Buletin Agroteknologi, December 2020, 1(2):60-77
DOI: https://doi.org/10.32663/ba.v1i2.1163

BULETIN AGROTEKNOLOGI
ISSN 2722-7235 (Online media)
https://journals.unihaz.ac.id/index.php/bulgro

Effects of coffee management on Bee Floral Diversity, Honey Yield and Quality: The Case of Gera District, Jimma Zone, South West Ethiopia

Shabu Jemal Abakorma[1]*, Kitessa Hundera[2], Zerehun Kebebew[3]

[1] Department of Forestry, Wollega University, P.O. Box. 44, Gimbi, Ethiopia
[2] Department of Biology, Jimma University, P.O. Box. 378, Jimma, Ethiopia
[3] Department of Natural Resource Management, Jimma University, P.O. Box. 307, Jimma, Ethiopia

Article Information

Received: April 10, 2020
Accepted: October 12, 2020

*Corresponding author
tourshabu@gmail.com

Keywords:
Forest-coffee,
Semi forest coffee,
coffee management,
bee flora diversity,
honey yield,
honey quality

ABSTRACT

This study was conducted to assess the effect of forest management for coffee cultivation on bee flora diversity, honey yield and quality as forest crop products in Gera district. Forest coffee (FC) and Semi-forest coffee (SFC) plots were selected for bee flora assessment. Total of 34 plots (FC = 17, SFC = 17) with plot size 20 m x 20 m (400 m^2) were assessed. Sixty bee flora species belonging to trees (30), shrubs (21) and woody lianas (9) were identified and compared across plots. Results show that more bee flora diversity in FC (2.03) than SFC (1.09) system. Honey yield data was collected from 78 (FC = 52, SFC = 26) beekeepers. The honey yield of FC was higher than SFC system in both high and low production years. The honey production on average was 9.58 kg $hive^{-1}$ for FC and 6.44 kg $hive^{-1}$ for SFC in high production year while 6.5 kg $hive^{-1}$ for FC and 4.24 kg $hive^{-1}$ for SFC in low production year. To assess the honey quality, 6 kg honey samples (FC = 3, SFC = 3) were collected. Six honey quality parameters i.e. moisture, ash, pH, free acidity, electrical conductivity (EC) and total soluble solid (TSS) contents. The biochemical variation in the composition is significantly different ($P<0.05$) in ash content, pH, EC and free acidity when comparing FC with SFC honey samples while the percentage of moisture and TSS contents were insignificant ($p>0.05$). The study revealed that coffee management is associated with a decline in bee flora diversity, honey yields and on top of this, it has implications on honey quality deteriorations. Thus, there is an urgent need for control and monitoring on the expansion of SFC cultivation, which needs immediate conservation measures. Therefore, conservationists have to take actions for biodiversity conservation specially bee flora species diversity and ecosystem services that accompanied with coffee management and FC intensifications.

INTRODUCTION

Ethiopia has huge potentials for beekeeping given the prevailing suitable ecological conditions and floral diversity, thus making it highly suitable for sustaining large numbers of bee colonies and the long established practices of beekeeping. As of 2015, the country is the top producer of honey in Africa while ranking amongst the top ten in the world. It accounts for 23.6% of the continent's total honey production (McGill et al., 2016). Forests have a potential to provide adequate bee-forage in terms of both quality and quantity of nectar and pollen grains. For this reason, beekeeping has also the potential to increase opportunities for forest conservation. When promoted among forest adjacent communities, beekeeping provides reliable livelihood options (Deffar, 1998).

In spite of the suitable ecological conditions and floral diversity, Ethiopia produces about 163,257.42 metric tons of honey in 2007–2011 (McGill et al., 2016), but it has the potential to produce 500,000 tons of honey per year (Ayalew, 2008). The low honey production in Ethiopia can be attributed to the dominantly small-scale operations, which employ traditional methods of production. Moreover, the human encroachments and modification of natural forests, the bees and the plants they depend on, are constantly under threat (Zewde, 1998).

Forest coffee (FC) and honey from specific forest types fetch high premium which are plant crop products. It is several of the widely cultivated forest-derived cash crops (Wiersum et al., 2007). It has acquired significant economic importance in the country as commonly harvested from natural forest (Kilawe & Habimana, 2016) particularly in south westernt (SW) part of Ethiopa. Coffee is one of the most important cash crop plants that farmers need to miximize its production through traditional forest management practices (Gole, 2003). According Hwang et al. (2020) findings, the expansion of areas of intensive management of the coffee forest and the intensification of the consequent degradation of that forest occur in the study area due to rising of coffee prices. These leads to the gradual modifications of FC in to semi-forest coffee (SFC) systems in the course of removal of trees and undergrowth vegetation. The results from the tie-point method suggests that the expansion of areas of intensive management of the SFC.

Thus, frequent clearing of small tree, shrubs and climbers in managed forest has negative effects on structure and composition of communities and species diversity in the forest including regeneration of tree species and coffee itself (Senbeta & Denich, 2006; Gole, 2003). These indicates that there is trade-offs between maximizing production and maintaining the forest and its biodiversity (MEFCC, 2018).

Furthermore, as coffee management continues, the FC could be changed to coffee farms with a few shade trees (Kufa, 2010) resulted in a loss of forest-based woody species including important bee plants once FC are converted into SFC systems (Tadesse et al., 2014). Even coffee management influences coffee population structure and bee-friendly tree resulting in vulnerability of both farmers and the global coffee sector to climate change (Berecha et al., 2010; Imbach et al., 2017). Thus, the high coffee mangement intencties causes a reduction in bee floral diversity, ultimately affecting the quantity and quality of honey as forest crop productions. Therefore, a comprehensive study is needed on the effects of coffee management on bee floral diversity, honey yield and quality of Gera district, as well as SW part of Ethiopia. This was areas of investigations that has been neglected and yet holds significant potential for biodiversity conservation, improve ecosystem services and maintains forest derived crop products.

MATERIAL AND METHODS

Descriptions of study area

The study was conducted in Gera District Jimma Zone of Oromiya Region, South-west Ethiopia. It is located within the longitudinal range 35° 57′ and 37º 37′ East and latitudinal range of 7° 13′ and 8º 56′ North (Figure 1). The mean annual maximum and minimum temperatures are 24.2ºC and 14.2ºC, respectively, and the mean annual rainfall is between 1,880 and 2,080 mm. The major soil types are: Arcisol, Nitisol and Leptosol (Tulu et al., 2014). The remnant forest vegetation at Gera area can be categorized as tropical Afromontane moist forests which have been further classified into: natural forest (virgin and disturbed) and plantation forests (Tadesse et al., 2014). Within this moist, shaded curtain of vegetation, Ethiopia's rich varieties of *Coffea arabica* evolved in a wild. It is one of the remnants of broad leaf moist forest in Ethiopia comprising economically and ecologically important plants (Mohammed & Bekele, 2014). The vegetation cover of the area was estimated to be 56% of the total area.

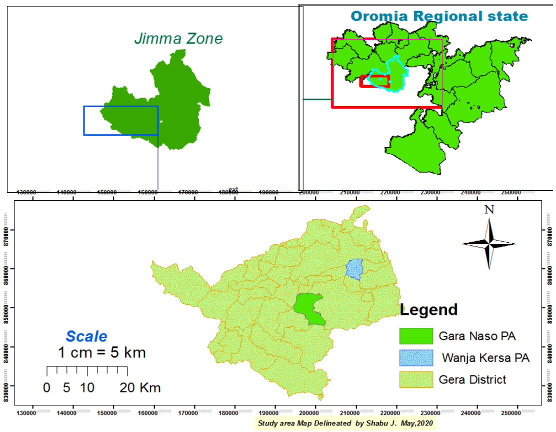

Figure 1 Map and study of location of study sites

Study site selection

For this study, FC and SFC forest with traditional bee keeping activities were considered based on the intensity of forest management practices. Here in FC system, coffee is harvested directly from spontaneously regenerating natural population of coffee. The only management practice in the forest system is access clearing to allow movement in the forest during harvesting time while SFC represents a system in which the forest is managed mainly for coffee productions. The difference here is the intensity of management practices. SFC systems is somewhat apart of semi plantation coffee. SFC plantations clear-cut around the coffee that mainly minimizes the canopy cover leaving only selected shade tree. The selected SFC was about ten years old since they were converted from FC system and FC conversion under smallholder farmers were considered for this study.

