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Beekeeping promotes conservation of traditional home-gardens in Ethiopia

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Abstract: In Ethiopia, agrobiodiversity is managed through indigenous knowledge of rural communities, where the selection of plant species varies depending on the sociocultural practices and local economic needs. Traditional beekeeping has been practiced by millions of households in rural Ethiopia over a long historical period. However, the contribution of beekeeping in maintaining agrobiodiversity has not been systematically assessed in the country. This study was conducted in Central and Western Ethiopia to assess and compare traditional conservation practices, as well as the diversity and abundance of vegetation found within home-garden maintained by beekeepers and non-beekeepers. The results of the study showed that beekeepers traditionally retain more remnants of trees and shrubs in their home-garden to favor sustainable beekeeping, compared to non-beekeepers who instead are more likely to expand crop production. The mean number of floral species in beekeeper and non-beekeeper home-gardens was 22.8 ±3.2 and 14.2 ± 2.1, respectively. The higher species richness of bee visited plants in beekeepers' home-gardens may be associated with traditional ecological knowledge accumulated by beekeepers over the years to maximize harvests of bee products. We therefore recommend the integration of beekeeping to other conservation interventions, such as community forestry, watersheds and protected areas as sustainable conservation practices. We suggest that necessary financial, technological, and extensional support should be enhanced to align improved beekeeping to any conservation efforts.
Keywords: Home-garden, conservation, beekeeping, bee products

Introduction

Understanding the relationships between agroforestry conservation and food production should bridge human needs and ecosystem health, which is a major concern for ecologists and agriculturists (Breeze *et al*., 2019). In Africa, many people are reliant on natural resources for their survival, either through collection of natural resources for direct use or indirectly benefiting from biodiversity and ecosystem services (Egoh *et al*., 2012). Several agroforestry practices in Africa can be relevant for different agro-ecological zones with a range of diverse vegetation compositions that can sustain both livelihoods and landscape conservation (Mbow *et al*., 2014). Traditional home-gardens are characterized by higher diversity of plant species, where the selection of plant species and their management varies between home-gardens. The variation in home-garden woody species richness could be due to site management strategy, socioeconomic factors and farmer's preferences (Abiyot and Zemede, 2014; Mohammed and Zemede, 2015; Molla and Kewessa, 2015).

Beekeeping can promote sustainable development that enhances conservation of natural resources and economic development while actively involving the participation of local people in natural resource management (Cheng *et al*., 2020; Kaluza *et al*., 2018; Elzaki and Tian, 2020). Beekeeping in Africa can preserve nature, provide food security through pollination, and maximize organic bee products. Beekeeping landscapes consist of adequate floral resources designed to favor sustainable beekeeping, and at the same time support biodiversity enhancement (Picknoll *et al*., 2021).

Beekeeping may be integrated into sustainable agroforestry practices that potentially contribute to the maintenance of biological and cultural diversity (Athayde *et al*., 2016). Honey production may not only uplift the income of rural communities, but also contribute to the restoration and protection of flora resources (Chazovachii *et al*., 2012; Achmad and Diniyati, 2018). Beekeepers favor tree plantation to sustain bee colony population and to produce honey over multiple seasons, unlike other conventional farming system that enhance agricultural yield through demolition of natural resources (Buchori *et al*., 2008). Sustainable beekeeping and honey production can be met through agroforestry intensification, including the plantation and management of multipurpose bee flora species in the system.

Ethiopia has an estimated of 10 million native honeybee colonies, the largest number in Africa (Negash and Greiling, 2017). Beekeepers in rural areas of the country produce honey through practicing backyard beekeeping management. The existing knowledge regarding the interconnection between beekeeping and agrobiodiversity conservation is not systematically evaluated. The understanding of agroforestry in terms of flora distribution may provide important data that will be helpful in natural resource conservation planning. In this study, the socioecological practices, vegetation composition and diversity were assessed and compared between home-gardens managed by beekeepers and non-beekeepers. We hypothesize that beekeeper home-gardens have higher vegetation diversity, and thus, play a greater role in sustainable agrobiodiversity conservation.

Materials and Methods

Study sites

The study was conducted in Southwest, West Shewa and Horo-Guduru Wollega (Figure 1), where agriculture is dominantly practiced. The major cereal crops grown in these areas are teff (*Eragrostic teff*), maize (*Zea mays*), wheat (*Triticum sativum*), and barley (*Hordeum vulgare*). Pepper (*Capsicum frutescens*), coffee (*Coffea arabica*), and chat (*Catha edulis*) are the dominant cash crops (Endale et al., 2016). Studying the floral composition and diversity of home-gardens is important to distinguish the current conservation status of rural home-gardens and to understand the vegetation conservation practices between beekeepers and non-beekeepers.

