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Diversity, preference, and conservation priority of woody plant species in coffee agroforestry system in southwest Ethiopia

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The natural forest in southwest Ethiopia is progressively modified to coffee agroforest. To this effect forest composition and diversity is simplified to local preferred coffee shade trees. Woody plant species that are less managed require the conservation priority in coffee agroforest. The study aims at assessing diversity of plant species, investigating local people preference and finally identify woody plants for conservation priority in coffee agroforest in southwest Ethiopia. Data were collected on ecological and ethnoecological information through field assessment and individual interview. Vegetation data were collected from 63 plots distributed across five sites. Ethnoecological data were collected from 96 individuals across five villages living adjacent to the forest through semi-structured interview. The result showed that 48 different woody plant species belonging to 27 families were recorded. Most of the families were represented by single species. The regeneration status of these woody plant species are unsatisfactory or poor. Three species; *Cordia africana*, *Croton macrostachyus*, and *Milletia ferruginea* were accounting for 41 percent of the total number of woody plant species in coffee agroforest. The aggregate relative preference score showed 15 most preferred woody plant species in coffee agroforest. The use value of these species were cited mainly for timber, hanging beehive and beehive making than coffee shade. The findings suggest that 12 woody plants need high conservation priority, 19 species need moderate conservation priority and 17 woody plants need low priority for conservation. The Spearman correlation showed negative correlation between woody plant abundance and conservation priority [r_s (46) = −0.681, p = 000]. The study findings suggest that woody plant conservation priority in coffee agroforest should take into consideration local preference of woody plant species.

KEYWORDS

diversity, ecological, ethnoecology, use value, local preference, coffee shade

1 Introduction

Coffee agroforest is human modified natural forest where the local people progressively manage wild coffee inside the natural forest leading to the development of coffee agroforest (Senbeta and Denich, 2006; Schmitt et al., 2010; Aerts et al., 2011; Hundera et al., 2015; Mertens et al., 2018). The experience is more practiced over the last two to three decades in

southwest Ethiopia (Cheng et al., 1998; Schmitt et al., 2010; Mertens et al., 2018; Kefalew et al., 2021). Rapid forest cover change assessment has shown 26.1% of the Belete Gera forest is modified to coffee agroforest (Cheng et al., 1998). As forest modification to coffee production continue, coffee agroforest plays an important role in conservation of woody plant species in southwest Ethiopia (Senbeta and Denich, 2006; Hernandez et al., 2013; Hundera et al., 2013; Tadesse et al., 2014; Valencia et al., 2016).

Coffee management intensification simplify forest composition and structure through selective removal of woody plant species (Senbeta and Denich, 2006; Schmitt et al., 2010; Aerts et al., 2011; Hundera et al., 2013; Hwang et al., 2020). A study from Bonga region southwest Ethiopia has shown that coffee management activities roughly remove 30% of the canopy tree species in coffee agroforest (Schmitt et al., 2010). Under large canopy size, light demanding woody plant species take an advantage over shade tolerant species. Likewise continuous coffee management such as weeding and slashing undergrowth plants hamper the regeneration of late successional woody plant species in coffee agroforest (Aerts et al., 2011; Hundera et al., 2013, 2015; Valencia et al., 2016). Moreover, the response of pioneer and late successional woody plants to coffee management intensity resulted in a change of woody plant species composition and structure (Hundera et al., 2015; Valencia et al., 2015; Shumi et al., 2019).

Regeneration status of woody plants indicate the population structure of an individual and woody plant composition of coffee agroforest (Tadese et al., 2021). Seedlings and saplings are the indicators of woody plant regeneration status (Siraji and Balemaly, 2021; Tadese et al., 2021). Woody plant species with poor regeneration or absence of seedling and sapling require effective conservation priority (Teketay et al., 2018; Tadese et al., 2021).

Ecological and sociocultural value determine the local people preference of woody plants (Tabuti et al., 2009; Kalanzi and Nansereko, 2014; Valencia et al., 2015; Tumuhe and Nyamaizi, 2020). A study has shown that locally preferred woody plants are dominant in coffee agroforest (Valencia et al., 2015). The shade value of woody plants are the primary criteria for woody plant management in coffee agroforest in southwest Ethiopia (Albertin and Nair, 2004; Kalanzi and Nansereko, 2014; Ordoñez-Jurado et al., 2021). Despite diversity of woody plant species in coffee agroforest, only a few species are preferred to coffee shade (Soto-Pinto et al., 2007; Muleta et al., 2011; Hundera et al., 2015; Hundera, 2016). Woody plants such as *Millettia ferruginea*, *Albizia* spp., and *Acacia* spp. are the most preferred coffee shade trees in southwest Ethiopia (Muleta et al., 2011).

Some woody plant species in coffee agroforest provide products such as construction materials, fuelwood, medicinal and timber, and heavily utilized (Albertin and Nair, 2004). Although these uses are known, the general picture of how people use these trees is unknown.