Methods of data collection

Both vegetation (bee flora) and socioeconomic data were collected in 2017. Two stage sampling techniques were applied to collect the data. The forest was divided into FC and SFC. Ten (five each) transect lines and a total of 34 plots (17 each) with an area of 20 m x 20 m (Senbeta & Denich, 2006) at a distance of 500 m between transect and within the plots were established to collect the bee flora species data. The starting point of the first transect line was located randomly. In each quadrant, all bee flora species belonging to (trees, shrubs and woody lianas/climbers) growing habits were counted. Because those are most affected species by management for coffee production, even though there is most important herbaceous bee plant are available. Then scientific and local name of identified bee flora species were triangulated (Bekele-Tesemma, 2007; Edwards, 1995; Fichtl, 1994).

Socioeconomic information focusing on household (HH) traditional beekeeping activities alongside with coffee management of each selected *kebele* was randomly selected from *WaBuB* (Forest Management Association) community for interviews. The sample size was determined using the formula following Bartlett et al. (2001). Accordingly, a total of 82 sample HH head were selected from the total bee keepers. Allocations of the number of sample HHs to each study site, was proportional to the number of HH head participated on beekeeping in each selected site, accordingly, 54 HH from FC and 28 HH from SFC were selected for this study. The interviewed households were selected randomly using the lottery approach.

Data analysis

Bee flora species composition and diversity analysis

The abundance of bee flora species defined here as the total numbers of all individuals' bee plant species in all 34 quadrants were estimated for each management system (FC and SFC). The relative frequency of each bee flora species that are top ranked among most important bee flora not among the all surveyed species (according information obtained from focus group discussion (FGD) were calculated.

The Shannon diversity indices for the common bee flora species in the study area were estimated in the two different forest management systems (FC and SFC). To compare bee flora species composition of the two forest types, species richness, Shannon diversity index, and Shannon evenness index were calculated by common biodiversity indices formulations (Dallmeier, 1992; Senbeta & Denich, 2006). Furthermore, the similarity of bee flora species between habitats (FC and SFC) was also calculated by Jaccard similarity coefficient (Jaccard, 1912). To summarize the overall obtained result i.e. bee flora species abundance, frequency, and diversity, the statistical computations were made by Microsoft (excel word 2010) and the result were presented in the form of tables. Furthermore, the distributions of bee flora species between the plots of the two forest types (FC and SFC) were evaluated by using χ^2-tests (chi-square) with SPSS version 23 to test whether the coffee management bring significant effects on bee flora compositions between expected and observed bee flora species recorded. Then, the data were interpreted.

Honey production data analysis

It was analyzed as an average production in (kg hive^{-1}) for both forest types in both high and low production years that obtained from respondents. The data collected were summarized by using descriptive statistical methods (such as frequencies, percentage and graphs) and the obtained results were presented in the form of tables and figures. The statistical computations were made by Microsoft Excel 2010.

Honey quality analysis

The honey quality, which expressed as physicochemical properties of the honey, was determined. During primary data collection, a total of 6 kg of honey samples, (n = 3 kg) from FC and (n = 3 kg) from SFC were considered taking an account as bees can be forage a radius of 6,000 m and an area of 113 km^2 away from their hives (Couvillon et al., 2015). Thus, the two sites were more than 25 km far apart and the forest coverage's were 3,774 ha, 811 ha for FC, and SFC respectively (OC. WaBuB, 2008). Hence, there is no bias of mixing up of the taken honey samples by bees. The 3 x 3 factorial arrangement replicated thrice was used. All collected honey samples were fresh that directly taken from bee keepers (traditional hives) during the peak honey harvesting season (March to April) (Bareke & Addi, 2019) and coded as honey samples from FC site, (FC- HS1, FC- HS2, FC-SH3) from SFC site, (SFC- HS1, SFC- HS2, SFC-HS3) and packed with plastic bottles with their specifications of harvesting days. There were no differences in harvesting seasons of all collected honeys samples. Hence, the physicochemical compositions (moisture content, ash contents, pH, free acidity/FA), electrical conductivity/EC), total soluble solid/TSS) of honey samples were determined according to the Harmonized Methods of the International Honey Commission (HMIHC) and Ethiopian honey quality Standard (Muli et al., 2007; QSAE, 2005). Physicochemical properties (ash contents, pH, FA, EC, TSS) of the collected honey samples except moisture content were analyzed at Department of food Science and Post-Harvest Management, and Natural Resource Management Department at Soil Science laboratories, Jimma University College of Agriculture and Veterinary Medicine. However, the moisture contents of honey samples were estimated by modern Automatic Temperature Compensation versatile refractometer model number *M106401* at farm gate.

The results were subjected to analysis of variance. All statistical computations were made by using SPSS version 23-computer software in order to determine whether there were significant differences in quality existed for selected parameters between honeys harvested from both sites. Differences between means at the 95% ($p \leq 0.05$) confidence level were considered as significant differences.

RESULTS AND DISCUSSION

Demographic characteristics of respondents

From the total of 82 samples HH selected, 78 respondents (92%) were interviewed. The average age of the respondents were 33.68 years that about 69.4% of them lies between 25 to 40 years with average bee keeping experience of 13.84% years and about 80.2% of them acquired habits of beekeeping from their parents while the rest 19.8% of them acquired it through motivation (interest) of themselves (Table 1). In both forest management type's traditional hives are hung up in trees to catch swarms. Bee swarm are colonizing hive naturally. The result showed that different age groups can perform beekeeping and in most cases, people at younger and older ages are more engaged in forest beekeeping.

The common bee flora species in FC and SFC of Gera district

A total of 60 bee flora species belonging to 35 families were recorded for both (FC and SFC) systems (Table 2). This shows that Gera forest contains a high number of bee flora species that are remarkable for honey productions. The recorded bee flora species in present study were higher than the previously reported ones by Senbeta et al. (2013) which revealed that 32 plant species representing 19 families were recorded as being sources of honey bee forage in coffee forest of Ethiopia; Yayu, Bonga, Harenna and Sheko forest. The most common and important bee flora species in the study area according to FGD conducted includes *Schefflera abyssinica, Croton macrostachyus, Olea welwitschii, Pouteria adolfi-friederici, Syzygium guineense, Teclea nobilis, Vernonia amygdalina, Vernonia auriculifera.* This is supported by Berecha et al. (2014) who conducted the same study area states that this bee forage flowers at different times of the year and thus offers a possibility of harvesting honey up to four times per annum in some cases. This agree with Ito (2014) which revealed that beekeepers place their traditional bee hives where those tree species are dominated due to their rich nectar and can produce quality honey.