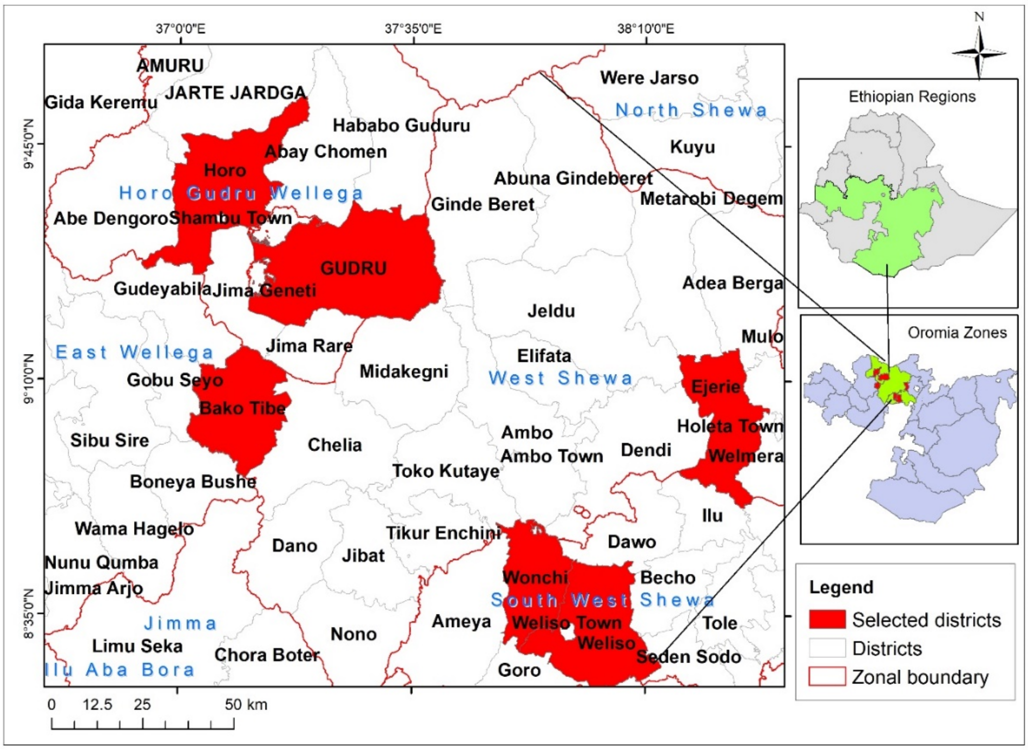

Figure 1. Map showing the study areas

Sampling procedure and data collection

The study was carried out in three zones of Oromia Regional State in order to compare the socioecological practices, the vegetation composition, plant diversity and plant abundance between beekeepers and non-beekeepers home-gardens conducted from September 2016 to June 2018. A total of 90 beekeepers and 90 adjacent non-beekeeper home-gardens were involved in the study zones. From each zone, 30 beekeeper home-gardens, and 30 non-beekeeper home-gardens were selected and assessed. Permission from the home-gardens owner was secured after explaining the purpose of the study. Field data was collected through direct home-garden observation. Semi-structured questionnaires were used to gather data on socioecological practices, such as the degree of home-garden utilization (income sources) and awareness of home-garden conservation. Questions also related to beekeeping practices (such as hive types, number, and honey yield). Plant species were identified using two botanical field guides containing more than 400 important Ethiopian bee flora species supported by pictures (Fichtl and Adi, 1994; Adi et al., 2014).

Home-garden size was categorized into four classes with interval increments of 0.25 ha: small size (< 0.25 ha); medium size (0.25-0.50 ha); large size (0.51-0.76 ha) and very large size (0.77-1.00 ha) according to Mohan et al. (2007). Vegetation cover was visually estimated and home-gardens were placed in categories ranging from “very low” (<10% vegetation coverage), “low” (10% - 20% vegetation coverage), “medium” (21% - 30% vegetation coverage), “high” (31% - 40% vegetation coverage), and “very high” (41% - 50% vegetation coverage) (Wrzesień and Denisow, 2016).