Overexploitation of woody plant species obviously lead to the concern of conservation priority for sustainable utilization (Lokonon et al., 2019). Woody plant composition and diversity is manipulated in coffee agroforest due to local people preference for specific uses (Senbeta and Denich, 2006; Valencia et al., 2015, 2016). Effective conservation in coffee agroforest among others requires identifying managed woody plant species and their local uses (Senbeta and Denich, 2006; Tabuti et al., 2009; Valencia et al., 2014).

Coffee management activities and local uses raises the concern for conservation of woody plant species in coffee agroforest in southwest Ethiopia. It is obvious that coffee management activities and local uses hamper woody plant species conservation effort in coffee agroforest (Hundera et al., 2015). Woody plant species conservation should follow the priority for conservation. Nevertheless, there is limited information on woody plants that require priority for conservation in coffee agroforest in southwest Ethiopia. Less known is the local people priority and the status of woody plant species in coffee agroforest. To contribute to this knowledge gap, the study was undertaken with the following objectives; (1) to assess the diversity of woody plant species maintained; (2) to investigate the local preference of woody plant species; (2) identify priority woody plant species for conservation in coffee agroforest in southwest Ethiopia.

2 Materials and methods

2.1 Study area

The study was conducted at Belete forest southwest Ethiopia. Geographically, it is found between 36° 15′ E and 36° 45′E and 7°30′ N and 7°45′N (Figure 1). Belete forest belongs to the moist evergreen Afromontane forest of southwest Ethiopia. The forest is one of a few remnant Afromontane moist evergreen forests in southwest Ethiopia. Belete forest, together with Gera forest, was designated as one of 58 national forest priority areas in Ethiopia in 1989 (Cheng et al., 1998). The study area is characterized by a mosaic of forest, cultivated land and settlements. The most accessible area is managed for coffee production involving planting of wild coffee taken from coffee forest and intensive (under growth removal and canopy reduction) management for coffee agroforest. The forest has been under participatory forest management for the last two decades. The forest is divided into blocks of forest among the forest user groups. Forest is a source of livelihoods for people living in and adjacent to the forest. The present study worked with five forest user groups namely: *Dabbiyee*, *Gurrattii*, Q*artammee*, *Mexxii-Caffee*, and *Sokii* forest user groups. The total number of households within a village are in the hundreds. The dominant ethnic group are the Oromo, most of whom are Muslim with a few Christians. The local people organized into forest user groups and signed an agreement with Oromia Forest and Wildlife Enterprises to be entitled in accessing and using forest resources. Forest resource use pattern of the local people changes with time. Currently, the tradition of forest resources use is dominated by coffee production.

2.2 Data collection and analysis

Both ecological and ethnoecological data were collected (Lucena et al., 2013; Lokonon et al., 2019; Ribeiro et al., 2019; Korach et al., 2020). The data were collected in two steps. First coffee agroforest inventory was carried out to collect ecological data in five sites (*Dabbiyee*, *Gurrattii*, Q*artammee*, *Mexxii-Caffee*, and *Sokii*) and then coffee agroforest owners were interviewed on the use and preference of woody plant species in coffee agroforest. A total of 63 plots (400 m^2) (*Dabbiyee = 15*, *Gurrattii = 12*, Q*artammee = 11*, *Mexxii-Caffee = 12*, *Sokii = 13*) were selected for woody plant species inventory. It covered a total area of 2.52 ha. The plots were laid systematically along the transect in coffee agroforest in each site. Within 20 m × 20 m, all