Table 1 Demographic characteristics of respondents

Demographic characteristics of respondents		No of respondents	%
Level of educations			
	Uneducated	21	26.9
	basic education	31	39.7
	primary education	20	25.6
	secondary educations	6	7.8
Age	Average		
25<40	33.68	50	69.4
bee keeping experience	13.84	26	13.84
habits of beekeeping			
From parents	80.2	61	80.2
motivation of themselves	19.8	15	19.8

This is also in line with Amado (2015) which states those plant species are the dominated tree and shrubs in Gera forest. Therefore, it indicates that the different bee flora species in the study area were contained in different family species. The growth habits of recorded bee flora species in the study area were characterized as tree for example (*Schefflera abyssinica*, *Syzygium guineense)*, shrubs (*Vernonia amygdalina*, *Vernonia auriculifera*), wood liana (*Clematis simensis, Embelia schimperi, Hippocratas africana)* (Table 2). From all the species recorded 30 (50%) were trees, 21 (35%) were shrubs, 9 (15%) were woody lianas (Table 2). Hence, trees were more dominant bee forage followed by shrubs and woody lianas respectively in both forest types. Forest resources in SW are mostly harboring diversified tree species. This is the main reason for the dominance of bee flora species belonging to tree growth habits in the study area. The finding also further supported by Gebrehiwot & Hundera (2014) that states the growth forms of the species recorded from Belete moist evergreen montane forest was dominated by herbs followed by trees.

Table 2 Common bee flora species recorded in of Gera forest

Scientific names	Family names	Vernacular Name (Afanoromo)	Growth Habits	Forest types			
				FC		SFC	
				No.in	RF%	No.in	RF%
Albizia gummifera	*Fabaceae*	*Hambabbeessa*	T	3	17.6	15	64.7
Allophylus abyssinicus	*Sapindaceae*	*Se'oo*	T	9	35.3	4	23.5

Scientific names	Family names	Vernacular Name (Afanoromo)	Growth Habits	Forest types			
				FC		SFC	
				No.in	RF%	No.in	RF%
Apodytes dimidiate	*Icacinaceae*	*Wandabiyoo*	T	9	29.4	2	11.7
Bersema abyssinica	*Melianthaceae*	*Lolchiisaa*	T	65	53.0	34	58.8
Brucea antidysenerica	*Simaroubaceae*	*Qomanyoo*	T	32	64.7	6	29.4
Calpurinaa ureanse	*Fabaceae*	*Ceekaa*	S	15	5.8	0	0
Clausenia anisata	*Rutaceae*	*Ulumaayii*	S	39	58.2	17	47.0
Clematsi smensis	*Ranunculaceae*	*Iddafiitii*	L	17	35.3	6	17.6
Coffeaar abica L.	*Rubiaceae*	*Buna*	S	2829	100	3580	100
Combretum paniculatum	*Combretaceae*	*Baggee*	L	65	47.0	41	58.8
Cordia africana Lam.	*Boraginaceae*	*Waddeessa*	T	15	35.3	5	17.6
Croton macrostachyus	*Euphorbiaceae*	*Makkanniisa*	T	19	53.0	22	70.5
Diospyorus abysssinica	*Ebenaceae*	*Lookoo*	T	11	29.4	1	5.8
Diospyros welwitschii	*Ebenaceae*	*Wantafullasa*	T	6	29.4	0	0
Dombeya torrida	*Sterculiaceae*	*Daannisa*	T	1	5.8	0	0
Dracaena afromontana	*Dracaenaceae*	*Emoo*	S	8	5.8	3	5.8
Dracaena steuderi	*Dracaenaceae*	*Yudo*	T	3	11.8	4	23.5
Ehretia cymosa	*Boraginaceae*	*Ulaagaa*	T	15	41.1	5	23.5
Ekebergia capensis	*Meliaceae*	*Somboo*	T	3	11.7	0	0
Embelia schimperi	*Myrsinaceae*	*Haanquu*	L	104	82.0	39	41
Erythroccoca abyssinica	*Euphorbiaceae*	*Mixoosaree*	S	19	53.0	10	29.4
Fagaropsis angolensis	*Rutaceae*	*Sigluu*	T	1	5.8	0	0
Ficus sycomorus	*Moraceae*	*Harbuu*	T	8	29.4	5	17.6
Galinieria saxifraga	*Rubiaceae*	*Simararuu*	S	50	64.7	24	47.0
Gouania longispicta	*Rhamnaceae*	*Homochiisa*	L	39	47.0	4	23.5
Hippocratas Africana	*Celasteraceae*	*Qawoo*	L	65	64.7	34	58.8
Ilex mitis (L) Radlk	*Aquifolicfae*	*Miyeessaa*	T	1	5.8	1	5.8
Jasminum abyssinicum	*Oleaceae*	*Hidda Ilchilmee*	L	202	94.1	31	64.7
Justicia schemperiana	*Acantaceae*	*Dhummuugaa*	S	356	53.0	70	47.0
Landolphia buchananni	*Apocynaceae*	*Yeeboo*	L	265	82.3	47	64.7
Lepidotrichilia volkensii	*Meliaceae*	*Goraa*	S	41	47.0	27	29.4
Macaranga capensis	*Euphorbiaceae*	*Wongo*	T	6	29.4	0	0
Maesa lanceolata	*Myrsinaceae*	*Abbayyii*	S	3	17.6	0	0
Maytenus gracilipes	*Celastraceae*	*Kombolcha*	S	611	88.2	75	70.5
*Millettia ferruginea****	*Fabaceae*	*Askira*	T	17	23.5	43	70.5
Olea capensis L.	*Oleaceae*	*Gegema*	T	49	64.7	13	29.4
Olea welwitschii	*Oleaceae*	*Baya*	T	16	58.8	4	17.6
Oxyanthus speciosus	*Rubiaceae*	*Imbrango*	T	11	41.1	36	35.3
Phoenix reclinata	*Arecaceae*	*Meexxii*	T	1	5.8	0	0

Scientific names	Family names	Vernacular Name (Afanoromo)	Growth Habits	Forest types			
				FC		SFC	
				No.in	RF%	No.in	RF%
Pittosporum viridiflorum	*Pittosporaceae*	*Soolee*	S	12	35.3	4	5.8
Polyscias fulva	*Araliaceae*	*Kariyo*	T	2	11.7	2	11.7
Pouteria adolfi-friederici	*Sapotaceae*	*Qararoo*	T	2	11.7	4	17.6
Premna schimperia	*Lamiceae*	*Qoraasuma*	S	12	11.7	2	11.7
Prunus africana	*Rosaceae*	*Oomoo*	T	2	11.7	5	23.5
Psidium guajova	*Myrtaceae*	*Zaytuuni*	S	0	0.0	1	5.8
Phytolacca dodecandra	*Phytolaccaceae*	*Handode*	L	0	0.0	2	5.8
Rhamnus prinoides	*Rhamnaceae*	*Geeshoo*	S	6	11.7	0	0
Rytignia neglecta	*Rubiaceae*	*Mixoo*	S	130	82.3	27	58.8
Sapium ellipticum	*Euphorbiaceae*	*Bosoqa*	T	1	5.8	0	0
Schefflera abyssinica	*Araliaceae*	*Bottoo/Gatamaa*	T	34	88.2	8	47.0
Senna septentrionali	*Caesalpiniaceae*	*Sanaamakii*	S	0	0.0	12	5.8
Solanecio mannii	*Asteraceae*	*Hamiitiballoo*	S	3	11.7	1	5.8
Solanecio gigas	*Asteraceae*	*Xomboroqo*	S	14	5.8	8	17.6
Syzygium guineense	*Myrtaceae*	*Baddeessaa*	T	54	76.4	9	29.0
Teclea nobilis	*Rutaceae*	*Mixiriti*	T	27	53.0	16	41.1
Trema orientalis	*Ulmaceae*	*qa'ee*	S	6	17.6	4	17.6
Urerahypselo dendron	*Urticaceae*	*Laankessaa*	L	7	23.5	2	17.6
Vepris dainelli ***	*Rutaceae*	*Hadheessa*	T	14	35.3	5	5.8
Vernonia amygdalina	*Asteraceae*	*Ebbicha*	S	3	12.0	61	82.0
Vernonia auriculifera	*Asteraceae*	*Reejjii*	S	33	41.1	99	64.0