Species diversity

In order to get a better picture of vegetation diversity of home-gardens, species inventory was made on 25-meter x 25-meter main plot for woody species. This is because the minimum home-garden size owned by the household was 625 m^2 based on interviews and cross-checked by personal observations. To measure the diversity of herbs 2 m^2 subplot size was established at each corner and in the centers of the main plot. The floral abundance and species richness of all flowering ground vegetation useful for beekeeping were recorded. The Shannon-Wiener Index (H), the most commonly used diversity indicator, was calculated and a value of zero was assigned when there was only one species and a maximum value when all species are present in equal abundance.

The equation is

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

Where H is the Shannon-Wiener Diversity Index, the proportion of species *i* relative to the total number of plants is calculated and multiplied by the natural logarithm of this proportion. The resulting product is summed across species and multiplied by -1.

Species evenness

$$J = \frac{H'}{H'max} = \frac{\sum_{i=1}^{s} \text{PilnPi}}{\ln s}$$

Where H'= the value of the Shannon-Weiner diversity index, S = number of species in the community, Pi = the proportion of individuals of the i^{th} species expressed as proportion of total cover, ln = log $base_n$, J = Evenness of species in sampling area, H'max = Maximum value of diversity. Abundance (number of individuals per species), and frequency (fraction of home-gardens containing the species expressed as percentage) were calculated following Kabir & Webb (2008). Vegetation inventory was conducted from September to November when all flowering herbaceous and other tree plants were abundantly found.

Data analysis

Plant species found in all study sites have been identified and recorded by their respective local name, scientific name, number and their relative abundance. We found that some species are more frequent and abundant in relation to the total number of species. Therefore, we separated the most common 12 woody plant species and five herbaceous species (Table 2). Data was analyzed using SPSS software version 20. Analysis of Variance (ANOVA) was employed to compare bee colonies, honey yield and home-garden size categories. The non-parametric (Mann–Whitney U test and Kruskal-Wallis) were used to analyze the differences in the species richness, diversity and evenness among study zones and between beekeeper and non-beekeeper home-gardens. Sigma-Plot version 12.5 was used to draw the figures.

Results

Socioeconomic and home-garden resource utilizations

Most households in the study areas were male-headed (79.4%), and the mean household age was 42.7 years. The type of home-garden resources utilized confirms the fact that communities heavily depend on nature for their social and economic well-being. Results show that farmers' management actively determines conservation of certain plant species in home-gardens. Income from crops contributed 72% of non-beekeeper's household income, while 44.3% of beekeepers' household income was from crops. Income from bee products made up 36.5% of the total income of beekeeper households (Figure 2).