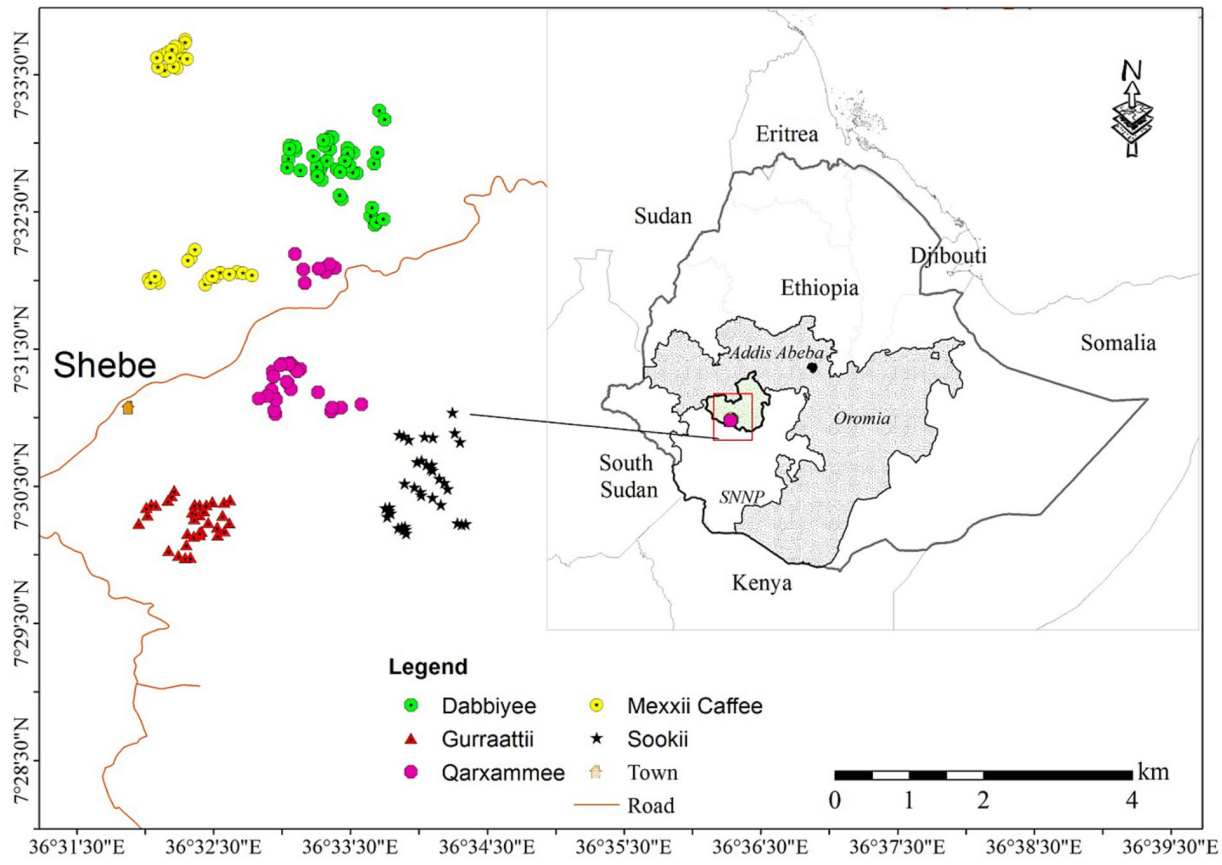

FIGURE 1
Map of Ethiopia with Oromia region, Jimma zone, location of study villages.

woody plant species with diameter at breast height ≥ 10 cm were identified and recorded. The researcher identified woody plant species in the field by their local names with the help of local people and cross-checked using available literature (Bekele-Tesemma, 2007; Eyasu et al., 2020). The specimen of woody plants difficult to identify in the field were collected and taken to lab for further identification with the help of botanist. Plant specimens were deposited at Jimma University Department of Biology. For regeneration assessment, seedlings and saplings were identified, counted and recorded within a sub-plot of 10 m × 10 m and 5 m × 5 m, respectively. All methods were performed in accordance with the relevant guidelines and regulations. Plant identification was done following the flora of Ethiopia and Eritrea.

Ethnoecological data were collected through semi-structured interview. A checklist for an interview was prepared focusing on the use and preference of woody plant species in coffee agroforest. All woody plant species recorded in the field were included in the semi-structured questionnaire. Free listing technique was used to record the use of each woody plants. Coffee owners list as much as they can remember the use of the plant (Martin, 1995). The use of woody plant mentioned by interviewees were grouped into different use categories. Moreover, coffee owners were asked to mention the most preferred coffee shade trees and their management practices. The ethnoecological data were collected from 96 individuals (11 females) (*Dabbiyee* = *20*, *Gurrattii* = *18*, Q*artammee* = 17, *Mexxii-Caffee* = *21*, *Sokii* = *20*). The age of interviewees ranges from 20 to 80. Permissions were obtained from Oromia Forest and Wildlife Enterprises, Shabe Sombo district office and the lowest administrative Office (kebele) to undertake the study. All methods were performed in accordance with the relevant guidelines and regulations. The interviewees gave their consent on verbal than written form for an interview. To minimize the bias due to peer interference, an interview was carried out on an individual based on the convenient time and place to interviewee.

Alpha diversity and other indices were computed for diversity assessment using PAST version 4.03 software. Alpha diversity is expressed as the total number species (species richness) in coffee agroforest (Manaye et al., 2021; Marzialetti et al., 2021).

Species richness was computed using the formula:

$$S = \sum ni$$

where ni is the number of species in a coffee agroforest.

Woody plant species preference in coffee agroforest was analyzed using the number of citation given to each woody plant species for the respective use categories. Citation refers the number of use of wood plants the interviewee mentioned (Lucena et al., 2013; Lokonon et al., 2019). Literature has stated that more preferred woody plant species are more cited (Lokonon et al., 2019). Woody plant preference in coffee agroforest was estimated using the equation adopted from Duguma and Hager (2010) as follow:

$$MSc\ spp(x),use(y) = \frac{\sum score\ spp(x), use(y)}{n}$$

$$ARPS\ spp(x),use(y) = \frac{MSc\ spp(x),use(y)}{\sum Msc\ spp(all),use(y)} \times 100$$

$$AGRPS\ spp(x),use(y) = \frac{\sum ARPS\ spp(x)}{\sum APRS\ spp(all),use(all)} \times 100$$

Where $MSc\ spp(x),use(y)$ stands for mean citation score of species x for use type y, n stands for the total number of interviewees ($n = 96$); $ARPS\ spp(x),use(y)$ stands for the adjusted relative preference score of species x for use type y in % and $AGRPS\ spp(x),use(y)$ stands for the aggregate relative preference score of a species across all types in percentage. Aggregate relative preference score was computed for multiple use and shade value of recorded woody plant species in coffee agroforest.