*Note:-T = tree, S = shrubs, L = Liana, *** = endemic, No.in = number of individual, RF = relative frequency (absence or appearance per plot) (*Azene et al., 1993; Richard, 1994; Edward, 1989*; www.theplantlist.org*

Bee flora species abundance and diversity in both forest management systems (FC and SFC)

Bee flora species abundance

The survey result showed that total number of bee flora species was higher in FC (57) system than SFC (50) system (Table 2). It indicates that the coffee forest has high flora resources. According to Gole et al. (2008), coffee forests have to be viewed as a complex mosaic of different plant communities. However, in both forest management systems there were unique bee flora species recorded. In FC system, about 16.6% floral species were identified and about 5% of them were exclusively found in SFC sample plots. Nevertheless, except *Fagaropsis angolensis* and *Dombeya torrida*, the rest species were observed outside of the plots of SFC site indicated that could be grown in forest type, while only *Senna septentrionali* bee forage species was not observed in FC system. From the result, the dominant bee flora tree species for FC includes *Syzygium guineense, Olea welwitschii*, and *Schefflera abyssinica.* The finding is in line with Amado (2015) which states that those are dominant species in the tree layer of plant community types in Gera forest. According to Alemu (2012), the dominant tree species here in SFC includes *Albizia gummifera*, *Croton macrostachyus* and *millettia ferruginea*. The finding is similar to Berecha et al. (2014) that states that those tree species are dominant in SFC site for their preferences of coffee shade. Regarding the abundance of bee forage, most of individual bee plant species recorded in FC site was *Coffea arabica, which* was about 53.06% of the total species, while 80.34% (Table 3) of was *Coffea arabica* for that of SFC site. This indicated that almost all bee flora recorded in SFC site was *coffea* dominated. The farmers in SFC systems plants coffee seedling to fill the space and removing coffee seedling where it was high in the plot even now looks like semi plantation coffee form while such management actions were not common in FC system. Thus, coffee domination indicates that the high coffee management intensities in SFC system for coffee cultivation were very high. That is why coffee represents a much greater of total flora species in semi-forest coffee.

Furthermore, there were bee flora tree species debarking (Figure 2) observed in SFC management system during plot inventory. This is the reason why important bee flora was reduced in SFC system than FC systems. This showed that forest derived coffee corps became high prices in world market that is why farmers more intensified the forest to coffee framings by reducing shades even changing it in to semi plantation coffee systems. This showed that continued conversion factors for coffee cultivations linked with declining of bee forages abundance and its composition. Hence, the result clearly showed that FC land conversion and high coffee management affects the abundance of bee flora.

Table 3 Bee flora growth habit and coffee dominance compared with other bee plant

I	*bee flora Growth habit*		Species recorded	%
	Tree		30	50
	Shrub		21	35
	Woody liana		9	15
II	*Regarding the % coffee dominance compared with other bee plant*			
	Site	Number of individual Coffee	total bee plant	%
	FC	2829	5331	53.06
	SFC	3580	4455	80.3

Relative frequency

From the survey result complementary bee plants, the most ten leading species interims of their significances in honey productions due to their high floral nectars, were identified (Table 4). Even honey products are named after these species. Like Butoo from *Schefflera abyssinica* (white honey), Ibicha from *Vernonia amygdalina* (black honey), makkannisa from *Croton macrostachyus* and keraro honeys (light red) from *Pouteria adolfi-friederici* are recently most common honey types of the Gera district. Even if coffee was highly frequent in both forest types and important bee forage but did not included here because of its bloom not honey harvested commonly after this species. This is supported by Tulu et al. (2014) who conducted research at Gera states that those bee forage flowers at different times of the year and thus offers a possibility of harvesting honey up to four times per annum in some cases.

Figure 2 Bee flora debarking observed in SFC system

Schefflera abyssinica was top ranked in FC site and most dominant bee tree while *Vernonia amygdalina* was top ranked SFC in site and most dominant bee forage. Thus, the frequent removal of undergrowth vegetation allows high in recovering of *vernonia species* in SFC systems. This showed that coffee management effects on very important beloved tree in the entire ecosystems.

Table 4 Relative frequency of top ranked bee flora of FC and SFC sites

No	Bee flora top ranked order	Forest types					
		FC			SFC		
		No. Individual	Relative frequency	Rank	No. Individual	Relative frequency	Rank
1	*Schefflera abyssinica*	34	88.2	1st	8	47	4th
2	*Croton macrostachyus*	19	53	5th	22	70	2nd
3	*Pouteria adolfi-friederici*	2	12	9th	4	17	8th
4	*Syzygium guineense*	54	76.4	3rd	9	29	7th
5	*Vernonia amygdalina*	*3*	12	9th	61	82	1st
6	*Vernonia auriculifera*	*33*	41.1	7th	99	64	3rd
7	*Olea welwitschii*	16	58.8	4th	4	17	8th
8	*Teclea nobilis*	27	53	5th	16	41	5th
9	*Vepris dainelli*	12	35.3	8th	4	5	10th
10	*Embelia schimperi*	104	82	2nd	39	41	5th

Bee flora species diversity in relation to both forest types

The computed Shannon diversity for bee flora in FC system (2.03) was higher than that of SFC system (1.09) (Table 5). Higher diversity in FC management system is an indication of the site had more plant species, since a greater variety of species allows for greater species interactions, while the continued FC conversion activities reduces the diversity of bee flora species resulting in coffee dominated in SFC systems. The finding is similar to Senbeta & Denich (2006) which state that low Shannon diversity in the SFC systems is an indicative of the high abundance of one or a few species. Hence, the low diversity of the SFC system can be attributed to a large number of *Coffea arabica* individuals. According to Gole (2003), managed forests (SFC) diversity decreases with duration and intensity of management, the lowest being in the Semi-Forest-Plantations. These findings imply that the high intensive management in SFC for coffee production reduced bee flora diversity thus, conservation of forest tree species is a viable sustainability strategy from a biodiversity point of view, and that initiating smallholder beekeepers of FC management system is a viable for conserving biodiversity to halt it from further intensifications. In this study, species richness (S) was computed as, the observed number of bee flora species for each forest management system (Table 5). As a result, among identified 60 bee flora, the numbers of species observed in all plots of the FC were 57, which were relatively higher than those in that of SFC (50) system.

Table 5 Shannon diversity index for bee flora species in FC and SFC management systems

Bee flora diversity Index	Forest types	
	FC	SFC
Number of individuals (N)	5331	4455
Observed number of species (S)	57	50
Shannon diversity (H')	2.03	1.09
Shannon evenness (E)	0.502	0.279
Jaccard's similarity coefficient	⟹ 0.29 ⟸	
X^2 test	1747.289	
p -value	0.001	

The reason why FC was higher bee flora species richness and diversity than SFC is due to the less intensity of its managements. This is supported by Senbeta & Denich (2006) which revealed that the dominance of species rich families rank also changes when the FC is converted into SFC system, reflecting the targeted removal of species. Thus, in this study 92.5% (Table 6) respondents from FC management system confirms that there was only once per year clearing under coffee which is only during coffee collecting seasons. Meanwhile there was less human interventions and this creates good opportunity from natural regeneration of species as well as good vegetation cover; this may be the reason for higher species richness and diversity in FC system while, in SFC system about 73.9% (Table 6) responded that clearance under coffee were twice. In addition to this filling the gap by planting coffee seedling in SFC were familiar. Thus, there were repeated removals of undergrowth vegetation to improve coffee productions consequently lower diversity of bee flora here in this finding. According to Senbeta & Denich (2006), higher value of Shannon diversity indices (H') in FC area, and noted that FC have more species and important for the conservation of important plant genetic resource including wild coffee species. Furthermore, altitudinal differences of FC and SFC may cause also in species difference. Moreover, the main problems regarding in honey production in management systems are summarized in the following table.