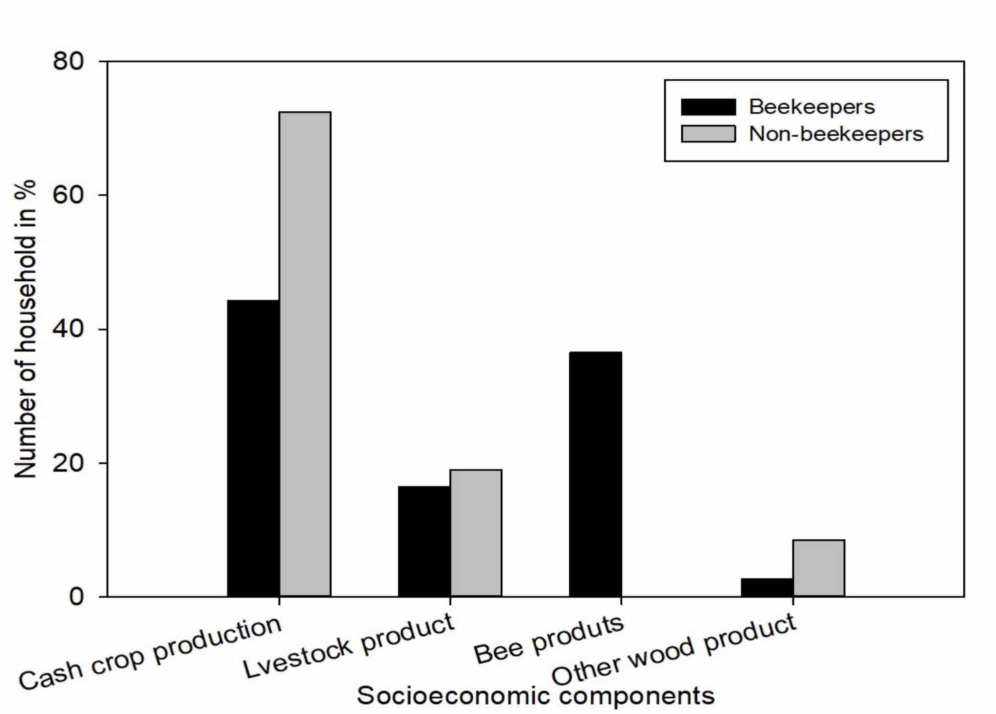

Figure 2: The socioeconomic components of beekeeper and non-beekeeper households

Beekeeping practices

Three beekeeping practices were found in the study areas (1) traditional beekeeping using log hives (2) transitional beekeeping, an intermediate beekeeping technology between traditional beekeeping and movable frame hive technology, and (3) the modern movable frame hive technology. Traditional beekeeping is the dominant practice in all study areas (96.3%), with little transitional beekeeping (2.4%), and few movable frame hives (1.7%). Due to these small sample sizes, statistics on transitional beekeeping technology and movable frame hive technology were omitted here. The mean number of honeybee colonies (in traditional hives) owned by beekeepers were significantly different across the study zones ($F_{2,87} = 10.74$, $P = 0.021$), and districts ($F_{5,84} = 4.38$, $P = 0.024$). The highest mean number of beekeeping in traditional hives was recorded in Guduru district of Horo-Guduru Wollega Zone (19 ± 1.2 colonies/household), and the lowest in Woliso district of Southwest Shewa Zone (2 ± 0.2 colonies/ household), all with decreasing trend from the year 2016 to 2018 according to the reports of beekeepers (Figure 3).

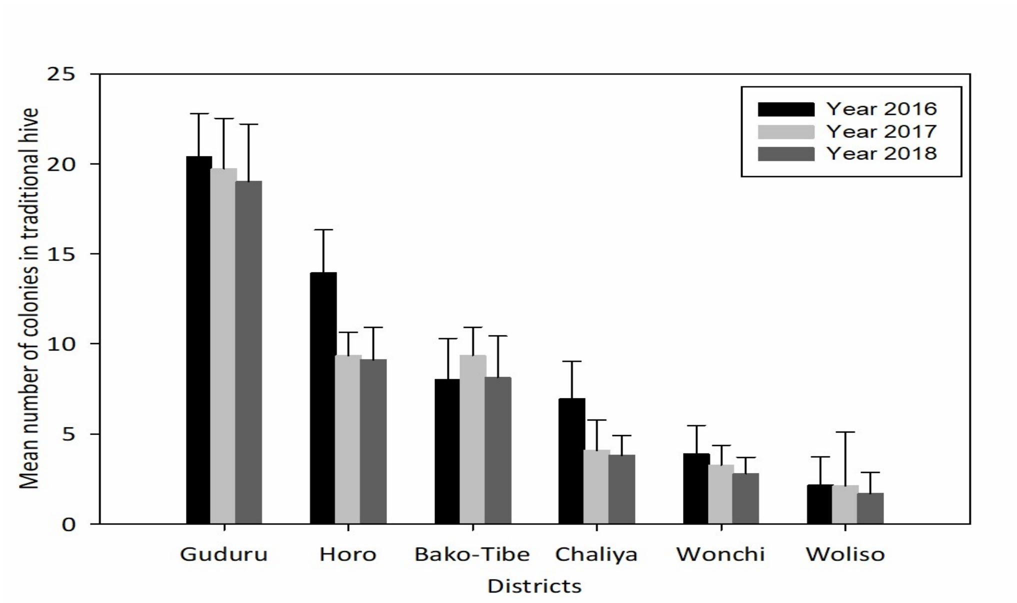

Figure 3. Distribution of beekeeping in traditional hive across districts. The results are expressed as mean value and statistically different among districts. Bars with different color representing the trend of mean number of colonies from 2016- 2018.

According to the survey results, honey production is varying across the study areas. Honey was harvested once a year (at the end of November) in Southwest Zone and two times a year (end of November, and at early June) in West Shewa and Horo-Guduru Wollega Zones. The highest mean honey yield from traditional hives was reported in Guduru district of Horo-Guduru Zone (6.8±2.0 kg/hive), followed by Chaliya district of West Shewa zone (5.95± 1.2 kg/hive), whilst the least in Woliso district of Southwest Shewa (3.5±1.3 kg/hive). Beekeepers in Southwest Shewa zone have frequently mentioned that, poor bee flora vegetation, inadequate skill in seasonal beekeeping management and weak beekeeping extension support are some of the problems that might be hinder sustainable beekeeping in the area. Moreover, beekeepers in all study areas stated that the number of bee colonies, the occupation rate of swarms in traditional beehives, and the quantity of honey harvested have been decreasing over the years.