The woody plant conservation priority (CP) analysis adopted with some modification the technique that was employed by scholars (Dzerefos and Witkowski, 2001; Oliveira et al., 2007; de Albuquerque et al., 2011; Lokonon et al., 2017; Kafoutchoni et al., 2018; Ribeiro et al., 2019; Oliveira et al., 2021). Table 1 portrays the criteria and score employed in the analysis. Woody plant species is calculated using the formula:

$$CP = 0.5(BS) + 0.5(UR)$$

Where CP corresponding to Conservation Priority, BS corresponding to biological score estimated based on relative density (D) as BS = D × 10. The usage risk (UR) is estimated based on management risk and use value (U) as UR = [0.5(H) + 0.5(U)] × 10. Use value is estimated as the average of the sum of the local importance (L) and the diversity of use (V) (Ribeiro et al., 2019). For woody plants that have timber and construction value additional value of 10 points were added as additional usage pressure (Ribeiro et al., 2019). Finally woody plants divided into three categories, category 1 with high priority species for conservation (CP ≥ 85), category 2 with moderate priority species for conservation (60 ≤ CP < 85) and category 3 with low priority for conservation (CP < 60). Spearman correlation was computed to test the relationship between woody plant species preference and conservation priority.

TABLE 1 Criteria and scores used to determine woody plant species conservation priority in coffee agroforest.

Criteria	Score
A. Relative density (D)	
Not recorded- very low (0–1)	10
Low (1 < 3.5)	7
Medium (3.5 < 7)	4
High (≥7)	1
B. Management risk	
Total removal of tree species (i.e., non-coffee shade tree)	10
Thinning or stem reduction of tree species (i.e., retained non-coffee shade trees)	7
Slashing and under growth removal of tree species (i.e., shade secondary use)	4
Branch removal or canopy reduction of tree species (i.e., Shade primary use)	1
C. Local use (L)	
High (quoted by >75% of local informants)	10
Moderately high (cited by 50 ≤ 75% of local informants)	7
Moderately low (cited 25 < 50% of local informants)	4
Very low (quoted <25 < 10% of local informants)	1
D. Diversity of use	
One point is added for each use, maximum 10 points	1–10

3 Results and discussion

3.1 Diversity of woody plant species

Findings on ecological data showed that many woody plant species associated with coffee agroforest in southwest Ethiopia. The result showed that 48 different woody plant species belonging to 27 families were recorded in 63 plots (Table 2). Most of the families were represented by a single species. Only a few family consists of a maximum of four species. Among the recorded woody plants three woody plant species, *Cordia africana, Croton macrostachyus, Milletia ferruginea* were more abundant compared to the other species accounting for 41 percent of the number of woody plants. Forty five woody plants had contributed each less than 5 percent of the total abundance. The lower abundance of many woody plants were the outcome of coffee management that resulted in stem reduction. Muleta et al. (2011) have reported the family Fabaceae dominate coffee agroforest in southwest Ethiopia. Aerts et al. (2011) reported *Croton macrostachyus* and *Milletia ferruginea* dominate coffee agroforest in southwest Ethiopia. This is attributed to the regeneration characteristics of individuals (Aerts et al., 2011). A Study from Dallo Mena district, southeast Ethiopia has reported 10 different tree species in shade grown coffee (Mengistu and Asfaw, 2016). Another study from Jimma area southwest Ethiopia have reported 38 different tree species in coffee agroforest (Worku et al., 2015).

Higher species diversity with Fisher alpha 12 and Shannon Weiner diversity (H) 3.08 were found in coffee agroforest (Table 3). Previous studies categorized Shannon Weiner diversity as high with a value ≥3, medium with a value between 2 and 3, low with a value between 1 and 2, very low with a value <1 (Atsbha et al., 2019; Fentaw et al., 2022). A Shannon Weiner diversity value of 3.08 of the present study belongs to a high diversity category. The individual based rarefaction curve showed the estimated number of species as more number of individuals recorded (Figure 2). The Choa-1 value of 51.5 showed the maximum species richness estimated with more sampling effort (Table 3). Worku et al. (2015) have reported Fisher alpha diversity of 8.53 in coffee agroforest in Yayu southwest Ethiopia. Kewessa et al. (2019) have found a Shannon diversity of 1.74 in coffee agroforest Bale Eco-Region, southeastern Ethiopia. Senbeta and Denich (2006) have reported a Shannon diversity of

TABLE 2 Woody plant species recorded in coffee agroforest.