Table 6 The major problems of honey production of the district (FC and SFC sites)

No	Problems	Forest management sites		Rank in %
		FC (%)	SFC (%)	
1	Pests and predators	(54) 96.1	(24) 92.3	High
2	Migrations and absconding	(32) 57.4	(20) 80.7	High
3	Lack of bee forages	(18) 32.1	(11) 42.3	Medium
4	Chemical and pesticides	-	(8) 29.1	Medium
5	FC conversion	(7) 12.9	(9) 34.6	Low to
	honey trunk disappearance	50 (92%)	21(95.8%)	medium
				95%
	Intensity of management			
	once per year	50 (92.5%)	3 (12.5%)	
	Twice	4 (7.4%)	17 (73.9%)	

This study is in line with Dinka & Kumsa (2016) and Gebretsadik & Negash (2016) that revealed that developing countries face different constraints in beekeeping sub-sector such as; races of honey bees, honey bee diseases, predators and parasites, the loss of bee floras. Moreover, the similarity coefficient between the sites shows low similarity values (Jaccard's similarity coefficient = 0.29) (Table 5). This is that the both forest management systems had low in similarity of bee floral species compositions for both forest management systems.

Likewise, bee flora compositions were varied with the source forest management types (X^2 = 1,747.289, $p<0.001$) and between the two management systems (Table 5). There were significantly different from observed and expected value related to bee flora sources of forest management systems. Each of these types of relationship involves some form of differences between the observed and expected values. This indicates that FC provides more bee flora than SFC management systems or the conversions of FC activities and coffee management arose negative significant effect on bee flora compositions.

Survey data results

Features of forest beekeepers and trends of honey productions of the district

From the survey data result the average numbers of traditional beehives owned for individual HHs from last five years were ranged from 47.8-62.72 for FC and 44.84-24.36 (Figure 3) for SFC management systems. The aim of this survey was to state the situation of traditional honey production system with increasing of the coffee management intensities.

From the results, the average traditional hives of HHs of FC system is increasing trend where as it was highly decreased in SFC. Even if the hive hanging may has a risk of falling on tree cause death, the preference of SFC system for honey bee keeping became decreasing and the problem may be due to FC conversions, that is why the farmers were focusing on coffee cultivations. Furthermore, trees and lianas that are used in traditional hive making were highly decreased. This in turn causes the decrease in bee colonies and honey production from time to time. Thus, most of the respondents reasoned out that pests and predators, migrations and absconding followed by FC land conversion and high level of its management intensity are responsible for the observed decreases (Table 6). On the other hand, about 95 % (Table 6) responded that honey trunk or 'holka' disappeared consequently there were no addition of a new swarm of bees to forest. This also agree with JICA (2005) who states that honey productivity in SW has been reportedly declined due to deforestation, forest conversion and trunk honey or 'Holka' disappeared. This finding revealed that the trends of honey productions and bee colonies were decreasing from time to time in both forest types but for SFC system the situations are more observed (Figure 4).

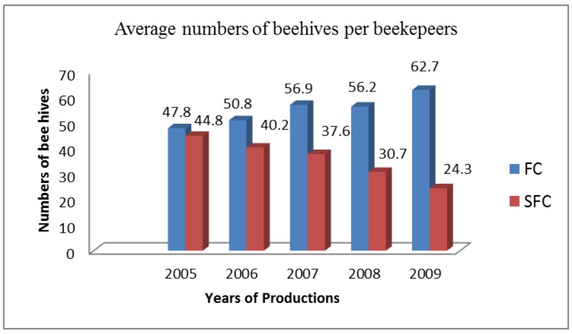

Figure 3 Numbers of average traditional hives per beekeepers of both sites

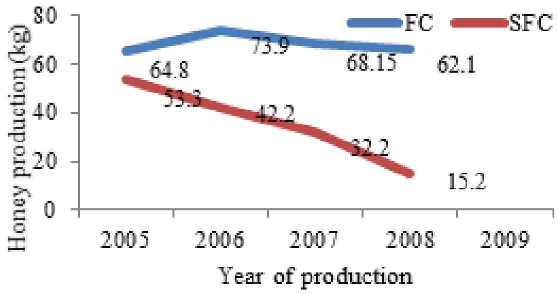

Figure 4 Trends of honey productions

From the results, it can be seen that the total average annual honey productions (very valuable forest derived plant crop products) per beekeepers were in a decreasing trend in both sites, except 2006 production year for FC site that showed higher which was 73.9 kg/beekeeper (Figure 4). This results are greater than previously reported in this area by JICA (2005) which states that about 34 kg of honey may be produced in a high production year by one HH for that of beekeepers at FC management system but, less results were recorded for beekeepers at SFC management system which was (32.2-15.2) kg (Figure 4) annually for that of the last two years than previously reported one, in this finding. Thus, continued observed declining in honey productions of SFC management systems may be due to the forest is becoming less preferable for beekeeping activities, which may accompany with the intensity of SFC management systems that resulted declining of bee flora resources and bee colonies.

Current honey production status

Numerically, the honey yield of FC was higher than SFC system in both high and low production years. Thus, the obtained data result showed that honey yield was an average 9.58 kg hive^{-1} for FC and 6.44 kg hive^{-1} for SFC in high production year while 6.5 kg hive^{-1} for FC and 4.24 kg hive^{-1} for SFC in low production year (Figure 5).

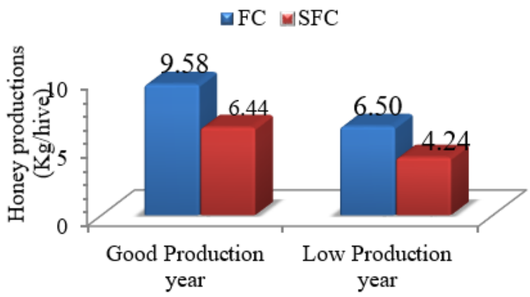

Figure 5 Current honey production status of both FC and SFC systems

The finding is supported by (Tadesse et al., 2014) who states that land use changes decreased the amount of forest honey production because of loss of native bee forage and bee hive supporting tree and shrub species. Findings of present study indicated that the rate of FC conversions is increasing from time to time to improve coffee productions, of which about 76.9% (Table 7) of respondents argued that because of coffee price increases and the remaining are due to population increases, shortage of land and followed by ownerships problems. Surprisingly, one recent study by Mitiku et al. (2018) revealed that coffee intensification process does not result in improved coffee productivity nor in increased profits and they found that less intensive coffee production and conservation of forest tree species is a viable sustainability strategy even from an economic point of view. So, if further coffee intensifications did not add up on economic profitability as the same times decreasing of forest honey production because of FC conversions and high coffee management, therefore it requires urgent conservation measures.

Table 7 The main driving forces of FC conversions and shade tree protection for bee forage during management intensifications by forest owners.

Causes	Rsp.	%
increasing Coffee price	60	76.9
population increases	10	12.8
ownerships problems	5	6.4
Other	3	3.8
shade tree selection criteria		
Selects bee tree	63	80.7
not considered	15	19.2

Note: Rsp. = respondents

Regarding to shade tree selection criteria for coffee and bee keeping aspect, about 80.7% (Table 7) respondents selects and protects those bee forage species. The finding is similar with Hundera (2013) which revealed that farmers protect those plant species either for bee hive installations or a large amount of its flower resources in their coffee forest even if these species are not good for coffee shade. Even if the respondents argued that they protect the bee tree, the result from fieldwork justified that the reductions of important bee forage species in SFC system were very high.

Physicochemical characteristics of honey

The physicochemical properties of honey play an important role in determining the honey quality and can be affected by bee floral origin and its diversities including the purity of environment. Thus, the present study dealt with the major physicochemical properties of honey in relation to whether the conversions of FC to SFC and coffee management systems and diversity of bee floral differences related to quality aspects as indicated below.