There were substantial differences in home-garden land sizes between beekeepers and non-beekeepers ($F_{1, 178} = 6.4$, $P = 0.012$), and among the study zones ($F_{2, 177} = 6.28$, $P = 0.002$). Most (41.6%) of home-gardens in Southwest Shewa zone characterized under the smallest home-garden size category (less than 0.25 ha), whereas, 15.6% of home-gardens in Horo-Guduru Wollega Zone categorized under the widest size category (0.77-1 ha) (Figure 4).

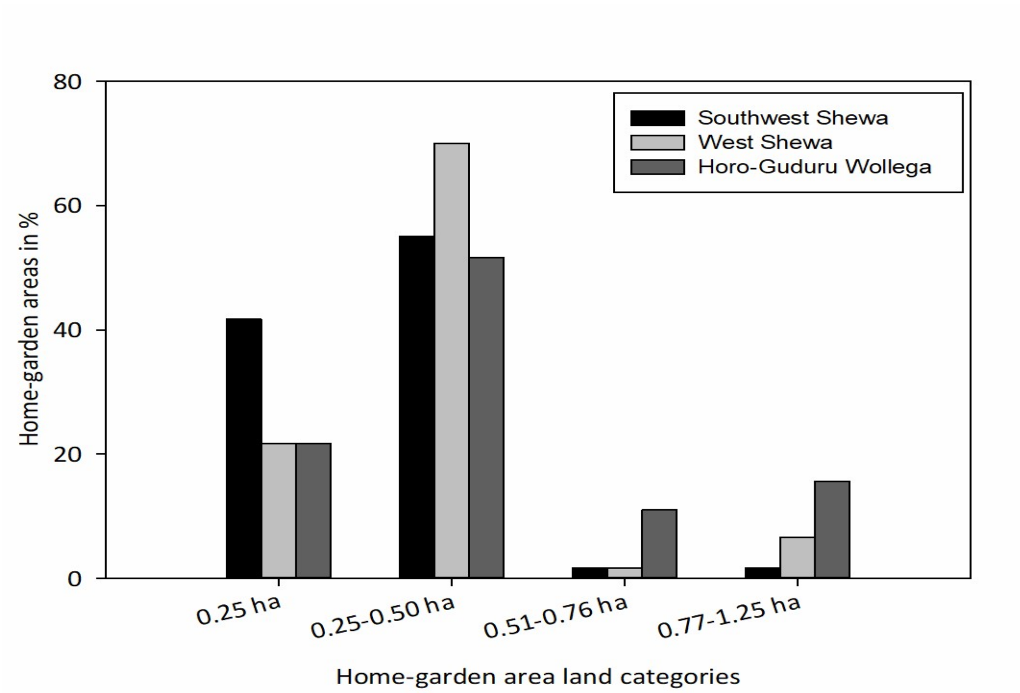

Figure 4. Homegarden area categories of the study zones. Bars with different colors indicating the study zones.

On the contrary, it was observed that the direct vegetation management at non-beekeeper's home-garden is rare. Nearly, about 43.8% of non-beekeeper's home-garden was characterized under very low woody vegetation cover (less than 10%) of the total home-gardens, whereas, most beekeeper home-gardens (51.7%) are characterized under vegetation cover categories between 10-20% cover (Figure 5). Selective harvesting of trees, cutting tree branches from farm border, slashing ground cover, extensive use of herbicides to destroy weeds from farm landscapes were common practices in non-beekeeper home-gardens.

