicated that, with appropriate forest management activities, Ades Forest could continuously supply NTFPs. However, special attention needs to be given to those plant species with multi-purpose uses, like *P. falcatus.*

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