The minimum, maximum and average of moisture contents of the honey from both forest management systems analyzed in the present study were indicated (Table 9). The percentage of moisture content of the honey samples obtained from the study area ranged from 18.1-22.3 with a mean value of 20.03. The moisture content of honey from FC site ranges from 19.2 - 22.3% with mean 20.5 (n=3), while honey sample from SFC site ranges 18.1 - 22.3% with mean 19.5 (n=3). There was no significant difference (P>0.05) between the both forest management systems in percentage of moisture content of sample honey collected (Table 9). The finding is in line with Getu & Birhan (2014) which states that no significant differences were observed in % of moisture content between honey samples obtained from the different locations in the same study area. However, the mean average moisture content of SFC is slightly lower indicates that good quality. Two samples exceeded (22.3%) the limit allowed by the Codex and Council of the European Union (EU) of <21% from both sites indicates that the honey was low quality interims of % of moisture content. But all average honey samples are within acceptable range (20.03%) which is similar finding with Getu & Birhan (2014) that revealed that the overall average contents of analyzed honey around Gonder was 20.6%.

Table 8 Summary of physicochemical properties of honey from Gera district both Forest types

Parameters	FC & SFC sites (N =6)				Standard Range	
	Mean	SD	Min.	Max.	Ethiopian	World
Moisture (%)	20.03	1.800	22.30	18.10	21	18 – 23
Ash (%)	0.31	0.067	0.49	0.19	0.01-0.6	0.25 – 1
pH	3.89	0.272	4.36	3.65		3.2 - 4.5
Free Acid (meq kg^{-1})	24.79	4.630	31.20	17.60	40/kg	5 – 54
Electrical conductivity (mS cm^{-1})	0.223	0.038	0.29	0.17		
Total soluble solids (%)	70.35	4.006	73.90	63.00		

Table 9 Physicochemical characterizations of honey from Gera district (both Forest types)

Parameters	FC site(n=3)				SFC site(n=3)				Standard Range		p-value
	Mean	SD	Max	Min	Mean	SD	Max	Min	ES	World	
Moisture (%)	20.5	1.37	22.3	19.2	19.5	2.1	22.3	18.1	21	18 – 23	0.220
Ash (%)	0.24*	0.086	0.39	0.19	0.39*	0.139	0.49	0.19	0.01-0.6	0.25 – 1	0.039
pH	3.72*	0.087	3.87	3.67	4.07*	0.29	4.36	3.87		3.2 - 4.5	0.003
F.A. (meq kg^{-1})	28.53*	2.11	31.2	25.6	21.06*	3.11	27.6	17.6	40/kg	5 – 54	0.000
E.C. (mS cm^{-1})	0.193*	0.024	0.23	0.17	0.253*	0.020	0.29	0.23			0.000
T.S.S. (%)	69.56	5.78	73.9	63	71.13	2.2	73.4	63			0.684

Note: *significant difference at (p<0.05), F.A. = Fatty acid, E.C. = Electrical conductivity, SD=standard deviation; TSS=total soluble solid, ES =Ethiopian Standard

High moisture content increases the probability risk that the honey will ferment upon storage. The final water content of a honey sample depends on a number of environmental factors during production such as weather, humidity amounts inside the hive, nectar conditions and treatment of honey. Here in FC site, the distance between '*mume'* and their residential area was far away and the harvested honey was transported with horseback (traditional). In addition to this, the environment has very high humidity that contribute to moisture content of honey which directly related to postharvest quality loss. The study result was similar to Muli et al. (2007) who conducted research in rural areas of Kenya, which states that the final water contents of honey samples depends on a number of environmental factors such as weather and amount of humidity in the hives. Furthermore, Sereia et al. (2011) revealed that the highest moisture content observed in the organic honey was due to the climatic conditions because the air saturation and the big nectar flow that happens after the rains. All the honey samples (n=6) analyzed for moisture had higher moisture content than the acceptable minimum limit, an indication that most farmers harvest ripened capped honey and that generally honey was harvested at peak harvesting season.

The ash content of the honey samples obtained from the study area ranged from 0.19-0.49 g with a mean value of 0.31 (Table 8). The average ash content of honey collected from FC (0.24%) numerically lower than the average ash content of honey samples collected from SFC (0.39%) (Table 9), there is a significant difference (p<0.05) in ash content between honey samples obtained from the two forest management types. The ash content of all the analyzed honey samples fell within the 0.01-1.2% range reported by QSAE (2005) and 0.6% maximum limit reported by the International Honey Commission (Bogdanov et al., 1999) the mineral content of honey. Thus, the mineral content of honey is related to the geographical and botanical origin of the honey. This suggestion stated that ash content of honey depends on the material contained in the pollen. In this finding, within the same geographical locations and same harvesting seasons, there was difference observed in both forest management systems. According to Abu-Tarboush et al. (1993), honey normally has low ash content and this depends on the floral type used by bees. This may be related to diversity of bee flora species or system of forest coffee management. This is further supported by L. R. Silva et al. (2009) which revealed that ash represents a direct measure of the inorganic residues left after honey carbonization, and this variability in the ash content can be explained by the floral origin of the honey.

The pH of sampled honey as a factor of FC conversion and its interaction is presented in Table 8. From the result, the value of honey pH showed that a significant difference (p<0.05) between honey harvested from FC and SFC management systems. Thus, the mean pH values of honey samples from FC were 3.72 which were lower than honey harvested from SFC (4.07). The variation may be due to diversified bee floral sources. This finding is in line with Shahnawaz et al. (2013) which states that floral difference may also cause the ranges of pH. There is a direct relationship between ash contents and pH, having higher ash contents result, higher pH value according to Arcot & Brand-Miller (2005) findings which is supported by this study. i.e. honey samples from SFC shows less acidic. Here honey from FC site is better than honey from SFC interims of the result of pH value, which shows more acidic. This indicates that the low pH of honey inhibits the presence and growth of micro-organisms and makes honey compatible with many food products in terms of pH and acidity (Areda, 2015). However, both honey samples ranged between 3.65 to 4.36 and an average of 3.89 (Table 8), which is the international acceptable pH value of honey. The finding is similar to that of Gebru (2015) who conducted research at Eastern Tigry region revealed that the average pH of honey was 3.86. Furthermore, the finding is similar to that of honey from Luso region (Portugal) (L. R. Silva et al., 2009) revealed that the mean pH value of honey was 3.88.

The electrical conductivity (EC) is a good criterion of the botanical origin of honey and thus is very often used in routine honey control. The EC level of honey samples analyzed in the present study, ranged from 0.17 to 0.29 $mScm^{-1}$ with a mean value of 0.223 $mScm^{-1}$ (Table 8). The mean conductivity of honey samples obtained from SFC (0.253 $mScm^{-1}$) system was significantly higher ($p<0.05$) than that obtained from FC (0.193 $mScm^{-1}$) system (Table 9). The conductivity depends on the mineral content of the honey; the higher mineral (ash) content, the higher the resulting conductivity. Here in these findings, high ash content was recorded in honey from SFC system and conductivity as well. According to A. D. S. Silva et al. (2013) the differences in EC of the various honeys are attributable to their differing geographical and botanical origins; this can serve to characterize different varieties of honey. This is also supported by Bogdanov et al. (1999). In a given geographical area, ash and acidity were useful for determining the botanical origin of honey. The best indicators for discrimination of honey with varying geographical origin were pH and electrical conductivity as a function of changes in the concentration of honey.