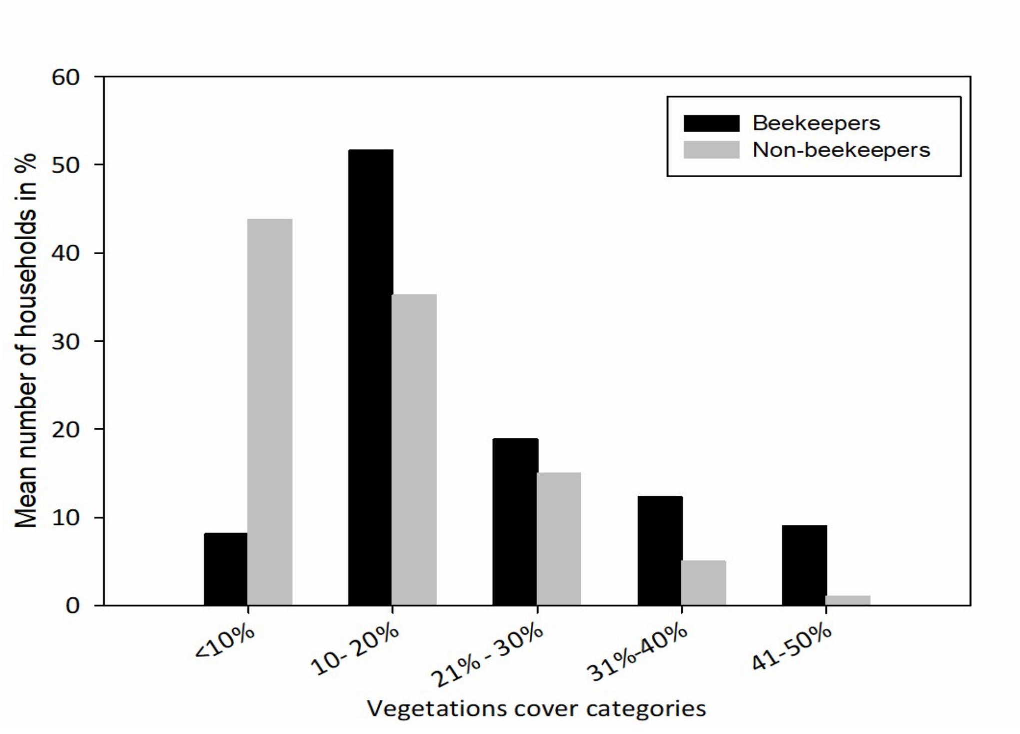

Figure 5. Vegetation cover category of beekeepers and non-beekeepers home-gardens

Hive placement of beekeepers

About 43.3% of Southwest Shewa Zone beekeepers place their traditional beehives under the eaves of their houses. Whereas, 53.7% of beekeepers in West Shewa Zone and 83.3% of beekeepers in Horo-Guduru Wollega Zone place their traditional hives on the trees grown in their home-garden. *Cordia africana* and *Croton macrostachyus* are beekeepers first choice for placing their traditional hives in their home-gardens. Furthermore, 69% of the beekeepers in Horo-Guduru Wollega Zone protect big trees beyond their home-gardens, placing their traditional hives on trees to trap swarms and to produce honey. This may be an important conservation practices of beekeepers to protect honey plants in their surroundings.

Home-gardens floristic composition

Home-garden size of the households ranges from 0.0625 ha to 1.25 ha. The mean total area of home-gardens sampled was 11.25 ha. Trees, shrubs and mass flowering annuals including crops are among the top food resources for honeybees in the study areas. Farmers plant both indigenous and exotic flora species around their home-gardens. The major exotic species planted were Eucalyptus species and to some extent *Grevillea robusta*. The total number of plant species that occur in beekeepers and non-beekeepers home-garden were 117 and 91, respectively. Seventy-eight of the plant species were commonly found in both beekeepers and non-beekeepers home-garden with different abundance and frequencies. The mean number of plant species per home-garden, number of woody species per ha and diversity of floral species are higher in beekeeper's home-garden (Table 1). In agreement with our hypothesis, it was found that the structure and composition of vegetation species, which is characterized by higher diversity and abundance in beekeeper home-gardens compared to non-beekeeper home-gardens.

Table 1 – Comparison of vegetation composition and diversity in beekeepers and non-beekeepers home-garden

Vegetation characteristics	Beekeepers home-garden ± SE	Non-beekeepers home-garden ±SE
Total number of observed species	$117^{a} \pm 8.1$	$91^{b} \pm 6.3$
Mean number of flora species in home-garden	$22.8^{a} \pm 3.2$	$14.2^{b} \pm 2.1$
Mean number of woody flora species in ha	$25^{a} \pm 2.8$	$11^{b} \pm 1.6$
Mean species evenness	$0.73^{a} \pm 0.02$	$0.67^{a} \pm 0.01$
Mean Shannon-Wiener Index (H')	$2.02^{a} \pm 0.40$	$1.60^{b} \pm 0.28$

NOTES: Means with different superscript letters in a row are significantly different at $p < 0.05$.

The higher diversity and abundance of bee flora species observed in beekeeper's home-garden may be associated with the unique indigenous knowledge of beekeepers to purposefully maintain bee flora species in their agroforestry system. These different plant species flower in different seasons, which is important for multi-season honey harvesting.