No	Scientific name	Family	Abundance	Rel. contribution (%)
1	*Alangium chinense*	Alangiaceae	2	0.38
2	*Albizia gummifera*	Fabaceae	26	4.99
3	*Allophylus abyssinicus*	Sapindaceae	2	0.38
4	*Apodytes dimidiata.*	Icacinaceae	5	0.96
5	*Bersama abyssinica*	Melianthaceae	10	1.92
6	*Cassipourea malosana*	Rhizophoraceae	1	0.19
7	*Celtis africana*	Ulmaceae	20	3.84
8	*Chionanthus mildbraedii*	Oleaceae	4	0.77
9	*Clausena anisata*	Rutaceae	4	0.77
10	*Cordia africana*	Boraginiaceae	66	12.67
11	*Croton macrostachyus*	Euphorbiaceae	41	7.87
12	*Diospyros abyssinica*	Ebenaceae	22	4.22
13	*Dracaena afromontana*	Dracaenaceae	3	0.58
14	*Dracaena steudneri*	Dracaenaceae	5	0.96
15	*Ehretia cymosa*	Boraginiaceae	4	0.77
16	*Ekebergia capensis*	Meliaceae	3	0.58
17	*Euphorbia candelabrum*	Euphorbiaceae	3	0.58
18	*Fagaropsis angolensis*	Rutaceae	12	2.30
19	*Ficus sur*	Moraceae	11	2.11
20	*Flacourtia indica*	Flacourtiaceae	5	0.96
21	*Galiniera saxifrage*	Rubiaceae	2	0.38
22	*Ilex mitis*	Aquifoliaceae	1	0.19
23	*Macaranga capensis*	Euphorbiaceae	4	0.77
24	*Maesa lanceolata*	Myrsinaceae	5	0.96
25	*Maytenus arbutifolia*	Celastraceae	1	0.19
26	*Milletia ferruginea*	Fabaceae	110	21.11
27	*Mimusops kummel*	Sapotaceae	3	0.58
28	*Olea welwitschii*	Oleaceae	21	4.03
29	*Oxyanthus speciosus*	Rubiaceae	3	0.58
30	*Persea americana*	Lauraceae	1	0.19
31	*Phoenix reclinata*	Arecaceae	3	0.58
32	*Pittosporum viridiflorum*	Pittosporaceae	1	0.19
33	*Polyscia fulva*	Araliaceae	9	1.73
34	*Pouteria adolfi-friederici*	Sapotaceae	18	3.45
35	*Prunus africana*	Rosaceae	14	2.69
36	*Rhus natelensis Krauss*	Anacardiaceae	1	0.19
37	*Rothmannia urcelliformis*	Rubiaceae	6	1.15
38	*Rytigynia neglecta*	Rubiaceae	2	0.38
39	*Sapium ellipticum*	Euphorbiaceae	5	0.96
40	*Schrebera alata*	Oleaceae	1	0.19
41	*Schefflera abyssinica*	Araliaceae	5	0.96
42	*Syzygium guineense*	Myrtaceae	26	4.99
43	*Teclea nobilis*	Rutaceae	2	0.38
44	*Trichilia dregeana*	Meliaceae	12	2.30
45	*Trilepisium madagascariense*	Moraceae	3	0.58
46	*Vangueria apiculata*	Rubiaceae	3	0.58
47	*Vepris dainellii*	Rutaceae	3	0.58
48	*Vernonia amygdalina*	Asteraceae	7	1.34
Total number		27	521	100

2.82 at Bebeka southwest Ethiopia. Rigal et al. (2018) has reported a Shannon diversity of 3.42 with 30.57 effective number species in coffee agroforest from southwest China.

Coffee agroforest is a source of livelihoods for the local people. It provided ecosystem services that benefit the forest users (Bukomeko et al., 2019). The present study showed that woody plants maintained in coffee agroforest provide diversity of uses. Ten uses such as fuelwood, charcoal, Construction, medicinal, coffee shade, bee forage, beehive, farm tool, hanging beehive and timber that determine the management of woody plants species in coffee agroforest were frequently mentioned. These uses can be destructive (timber, beehive, construction, charcoal, farm tool), partial destruction (fuelwood, medicinal) and non-destructive (coffee shade, bee forage, hanging beehive). Ecological and economic reasons are the driving factors for woody plant management in coffee agroforest. In coffee agroforest the shade value of woody plant species are the priority for tree selection and management. Nevertheless, the present study findings showed that coffee agroforest owners obtain multiple benefits from the managed woody plants. Girma et al. (2019) have stated that local people manage woody plants for construction, fuelwood and honey production. A study from Bangladesh showed that local people manage woody plants for multiple uses and the major uses are fruit, fuelwood, pole, timber, medicinal etc. (Tarit et al., 2015).

TABLE 3 Diversity indices of woody plant species in coffee agroforest.

Indices	Coffee agroforest
Taxa_S	48
Individuals	521
Dominance_D	0.08
Simpson_1-D	0.92
Shannon_H	3.08
Evenness_e^H/S	0.45
Brillouin	2.92
Menhinick	2.10
Margalef	7.51
Equitability_J	0.79
Fisher_alpha	12.89
Berger-Parker	0.21
Chao-1	51.5