The free acidity level of honey samples analyzed in the present study, ranged from 17.60 to 31.2 meq kg^{-1} with a mean value of 24.79 meq kg^{-1} (Table 8). The mean acidity of honey samples obtained from FC (28.53) system was significantly higher ($p<0.05$) than that obtained from SFC (21.06) system (Table 9). This variation may be due to difference of organic acids present in honey. Most of organic acids are present in honey in the form of esters, which contributes to its characteristic flavor and aroma. Some of the acids are introduced into honey via the nectar. The variation here in this finding may also be related to the difference of diversity of bee flora resources. This was agree with Yadata (2014) and Couvillon et al. (2015) which revealed that the acidity of any honey is directly related to the floral sources that created. Thus, the highest average acidity recorded was due to the diversity of honey flora sources. The result supports each other, hence the low pH value (high acidity) recorded in the FC system and high pH value (low acidity) recorded in the SFC system. However, Muli et al. (2007) reported that the considerable variation in the amount of acids in honeys perhaps reflects the time required for nectar to be completely converted into honey under differing conditions of the environment, colony strength and the sugar concentration of the nectar of floral sources.

The results of the TSS are presented in Table 8. It was ranged from 63.0 to 73.9% with a mean value of 70.35% (brix). Honey from the SFC (71.13) site had somewhat higher TSS, whereas that from the FC site had the lower percentage of TSS (69.56). In a forest management system, there was insignificant ($P > 0.05$) deference in TSS of total honey samples. Thus, the variation may be related to the botanical origin of honey or diversity of bee flora (Table 8). According to Bogdanov (1999), analysis of TSS can yield the valuable information about the floral origins and can also combines fructose and sugar content should not be less than 60 g/100 g for blossom honey (Table 9). Therefore, the analyzed honey is within an acceptable range. In general, among the determined parameters i.e. (pH, ash content, electrical conductivity and free acidity) of honey sample from SFC shows decline in quality than honey samples from FC site compared with Harmonized Methods of the International Honey commission and Ethiopian honey quality Standard (Bogdanov, 1999; QSAE, 2005), while only moisture and TSS contents were not influenced or did not shows significant differences by either bee floral diversity sources or FC conversion coffee management consequences. Furthermore, about 29.1% (Table 6) respondents' uses chemical and pesticide application in their SFC management systems while such activities were not observed in FC. These activities may bring effect on bee flora species and bee communities that accompanied with lower honey productions and quality.

CONCLUSION AND RECOMMENDATIONS

The present study provides preliminary information on the effects of coffee management on the diversity of bee flora, honey yield and quality. It clearly indicated that coffee forest management and intensification to SFC has negatively affected bee flora diversities. The study designated that the rate of coffee management is increasing from time to time, and increasing coffee price is as main driving forces. Thus, the increasing management intensity of SFC systems results in lower bee flora compositions and diversity. Furthermore, honey production of south westernt part in general and Gera district in particular is decreasing trend. This is shown to be related to FC conversion factors and preference of SFC system for honeybee keeping became diminishing. These finding implies that conservation of bee floral species of FC is a viable sustainability strategy from a biodiversity point of view, and that initiating smallholder beekeepers is a feasible activity in the arena of conservations and as well as a key for improving ecological services. Moreover, the intensification of FC conversion activity relates to the declining of honey quality. The biochemical variation in the composition is significantly different ($P<0.05$) in ash content, pH, EC and free acidity when comparing FC with SFC honey samples while the percentage of moisture and TSS contents were insignificant ($p>0.05$) which may indicate that both were not influenced by either bee floral diversity sources or FC conversion consequences. Generally, the study revealed that FC conversion to SFC (i.e. coffee management effects) are associated with declining bee flora diversity, honey yields and on top of this. It has implications for honey quality loss of SFC systems. Thus, there is an urgent need for control and monitoring on the expansion of SFC cultivation, which needs immediate conservation measures. The finding implications not just for total honey yield but also for honey quality itself are intriguing. It is required to values, grade, and conserved body made difference in terms of the price beekeepers are paid for higher quality honey. Therefore, conservationists have to take actions for biodiversity conservation specially bee flora species diversity and ecosystem services that accompanied with coffee management and FC intensifications. Further research has to be conducted on the effect of coffee management on honey quality and ecosystem services.

ACKNOWLEDGMENT

All praise is due to Allah, the '*Rubb'* of the worlds; exalted be He, I praise Him and thank Him who gave me the mind to think and the ability to do this work at all. We want to thank Jimma University College of Agriculture and Veterinary Medicine for financial support for this study. Our great thanks also go to Mr. Chala Gawe for his professional support especially for laboratory work in honey quality test.

REFERENCES

Abu-Tarboush, H. M., Al-Kahtani, H. A., & El-Sarrage, M. S. (1993). Floral-type identification and quality evaluation of some honey types. *Food Chemistry*, *46*(1), 13–17.

Alemu, A. (2012). Narrating local identity among the Southwestern Oromo of Ethiopia : Case of the Jimma and Gera. *African Study Monographs*, *33*(1), 17–47.

Amado, B. B. (2015). *Floristic Composition and Vegetation Structure of Gera Moist Afromontane Forest, of Oromia Regional State, Southwest Ethiopia*. Addis Ababa Universty.

Arcot, J., & Brand-Miller, J. (2005). *A Preliminary Assessment of the Glycemic Index of Honey*. http://www.rirdc.gov.au

Areda, B. T. (2015). Honeybee production and honey quality assessment in Guji Zone, Ethiopia. *Journal of Food Processing and Technology*, *6*(11), 512.

Ayalew, K. (2008). *Establishment of apiculture data base in Ethiopia*.

Bareke, T., & Addi, A. (2019). Bee flora resources and honey production calendar of Gera Forest in Ethiopia. *Asian Journal of Forestry*, *3*(2), 69–74.

Bartlett, J. E., Kotrlik, J. W., & Higgins, C. C. (2001). Organizational Research: Determining Organizational Research: Determining Appropriate Sample Size in Survey Research Appropriate Sample Size in Survey Research. *Information Technology, Learning, and Performance Journal*, *19*(1), 43–50.

Bekele-Tesemma, A. (2007). *Useful trees and shrubs of Ethiopia: Identification, Propagation and Management for 17 Agroclimatic Zones* (B. Tengnäs, E. Kelbesa, S. Demissew, & P. Maundu (eds.)). Relma in ICRAF Project.

Berecha, G., Aerts, R., Roldan-ruiz, I., & Honnay, O. (2010). *Anthropogenic Forest Fragmentation and Management A Threat to the Wild Coffee Gene Pool ? 25*(1).

Berecha, G., Aerts, R., Vandepitte, K., Van Glabeke, S., Muys, B., Roldán-Ruiz, I., & Honnay, O. (2014). Effects of forest management on mating patterns, pollen flow and intergenerational transfer of genetic diversity in wild Arabica coffee (Coffea arabica L.) from Afromontane rainforests. *Biological Journal of the Linnean Society*, *112*(1), 76–88.

Bogdanov, S. (1999). *Honey quality and international regulatory standards : review by the International Honey International honey standards are specified in a European Honey*. *80*(2), 61–69.

Bogdanov, S., Lüllmann, C., Martin, P., von der Ohe, W., Russmann, H., Vorwohl, G., Oddo, L. P., Sabatini, A. G., Marcazzan, G. L., Piro, R., Flamini, C., Morlot, M., Lhéritier, J., Borneck, R., Marioleas, P., Tsigouri, A., Kerkvliet, J., Ortiz, A., Ivanov, T., … Vit, P. (1999). Honey quality and international regulatory standards: Review by the international honey commission. *Bee World*, *80*(2), 61–69.

Couvillon, M. J., Riddell Pearce, F. C., Accleton, C., Fensome, K. A., Quah, S. K. L., Taylor, E. L., & Ratnieks, F. L. W. (2015). Honey bee foraging distance depends on month and forage type. *Apidologie*, *46*(1), 61–70.