The relative importance of bee forage species varied with local beekeepers' perception with regards to good bee forage drawing from their observation experience of honeybees visiting the flora of the species. The most common bee forage species, abundantly grown and highly preferred by beekeepers, are *Coffea arabica*, *Vernonia amygdalina*, *Dovyalis caffra*, *Croton macrostachyus*, *Cordia africana*, *Eucalyptus* spp., *Vernonia auriculifera* and others (Table 2). It has been also reported that mass flowering of herbaceous species, such as *Galinsoga parviflora*, *Trifolium* spp., *Guizotia* spp., *Bidens* spp. and *Hypoestes forskaolii* are abundantly grown in beekeeper home-gardens, flowering after the main rainy season (September). These herbaceous species are highly valued by beekeepers for their swarm and honey production (Table 2).

Table 2 – Lists of top woody and herbaceous flora species present at beekeepers and non-beekeepers homegardens

		Beekeepers		Non-beekeepers			
Scientific name of woody species	Local name (Afan Oromo)	Density/ha	Frequency (%)	Density/ha	Frequency (%)	Flowering time	Food source
Coffea arabica	Buna	361.96	41.11	111.82	26.67	After rains	Nectar
Vernonia amygdalina	Ebicha	214.22	57.78	117.69	45.56	Dec. to Feb.	Nectar and pollen
Catha edulis	Jima	208.36	12.00	344.89	20.22	Oct. to Dec.	Nectar and pollen
Ensete ventricosum	Warqe	297.42	62.22	311.38	68.89	Nov. to Jan.	Nectar and pollen
Dovyalis caffra	Koshomi	166.58	11.11	11.56	7.78	Feb. to June	Pollen and nectar
Croton macrostachyus	Bakanisa	134.40	62.22	82.31	52.22	May to June	Pollen and nectar
Eucalyptus camadulensis	Bargamo Dima	111.47	67.78	75.02	23.33	Apr. to June	Pollen and nectar
Cordia africana	Wadeesa	91.56	48.89	57.07	53.33	Sep-Nov	Pollen and nectar
Grevillea robusta	Gravilaa	83.38	32.22	4.27	2.22	Oct. to Dec.	Nectar and pollen
Vernonia auriculifera	Reji	109.87	51.11	79.82	44.44	Jan. to Feb.	Nectar and pollen
Eucalyptus globulus	Bargamo Adi	111.47	27.78	35.38	18.89	Apr. to June	Pollen and nectar
Justicia schimperana	Dhumuga	66.67	24.44	287.11	47.78	Nov. to Jan.	Pollen and nectar

		Beekeepers		Non-beekeepers			
Scientific name of herbaceous species	Local name (Afan Oromo)	Density/m^2	Frequency (%)	Density/m^2	Frequency (%)	Flowering time	Food source
G. parviflora	Kasa	21	52	15	57	All year	Pollen and nectar
Trifolium spp.	Sidisa	36	68	21	51	Sep. to Oct	Nectar
Guizotia spp.	Tufo	8	78	4	58	Sep. to Jan	Pollen and nectar
Bidens spp.	Kelo	12	54	5	43	Sep. to Oct	Pollen and nectar
Hypoestes forskaolii	Dargu	5	46	2	38	Sep to Dec	Pollen and nectar

Discussion

Most home-gardens in the study areas practiced mixed cultivation, with crops associated with trees. Beekeepers of the study areas plant and maintain different plant species in their home-garden to sustain honey production. It is confirmed by other studies that beekeeping in an agroforestry landscape that helps to ensure honey yield, enhance agricultural yield through crop pollination service and promote more tree-planting (Klein *et al*., 2008; Kovacs-Hostyanszki *et al*., 2017; Monique *et al*., 2018). Conversely, non-beekeepers in the study areas intensively grow agricultural crops in their home-gardens, considering that monoculture farming is generating more profit than other farming. However, dependence on monoculture farming, besides depleting the agrobiodiversity resources, has been ineffective in improving the living standards of rural people (Munthai, 1992; Gonthier *et al*.; 2014).

The higher plant species richness found in beekeepers' home-gardens is likely due to beekeepers actively engaged in the retention and protection of trees and shrubs, as they need the plants for traditional hive hanging and honey production. The positive association between agroforestry and beekeeping leads to profitability through increased beekeeping production which enhances the ownership and conservation of agrobiodiversity (Elzaki and Tian 2020). Honey and beeswax are in demand ecological products of beekeeping, in both national and international markets (Amulen *et al*., 2019), that could address beekeepers to promote agroforestry systems (Chanthayod *et al*., 2017, Musinguzi *et al*., 2018). We believe that beekeeping is a strong incentive for rural communities to promote conservation of the natural ecosystem in the face of current growing human population and demand for agricultural land, as described by Munthai (1992).