3.2 Preferred woody plants in coffee agroforest

The aggregate relative preference score (ARPS) showed 15 most preferred woody plant species in coffee agroforest (Table 4). Each woody plant species provided multiple uses and the relative importance differ between the species. Based on the all uses, *P. adolfi-friederici*, *C. africana*, *P. fulva*, *E. candelabrum* were the most preferred woody plants. The use value of these woody plants were mentioned more for timber, hanging beehive, beehive than coffee shade. *A. gummifera* and *M. ferruginea* were the most preferred coffee shade trees. The abundance of *P. adolfi-friederici*, *C. africana*, *P. fulva*, *E. candelabrum* were lower than *M. ferruginea* a well-known coffee shade tree in southwest Ethiopia. A study from Tanzania has shown local people give priority for the tree species that provide food, fodder and fuelwood (Wagner et al., 2019). Bukomeko et al. (2019) have studied the relationship between tree diversity and farmers need for the benefit of trees and found that farmers need did not match with tree diversity in coffee agroforest in Uganda. Lamond et al. (2016) have investigated underpinning factors for tree preference in coffee agroforest and reported that multiple uses (both ecological and socioeconomic) determine the tree selection in coffee agroforest. Albertin and Nair (2004) a have studied farmers' perspective on the role of shade tree in coffee production systems in Nicoya Peninsula, Costa Rica and have found tree species that are not preferred for coffee shade still maintained in coffee agroforest for the benefits they provided for the local people. The same author highlighted the need

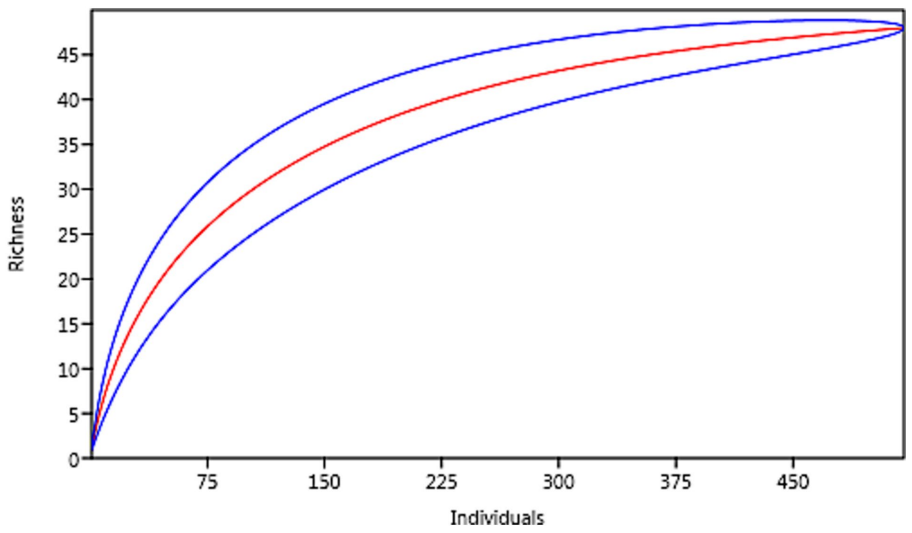

FIGURE 2
Individual based rarefaction curve.

TABLE 4 Uses and relative value of 15 most preferred woody plant species in coffee agroforest.

No	Woody plant species	Adjusted relative preference scores (ARPS) (%)										AGRPS (all use)	AGRPS (Shade use)	Abun
		Fue	Cha	Con	Med	Cof	Bef	Beh	Far	Han	Tim			
1	P. adolfi-friederici	0.00	0.00	0.01	0.00	0.05	0.06	0.00	0.00	0.16	0.29	5.79	5.05	18
2	*C. africana*	0.00	0.00	0.00	0.00	0.08	0.05	0.00	0.00	0.02	0.38	5.31	8.30	66
3	*P. fulva*	0.01	0.02	0.01	0.00	0.02	0.03	0.28	0.00	0.05	0.07	4.77	2.17	9
4	*E. candelabrum*	0.00	0.00	0.02	0.04	0.00	0.00	0.37	0.00	0.00	0.00	4.24	0.00	3
5	*O. welwitschii*	0.01	0.00	0.04	0.00	0.01	0.00	0.26	0.07	0.02	0.00	4.10	1.44	21
6	*P. africana*	0.03	0.10	0.01	0.01	0.04	0.00	0.00	0.08	0.02	0.11	3.95	3.61	14
7	*C. macrostachyus*	0.01	0.01	0.02	0.05	0.02	0.20	0.00	0.00	0.05	0.00	3.63	2.35	41
8	*T. dregeana*	0.00	0.00	0.00	0.31	0.01	0.00	0.00	0.00	0.02	0.00	3.58	1.44	12
9	*S. abyssinica*	0.00	0.00	0.01	0.00	0.07	0.26	0.00	0.00	0.00	0.00	3.54	7.04	5
10	*A. gummifera*	0.01	0.04	0.03	0.00	0.16	0.00	0.00	0.00	0.07	0.00	3.03	16.06	26
11	*M. ferruginea*	0.02	0.05	0.01	0.01	0.16	0.00	0.00	0.00	0.04	0.00	2.98	15.52	110
12	*C. africana*	0.05	0.18	0.00	0.02	0.00	0.01	0.00	0.00	0.03	0.00	2.93	0.18	20
13	*E. capensis*	0.01	0.02	0.00	0.01	0.10	0.01	0.00	0.00	0.08	0.06	2.93	9.93	3
14	*F. sur*	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.00	0.18	0.02	2.80	0.00	11
15	*F. angolensis*	0.00	0.00	0.08	0.17	0.01	0.00	0.00	0.01	0.00	0.00	2.61	0.54	12