Dallmeier, F. (1992). *Long-term monitoring of biological diversity in tropical forest areas : methods for establishment and inventory of permanent plots*. Unesco.

Deffar, G. (1998). *Data Collection and Analysis for Sustainable Forest Management in ACP Countries - Linking National and International Efforts*.

Dinka, J., & Kumsa, T. (2016). Factors Affecting Honey Production in Ambo District, West Shewa Zone, Oromia Regional State, Ethiopia. *International Journal of Economics and Business Management*, *2*(2), 170–182.

Edwards, S. (1995). *Flora of Ethiopia and Eritrea vol. 2, Part 2*. Uppsala Addis Ababa University.

Fichtl, R. (1994). *Honeybee Flora of Ethiopia*. Margraf Verlag.

Gebrehiwot, K., & Hundera, K. (2014). Species composition, Plant Community structure and Natural regeneration status of Belete Moist Evergreen Montane Forest, Oromia Regional state, Southwestern Ethiopia. *Momona Ethiopian Journal of Science*, *6*(1), 97–101.

Gebretsadik, T., & Negash, D. (2016). Honeybee production system, challenges and opportunities in selected Districts of Gedeo Zone, Southern Nation, Nationalities and peoples regional state, Ethiopia. *International Journal of Research-Granthaalayah*, *4*(4), 49–63.

Gebru, Y. G. (2015). *Characterization of Beekeeping Systems and Honey Value Chain, and Effects of Storage Containers and Durations on Physico-Chemical Properties of Honey in Kilte Awlaelo District, Eastern Tigray, Ethiopia* (Issue 0011).

Getu, A., & Birhan, M. (2014). Chemical Analysis of Honey and Major Honey Production Challenges in and Around Gondar, Ethiopia. *Academic Journal of Nutrition*, *3*(1), 6–14.

Gole, T. W. (2003). Vegetation of the Yayu forest in SW Ethiopia: impacts of human use and implicatiions for in situ conservation of wild

Coffea arabica L. Populations. *Ecology and Development Series*, *10*, 1–7.

Gole, T. W., Borsch, T., Denich, M., & Teketay, D. (2008). Floristic composition and environmental factors characterizing coffee forests in southwest Ethiopia. *Forest Ecology and Management*, *255*(7), 2138–2150.

Hundera, K. (2013). *Effects of Coffee Forest Management and Fragmentation on Plant Communities and Regeneration Patterns In Afromontane Moist Evergreen Forests in South West Ethiopia*. Jimma University.

Hwang, B., Hundera, K., Mekuria, B., Wood, A., & Asfaw, A. (2020). Intensified Management of Coffee Forest in Southwest Ethiopia Detected by Landsat Imagery. *Forests*, *11*(4), 422. https://doi.org/10.3390/f11040422

Imbach, P., Fung, E., Hannah, L., Navarro-Racines, C. E., Roubik, D. W., Ricketts, T. H., Harvey, C. A., Donatti, C. I., Läderach, P., Locatelli, B., & Roehrdanz, P. R. (2017). Coupling of pollination services and coffee suitability under climate change. *Proceedings of the National Academy of Sciences*, *114*(39), 10438–10442.

Ito, Y. (2014). Local Honey Production Activities and Their Significance for Local People: A Case of Mountain Forest Area of Southwestern Ethiopia. *African Study Monographs*, *48*, 77–97.

Jaccard, P. (1912). The Distribution of the Flora in the Alpine Zone. *New Phytologist*, *11*(2), 37–50.

JICA. (2005). *Report of the terminal evaluation on the Japanese technical cooperation for the participatory forest management project in Belete-Gera regional forest priority area phase 1 in the Federal Democratic Republic of Ethiopia*.

Kilawe, E., & Habimana, D. (2016). *Forestry Contribution to National Economy and Trade in Ethiopia, Kenya and Uganda*. Food and Agriculture Organization of The United Nations.

McGill, E., Dong, Y., Frimpong, K., Haile, R., Liu, M., Schaffer, A. M., & Valente Da Costa, L. (2016). *Improving household livelihoods with modern beekeeping and honey production*.

MEFCC. (2018). *National Forest Sector Development Program, Ethiopia Volume II: Program Pillars, Action Areas and Targets: Vol. II*.

Mitiku, F., Nyssen, J., & Maertens, M. (2018). *Can Coffee Certification Promote Land-sharing and Protect Forest in Ethiopia ?* 1–28.

Mohammed, A., & Bekele, L. (2014). Changes in Carbon Stocks and Sequestration Potential under Native Forest and Adjacent Land use Systems at Gera, South-Western Ethiopia. *Global Journal of Science Frontier Research: D Agriculture and Veterinary*, *14*(10), 1–11.

Muli, E., Munguti, A., & Raina, S. K. (2007). Quality of honey harvested and processed using traditional methods in rural areas of Kenya. *Acta Veterinaria Brno*, *76*(2), 315–320.

QSAE. (2005). *Honey specification: Ethiopian standard, ES 1202: 2005*. Quality and Standards Authority of Ethiopia.

Senbeta, F., & Denich, M. (2006). Effects of wild coffee management on species diversity in the Afromontane rainforests of Ethiopia. *Forest Ecology and Management*, *232*(1–3), 68–74. https://doi.org/10.1016/j.foreco.2006.05.064

Senbeta, F., Gole, T. W., Denich, M., & Kellbessa, E. (2013). Diversity of Useful Plants in the Coffee Forests of Ethiopia. *Ethnobotany Research and Applications*, *11*, 049–069.

Sereia, M. J., Alves, E. M., Toledo, V. A. A., Marchini, L. C., Serine, E. S., Faquinello, P., de Almeida, D., & Moreti, A. C. C. C. (2011). Physicochemical characteristics and pollen spectra of organic and non-organic honey samples of Apis mellifera L. *Anais Da Academia Brasileira de Ciencias*, *83*(3), 1077–1090.

Shahnawaz, M., Sheikh, S. A., Hussain, M., Razaq, A., & Khan, S. S. (2013). A study on the determination of physicochemical properties of honey from different valleys of Gilgit-Baltistan. *International Journal of Agricultural Science Research*, *2*(2), 49–053.

Silva, A. D. S., Alves, C. N., Fernandes, K. D. G., & Müller, R. C. S. (2013). Classification of honeys from Pará State (Amazon Region, Brazil) produced by three different species of bees using chemometric methods. *Journal of the Brazilian Chemical Society*, *24*(7), 1135–

1145.

Silva, L. R., Videira, R., Monteiro, A. P., Valentão, P., & Andrade, P. B. (2009). Honey from Luso region (Portugal): Physicochemical characteristics and mineral contents. *Microchemical Journal*, *93*(1), 73–77.

Tadesse, G., Zavaleta, E., Shennan, C., & FitzSimmons, M. (2014). Prospects for forest-based ecosystem services in forest-coffee mosaics as forest loss continues in southwestern Ethiopia. *Applied Geography*, *50*, 144–151.

Tulu, S., Berecha, G., Dereje, A., Gurmessa, B., Tesfaye, W., Shiferawu, M., & Abidissa, T. (2014). *Participatory rural appraisal report: GERA Woreda, West Oromia Region*.

Wiersum, K. F., Gole, T. W., Gatzweiler, F., Volkmann, J., Bognetteau, E., Ababa, A., Foundation, A., Action, S. L., Project, D., & Teferi, M. (2007). *Certification of wild coffee in Ethiopia : Experiences and challenges*. *April*, 1–13.

Yadata, D. (2014). Detection of the Electrical Conductivity and Acidity of Honey from Different Areas of Tepi. *Food Science and Technology*, *2*(5), 59–63.

Zewde, B. (1998). Forests and Forest Management in Wällo in Historical Perspective. *Journal of Ethiopian Studies, 31*(1), 87–121.