Beekeepers in the study areas selectively grow some key bee flora species that commonly and abundantly exist in their home-gardens (Table 2). During our vegetation assessments, coffee (*Coffea arabica*) is the dominant species commonly grown in beekeeper's home-gardens. *Croton macrostachyus*, *Vernonia amygdalina* and *Cordia africana* species as major coffee-shade trees, and all the species are important for honey production. It has also been realized by other authors that honey yield is positively related to percentage of coffee trees, as coffee shade trees flowering complement with coffee flowering to enhance honey production (Munyuli 2012). This finding is in accordance with studies from other regions that have highlighted the productive ecological dimension of beekeeping, consolidating agroforestry conservation, family livelihood development, and food security through crop pollination (Njaua *et al*., 2009; Requier *et al*., 2015; Devkota *et al*., 2016).

We found that beekeepers have cumulative empirical ecological knowledge that value plants, and also advocate for the plantation and conservation of trees beyond their home-gardens, assuming that trees are important for their honeybees and honey production. Unlike the non-beekeepers, beekeepers have no desire to cut down trees in their agroforestry plots. The beekeepers' home-garden management system has its important turning point in the history of sustainable agroforestry development (Munthai, 1992; Endalamaw, 2005; Parrotta et al., 2016). Whereas, the direct management of natural vegetation by non-beekeepers is minimal, and their home-gardens are characterized by less vegetation cover and diversity. The idea was confirmed by the fact that non-beekeepers reduce dense tree canopy as tree branches reduce solar radiation to the crops and possibly lower crop yield potential (Mbow *et al*., 2014; Sponsler and Johnson 2015; Mudzengi *et al*., 2020).

In our study, the richness and abundance of plants in beekeeper's home-gardens was considerably higher, compared to that of non-beekeeper's home-gardens. The higher vegetation diversity in beekeeper home-gardens may be associated with the unique indigenous knowledge of beekeepers, to purposefully maintain and protect honey flora species in their agroforestry system (Keasar and Shmida, 2009). High bee flora plant diversity further offers a wider range of flowering phenologies, by providing a continuous floral resource supply across seasons (Benjamin *et al*., 2018). On the other hand, it is important to consider that, higher bee flora diversity may not guarantee higher honey production (Kaluza *et al*., 2017; Benjamin *et al*., 2018). Honey production is also affected by the extent and density in which bee flora occur or their response to weather conditions (Porter-bolland, 2001). Different floral species with higher abundance provide continuous supply of resource-rich flowers at different seasons that encourage sustainable beekeeping and multi-season honey production (Blüthgen and Klein, 2011; Kaluza *et al*., 2017).

We have documented that beekeeper home-gardens promote the growth of trees, shrubs and mass flowering of annul plant species. The annual bee flora species mostly flower following the main rainy season, which is important for survival of honeybees by facilitating surplus honey production. For example, *Bidens* spp. and *Guizotia* spp. have a great cultural value in Ethiopia, abundantly flowering from early September to late November. Although beekeepers are not directly managing them for their honeybees, these annual species benefit beekeeping through increasing colony swarm production and honey yield, and the honey from such plants is widely utilized in traditional brewing practices in Ethiopia (Adi *et al*., 2014). It is further pointed out that annual flora species grown in fallow areas, field margins and roadsides served as excellent sources of pollen and nectar to honeybees (Decourtye *et al*., 2010), but little attention has been paid to this excellent resource so far in Ethiopia.

Conclusion

The present study shows that beekeepers and non-beekeepers differ in terms of home-garden management practices, which translate into differences in vegetation diversity and abundance. Higher bee flora species richness and abundance recorded at beekeeper home-gardens might be associated with the ecological knowledge of beekeepers accumulated over the years to maximize bee products harvesting, which could help to build the trust to favor the preservation of different plant species. The bee forage species abundantly grown and preferred by beekeepers are *Coffea arabica*, *Vernonia amygdalina*, *Dovyalis caffra*, *Croton macrostachyus* and *Cordia africana*. It is necessary to take full advantage of beekeeping to promote a sustainable agrobiodiversity development, and to improve the livelihood of local communities. We therefore recommend the integration of beekeeping in other conservation interventions in Ethiopia, such as community forestry, watersheds and other protected areas managements to achieve sustainable conservation practices. We suggest that necessary financial, technological, and extensional support should be enhanced to align improved beekeeping to any conservation efforts.

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