Fue, fuelwood; Cha, charcoal; Med, medicine; Cof, coffee shade; Bef, bee forage; Beh, beehive; Farm, farm tool; Han, hanging beehive; Tim, timber; AGRPS, Aggregate relative preference score; Abun, Abundance.

for incorporating more trees and fruit trees in coffee agroforest in the region. A study by Hundera (2016) has shown local people maintain *Schefflera abyssinica* and *Olea welwitschii* in coffee agroforest for honey production in southwest Ethiopia. Valencia et al. (2015) have reported bulk of tree species that have not been valued for coffee shade in coffee in Chiapas, Mexico. Reinforcing reasons that encourage tree management in coffee agroforest are the need for additional benefits such as timber, fuelwood, medicinal and other non-timber forest products (Valencia et al., 2015). A study by Kalanzi and Nansereko (2014) has shown local people in Bukomansimbi district of Uganda prefer tree species that provide multiple products in coffee agroforest.

3.3 Local priority for conservation of woody plant species

The present study findings showed that the conservation priority (CP) varies between woody plants. Three types of categories were identified for local conservation priority that took into account the management practices, utilization and regeneration status of each woody plant (Table 5). Category 1 indicates woody plant species that need high conservation priority and accordingly category 2 and category 3, moderate and low priority, respectively. As indicated in Table 5, 12 species are represented under category 1, 19 species are represented under category 2 and 17 species are represented under category 3. Woody plants that are destructively utilized and removed from coffee agroforest during slashing under growth plants belongs to category 1. These woody plants had a few individuals and insufficient regeneration. Local people do not value these woody plants for coffee shade and totally remove, if possible, from the system. Likewise woody plant species under category 2 are utilized destructively that resulted in low number of individuals leading to loss of the plants in the long run. The Spearman correlation showed negative correlation between abundance and conservation priority [$r_s(46) = -0.681$, $p = 000$]. Most preferred woody plants such as *Cordia africana, Polyscia fulva, Pouteria adolfi-friederic* and *Olea welwitschi* belongs to category 3, *Euphorbia candelabrum, Ekebergia capensis*, and *Fagaropsis angolensis* belongs to category 2 and known coffee shade tree species *Milletia ferruginea* and *Albizia gummifera* belongs to category 3. This work is the first attempt to classify woody plant species in coffee agroforest in southwest Ethiopia. It highlights the status of woody plants under coffee management practices. The study findings complement the notion coffee agroforest is tree diversity conservation hotspot (Valencia et al., 2014). Local farmers knowledge plays a decisive role in conservation of tree species in coffee agroforest (Valencia et al., 2015). Joshi et al. (2019) has stated that woody plant species recognized as useful are under pressure for utilization and need attention for conservation. In the present study *Cordia africa* which is extracted for timber is exceptional due to the nature of plant regeneration characteristics. *Cordia africana* is found in low abundance but withstand timber utilization. Joshi et al. (2019) has reported tree species require high conservation priority compared to shrubs. But, the present study showed that shrubs require more attention than trees as coffee management remove under growth including shrubs through slashing. The study also support Lokonon et al. (2017) that state most used species are not top priority for conservation. For instance, in this study *Cordia africana* is highly utilized for timber but categorized under category 3. *Rytigynia neglecta*, *Maytenus arbutifolia* and *Ilex mitis* are among the species with high diversity of uses but totally discouraged in coffee agroforest in southwest Ethiopia.

TABLE 5 List of woody plant species for local conservation priority in coffee agroforest.

No	Plant name	Major use	Manag	D	L	DU	H	U	CP	Categ	Abun	Sap/ seed
1	*Rytigynia neglecta**	Construction	Removed	10	10	5	10	7.5	103.75	1	1	Present
2	*Maytenus arbutifolia*	Fuelwood	Removed	10	10	5	10	7.5	93.75	1	2	Present
3	*Ilex mitis*	Fuelwood	Removed	10	7	7	10	7	92.5	1	1	Absent
4	*Sapium ellipticum*	Fuelwood	Removed	7	10	6	10	8	91.25	1	2	Absent
5	*Galiniera saxifrage*	Fuelwood	Removed	10	7	5	10	6	90	1	1	Absent
6	*Pittosporum viridiflorum*	Fuelwood	Removed	10	7	5	10	6	90	1	2	Present
7	*Schrebera alata*	Fuelwood	Removed	10	7	5	10	6	90	1	3	Present
8	*Cassipourea malosana*	Farm tool	Removed	10	4	7	10	5.5	88.75	1	2	Present
9	*Teclea nobilis*	Farm tool	Removed	10	7	4	10	5.5	88.75	1	3	Present
10	*Alangium chinense**	Construction	Retained	10	4	3	7	3.5	86.25	1	1	Absent
11	*Rothmannia urcelliformis**	Construction	Removed	7	7	6	10	6.5	86.25	1	1	Present
2	*Syzygium guineense**	Construction	Retained	1	10	5	10	7.5	86.25	1	1	Present
13	*Apodytes dimidiata*	Coffee shade	Retained	7	4	10	1	7	82.5	2	1	Present
14	*Persea americana*	Fuelwood	Retained	10	1	4	10	2.5	81.25	2	1	Present
15	*Mimusops kummel*	Construction	retained	7	7	8	4	7.5	80	2	1	Present
16	*Trilepisium madagascariense**	Construction	Retained	7	7	5	4	6	80	2	1	Present
17	*Flacourtia indica*	Fuelwood	Removed	7	10	5	10	7.5	78.75	2	1	Absent
18	*Fagaropsis angolensis**	Construction	Retained	4	10	5	7	7.5	77.5	2	1	Present
19	*Maesa lanceolata*	Fuelwood	Removed	7	10	6	10	8	77.5	2	1	Present
20	*Vernonia amygdalina*	Bee forage	Removed	7	4	5	10	4.5	77.5	2	1	Present
21	*Euphorbia candelabrum*	Beehive	Removed	7	10	4	10	7	76.25	2	1	Present
22	*Vepris dainellii*	Fuelwood	Removed	7	10	4	10	7	75	2	1	Absent
23	*Clausena anisata*	Fuelwood	Removed	7	4	5	10	4.5	73.75	2	1	Absent
24	*Oxyanthus speciosus*	Fuelwood	Removed	7	7	4	10	5.5	73.75	2	1	Absent
25	*Phoenix reclinata**	Construction	Removed	7	1	2	10	1.5	73.75	2	2	Absent
26	*Rhus natelensis*	Fuelwood	Removed	10	10	3	10	6.5	73.75	2	1	Absent
27	*Dracaena steudneri*	Medicinal	Removed	7	1	1	10	1	71.25	2	2	Absent
28	*Vangueria apiculata*	Fuelwood	Removed	7	7	5	10	6	70	2	1	Present
29	*Chionanthus mildbraedii*	Farm tool	Removed	7	7	4	10	5.5	66.25	2	1	Present
30	*Macaranga capensis*	Fuelwood	Removed	7	10	4	10	7	66.25	2	1	Absent
31	*Ehretia cymosa*	Farm tool	Removed	7	7	6	10	6.5	62.5	2	2	Absent
32	*Bersama abyssinica*	Fuelwood	Removed	4	10	7	10	8.5	55	3	1	Absent
33	*Celtis africana*	Fuelwood	Removed	1	10	7	10	8.5	51.25	3	1	Absent
34	*Polyscia fulva*	Beehive	Retained	4	7	3	7	3.5	48.75	3	1	Absent
35	*Trichilia dregeana*	Medicinal	Retained	1	10	7	7	8.5	47.5	3	2	Present
36	*Diospyros abyssinica**	Construction	Retained	1	7	4	7	5.5	46.25	3	1	Present
37	*Allophylus abyssinicus*	Fuelwood	Removed	7	10	8	10	9	43.75	3	1	Absent
38	*Ekebergia capensis*	Coffee shade	Retained	4	7	8	1	7.5	41.25	3	2	Absent
39	*Croton macrostachyus*	Bee forage	Retained	1	7	7	7	7	40	3	1	Absent
40	*Pouteria adolfi-friederici**	Timber	Retained	1	7	7	10	5.5	40	3	1	Absent
41	*Dracaena afromontana**	Construction	Removed			3	10	1.5	38.75	3	1	Present
42	*Schefflera abyssinica*	Bee forage	Retained	1	10	7	10	7	36.25	3	3	Present
43	*Cordia africana*	Timber	Retained	1	10	6	4	8	35	3	1	Absent

(Continued)

TABLE 5 (Continued)

No	Plant name	Major use	Manag	D	L	DU	H	U	CP	Categ	Abun	Sap/seed
44	*Prunus africana*	Fuelwood	Retained	1	7	5	10	6	33.75	3	1	Absent
45	*Olea welwitschi*	Beehive	Retained	1	7	7	4	7	32.5	3	1	Absent
46	*Ficus sur*	Hanging beehive	Retained	1	7	5	4	6	30	3	2	Present
47	*Milletia ferruginea*	Coffee Shade	Retained	1	10	6	1	8	27.5	3	1	Present
48	*Albizia gummifera*	Coffee shade	Retained	1	10	5	1	7.5	26.25	3	2	Present

Manag, management practices; D, density; L, local importance; Du, diversity of use; H, Utilization risk; CP, conservation priority; categ, conservation categories; Abun, abundance; Sap/seed, sapling/seedling.
*Associated destructive use.

4 Conclusion and implication to conservation

Coffee management activities and local uses raises the concern for conservation of woody plant species in coffee agroforest in southwest Ethiopia. The study findings highlight the diversity, local preference and conservation priority of woody plant species. We conclude that the most useful woody plants are not the most abundant in coffee agroforest. As most woody plants need high conservation priority, the presence of woody plants in coffee agroforest necessarily does not imply sustainability. Local preference determine woody plant species management and conservation in coffee agroforest. Woody plants are maintained in coffee agroforest for multiple uses than a single shade value. Non-coffee shade trees are the most preferred tree species in coffee agroforest. The study findings suggest that promotion of woody plant species management in coffee agroforest should include the multiple uses and preference of woody plant species.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

ZK: Conceptualization, Formal analysis, Writing – original draft. CO: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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